

Cilt 7 Sayı 1 Vol 7 No 1

Mart March

2026 2026

ISSN 2687-4318

J

journal of

CO

computational

DE

design

Ölçekler Arası Üretken Tasarım

Generative Design Across Scales

Cilt 7 Sayı 1
Mart
2026

Vol 7 No 1
March
2026

ISSN 2687-4318

J

journal of

CO

computational

DE

design

Ölçekler Arası Üretken Tasarım

Generative Design Across Scales

JCODE
journal of Computational Design

Cilt 7 Sayı 1 | Mart 2026

Vol 7 No 1 | Mart 2026

İstanbul Teknik Üniversitesi Mimarlık Fakültesi E-Dergisi

Istanbul Technical University Faculty of Architecture E-Journal

Yılda iki kez yayınlanır. | Published two issues in one year.

Yayıncı | Publisher

İstanbul Teknik Üniversitesi Rektörlüğü | Istanbul Technical University Rectorate

Editör | Editor

Prof. Dr. Gülen ÇAĞDAŞ

Doç. Dr. Sema ALAÇAM

Doç. Dr. Ethem GÜRER

Yayın Kurulu | Editorial Board

Doç. Dr. Aslı ÇEKMİŞ KANAN

Dr. Öğr. Üyesi Bahriye İLHAN JONES

Prof. Dr. Fehmi DOĞAN

Dr. Öğr. Üyesi Gamze GÜNDÜZ

Prof. Dr. Gülten MANİOĞLU

Dr. Hakan TONG

Prof. Dr. Hakan YAMAN

Prof. Dr. Halil ERHAN

Doç. Dr. Hasan Serdar KAYA

Prof. Dr. Leman Figen GÜL

Doç. Dr. Meltem AKSOY

Prof. Dr. Mine ÖZKAR KABAÇIOĞLU

Dr. Özgün BALABAN

Dr. Öğr. Üyesi Pınar ÇALIŞIR ADEM

Prof. Dr. Salih OFLUOĞLU

Doç. Dr. Sevil YAZICI

Danışma Kurulu | Advisory Board

Doç. Dr. Ahmet Emre DİNÇER (Ankara Yıldırım Beyazıt Üniversitesi)

Dr. Alexandra DELGADO-JIMÉNEZ (Universidad Nebrija)

Assoc. Prof. Dr. Benay GÜRSOY TOYKOÇ (Stuckeman School at Penn State University)

Assist. Prof. Dr. Dujuan YANG (Technical University Eindhoven)

Dr. Öğr. Üyesi Esra GÜRBÜZ YILDIRIM (Gaziantep Üniversitesi)

Prof. Dr. Fatih TERZİ (İstanbul Teknik Üniversitesi)

Assist. Prof. Dr. Gamze DANE (Eindhoven University of Technology)

Prof. Dr. Gülay ÖKE GÜNEL (İstanbul Teknik Üniversitesi)

Doç. Dr. Güven ÇATAK (Bahçeşehir Üniversitesi)

Doç. Dr. Güzden VARINLIOĞLU (University of Liverpool)

Prof. Dr. İpek GÜRSEL DİNO (Orta Doğu Teknik Üniversitesi)

Prof. Dr. Manolya KAVAKLI THORNE (Macquarie University)

Dr. Öğr. Üyesi Mehmet Tahir SANDIKKAYA (İstanbul Teknik Üniversitesi)

Prof. Dr. Michael J. OSTWALD (University of New South Wales)

Prof. Dr. Neşe ÇAKICI ALP (Koçeli Üniversitesi)

Prof. Dr. Özgür EDİZ (Uludağ Üniversitesi)

Dr. Öğr. Üyesi Özlem ATAK DOĞAN (Erciyes Üniversitesi)

Prof. Dr. Rahmi Nurhan ÇELİK (İstanbul Teknik Üniversitesi)

Doç. Dr. Serdar AYDIN (Mardin Artuklu Üniversitesi)

Dr. Öğr. Üyesi Şehnaz CENANİ DURMAZOĞLU (Medipol Üniversitesi)

Prof. Dr. Şule TAŞLI PEKTAŞ (OSTİM Teknik Üniversitesi)

Prof. Dr. Tuba KOCATÜRK (Deakin University)

Dr. Öğr. Üyesi Yazgı BADEM AKSOY (Medipol Üniversitesi)

Editorial Sekreteryası | Editorial Assistance

Ekin ÜNLÜ

Gülce KIRDAR

Salih ÖZDEMİR

Sinem KIRKAN

Varlık YÜCEL

Dizgi | Typesetting

Ekin ÜNLÜ

Gülce KIRDAR

Salih ÖZDEMİR

Sinem KIRKAN

Varlık YÜCEL

Logo | Logo

Melis DAĞ

Kapak | Cover

İlke YILDAN

Varlık YÜCEL

Web | Web

Begüm HAMZAOĞLU

Gülce KIRDAR

Özlem ÇAVUŞ

Salih ÖZDEMİR

Sinem KIRKAN

Varlık YÜCEL



ISSN 2687-4318

İletişim | Contact

JCoDe: Journal of Computational Design

Yayın Sekreterliği

İstanbul Teknik Üniversitesi

Mimarlık Fakültesi

Taşkılla, Taksim, 34437

İstanbul Türkiye

email: jcode@itu.edu.tr

web: jcode.itu.edu.tr

Ölçekler Arası Üretken Tasarım

Editörden

Hesaplamalı tasarım uygulamaları geliştikçe, ölçekler arasında etkin biçimde çalışan üretken yaklaşımlar geliştirmek önemli bir zorluk olarak karşımıza çıkmaktadır. Üretken düşüncedeki son gelişmeler arasında kural tabanlı sistemler, evrimsel arama, optimizasyon, pekiştirmeli öğrenme ve difüzyon modelleri yer almakta ve sistem ve biçimlerin keşfi için yeni olanaklar yaratmaktadır. Bu bağlamda, farklı çözünürlüklerdeki üretken akıl yürütmeler—detaylı bileşenler ve montajlardan iç mekân sistemlerine ve nihayetinde kentsel müdahalelere kadar—tasarım zekâsını temelden dönüştürmektedir.

Üretken tasarım yalnızca biçim üretimi için bir araç değil, temel paradigmaları değiştirirken yaratıcılığı, tasarımcının rolünü ve mimari pratiğin sınırlarını yeniden tanımlamaktadır. Yapay zekâ destekli sistemler, algoritmik yöntemler ve çok etmenli simülasyonlar, tasarımcıyı yalnız yaratıcılıktan, insanlar, makineler ve malzemeler arasında dağıtılmış faillige taşımaktadır. Bu sıçrama mimarlık ve tasarım eğitimi ile pratiğine yeni pedagojik yaklaşımlar, eleştirel değerlendirme ve etik sorguları beraberinde getirmektedir.

JCoDe'un on dördüncü sayısı, bu çok katmanlı dönüşümü çeşitli perspektiflerden ele alan sekiz makaleyi bir araya getirmektedir. Sayı, teorik tartışmaları oluşturan çalışmalar ile üretken sistemlerin felsefi ve ontolojik boyutlarının tartışılması ile başlamaktadır. GÜLEÇ'in çalışması bu anlamda Instagram ve Archigram üzerinden medya ile mimarlık arasındaki değişen ilişkiyi araştırarak, mimarlığın fiziksel yapılar inşa etmeden kendisini imgelerle nasıl temsil ettiğini sorgulamaktadır. BARON'un çalışması ise çok etmenli sistemleri Deleuze'cü terimlerle inceleyerek makine, asamblaj, rizom ve akış gibi hesaplamalı kavramları Processing'de görselleştirmekte ve bunların ontolojik çerçeveler olarak değerlendirilmesini tartışmaktadır. Dijital mekân üretimi ve algoritmik esneklik üzerine çalışmalar, toleransı bir üretken tasarım ilkesi olarak konumlandırmaktadır. Bu çerçevede KURAN YILDIRIM ve TASA, toleransı teknik esneklikten öte görerek ontolojik ve algoritmik açıklık olarak ele almakta, Deleuze'ün "oluş" ve "fark" kavramları ile Luciana Parisi'nin hesaplamalı estetiğinden yola çıkarak bu açıklığın belirsizliği tasarımın üretken bir parçası haline getirdiğini savunmaktadırlar. Bu tartışmalar üzerine inşa ederek YALÇIN, Uluslararası Mimarlık Bienali 2025 için bir enstalasyon çalışması aracılığıyla üretken bir mimari süreçte yaratıcı failliğin nasıl oluştuğunu incelemekte, diferansiyel büyüme algoritması, temsil araçları ve çok ölçekli 3B baskı teknolojileri arasındaki etkileşimleri belgelemektedir.

Yapay zekânın mimari tasarım süreçlerine entegrasyonunu inceleyen çalışmalar sayının diğer önemli bir eksenini oluşturmaktadır. ŞEKERCİ ve DEVELİER, Claude 3.5 Sonnet, Gemini 1.5 Flash ve ChatGPT 4o gibi yapay zekâ modellerinin iç mimarlık alanındaki betimleyici ve tasarım çıktı

performansını karşılaştırmalı olarak değerlendirmekte, mekânsal düzenleme ve iç mekân malzemeleri konusundaki güncel sınırlamaları ortaya koymaktadır. YILDIRIM CORUK, sistematik bir literatür taraması aracılığıyla yapay zekânın tasarım stüdyosu pedagojisine entegrasyonunu inceleyerek yapay zekânın fikir üretimi ortağı olarak rolünü, öğrenme çıktıları üzerindeki etkilerini ve eğitim-öğrenci ilişkilerini yeniden yapılandırma potansiyelini tartışmaktadır.

Hesaplamalı analiz yöntemlerinin mimari mirasa uygulanması bağlamında, KÖKSALAN İLDENİZ ve ŞAHİN'in çalışması, Birinci Ulusal Mimarlık Dönemi'nin önde gelen isimlerinden Mimar Kemalettin'e atfedilen on sekiz eğitim yapısının cephe tasarımlarını fraktal analiz kullanarak incelemektedir. Çalışma, mimarın eğitim düzeyine göre değişen bir tasarım yaklaşımı benimsediğini ortaya koyarak hesaplamalı yöntemlerin tarihsel mimari analizdeki potansiyelini göstermektedir.

Sayı, malzeme seçiminde hesaplamalı karar desteği üzerine bir çalışmayla sona ermektedir. ERES YALÇIN ve PAKDAMAR, ofis zemin malzemesi seçimine bulanık mantık yaklaşımı uygulamaktadır. Yatırım maliyeti, hizmet ömrü, işletme maliyeti ve çevresel etki gibi kriterleri Mamdani çıkarım sistemi kullanarak modellemekte ve dengeli, maliyet odaklı ve çevre odaklı senaryo bazlı değerlendirmeler sunmaktadır.

Generative Design Across Scales

Editorial

As computational design applications evolve, the field faces a pressing challenge: developing generative approaches that work effectively across scales. Recent advances in generative thinking include rule-based systems, evolutionary search, optimization, reinforcement learning, and diffusion models. These developments create new possibilities for exploring systems and forms. In this context, generative reasoning at different resolutions—from detailed components and assemblies to interior systems and urban interventions—fundamentally transforms design intelligence.

Generative design is not just a tool for form production; it shifts the paradigm. It redefines creativity, the designer's role, and the boundaries of architectural practice. AI-assisted systems, algorithmic methods, and multi-agent simulations move the designer from solitary creativity to distributed agency among humans, machines, and materials. This shift brings new pedagogical approaches, critical evaluation, and ethical principles to education and practice in architecture and interior design.

The fourteenth issue of JCoDe brings together eight articles that address this multi-layered transformation from various perspectives. The issue opens with studies that form its theoretical foundations, initiating discussion of the philosophical and ontological dimensions of generative systems. For example, GÜLEÇ's study explores the changing relationship between media and architecture through Instagram and Archigram, questioning how architecture represents itself with images without constructing physical buildings. In turn, BARON's study examines multi-agent systems in Deleuzian terms, visualizing computational concepts such as machine, assemblage, rhizome, and flow in Processing, and discussing their evaluation as ontological frameworks.

Studies on digital space production and algorithmic flexibility position tolerance as a generative design principle. KURAN YILDIRIM and TASA view tolerance as more than technical flexibility, approaching it instead as ontological and algorithmic openness. Drawing on Deleuze's concepts of "becoming" and "difference" and Luciana Parisi's computational aesthetics, they argue that this openness means uncertainty becomes a productive part of design. Building on these discussions, YALÇIN examines how creative agency forms in a generative architectural process through an insider study of an installation for the International Architecture Biennial 2025, documenting interactions among a differential growth algorithm, representational media, and multi-scale 3D printing technologies.

Studies examining the integration of artificial intelligence into architectural design processes constitute a significant axis of the issue. ŞEKERCİ and DEVELIER comparatively evaluate the descriptive and design output performance of AI models such as Claude 3.5 Sonnet, Gemini 1.5 Flash, and ChatGPT 4o in the field of interior architecture, revealing current limitations

in spatial layout and interior materials. YILDIRIM CORUK examines the integration of artificial intelligence into design studio pedagogy through a systematic literature review, discussing AI's role as an idea-generation partner, its effects on learning outcomes, and its potential to restructure instructor-student relationships.

In the context of applying computational analysis methods to architectural heritage, KÖKSALAN İLDENİZ and ŞAHİN's study analyzes the facade designs of eighteen educational buildings attributed to Mimar Kemalettin, one of the leading figures of the First National Architecture Period, using fractal analysis. The study reveals that the architect adopted a design approach that varied by educational level, demonstrating the potential of computational methods in historical architectural analysis.

The issue ends with a study on computational decision support in material selection. Specifically, ERES YALÇIN and PAKDAMAR apply a fuzzy-logic approach to selecting office floor materials. They model criteria—including investment cost, service life, operating cost, and environmental impact—using the Mamdani inference system and present balanced, cost-focused, or environmentally focused scenario-based evaluations.

Media Architecture: Instagram versus Archigram	01
Medya Mimarlığı: Instagram Archigram'a Karşı Gülşah Güleç Theoretical Article	
Representation and Interpretation of Multi-Agent Systems through Deleuzian Thought	29
Deleuzeyen Düşünceyle Çoklu-Etmen Sistemlerinin Temsili ve Yorumlanması Aysel Merve Baron Theoretical Article	
From Control to Contingency: Tolerance as a Generator of Digital Space	53
Kontrolden Belirsizliğe: Dijital Mekânın Üretiminde Tolerans İpek Kuran Yıldırım, Umut Tasa Theoretical Article	
Birlikte Yaratıcı Faillik: Diferansiyel Büyüme Üzerinden Üretken Tasarıma İçeriden Bakış	71
Co-Creative Agency: An Insider Perspective on Generative Design through Differential Growth Fikriye Aslı Yalçın Araştırma Makalesi	
How Well Can AI Contribute to Interior Architecture? A Comparative Analysis of Descriptive Accuracy	95
Yapay Zeka İç Mimarlığa Ne Ölçüde Katkı Sağlayabilir? Betimsel Doğruluk Üzerine Karşılaştırmalı Bir Analiz Yaren Şekerci, Müge Develier Research Article	
A Systematic Analysis of Artificial Intelligence Applications in Design Studio Pedagogy	133
Tasarım Stüdyosu Pedagojisinde Yapay Zeka Uygulamalarının Sistematik Analizi İpek Yıldırım Coruk Research Article	
Visual Complexity Analysis of Mimar Kemalettin's Educational Buildings	153
Mimar Kemalettin'in Eğitim Yapılarının Görsel Karmaşıklık Analizi Zeynep İldeniz Köksalan, Murat Şahin Research Article	
Ofis Mekanlarında Döşeme Kaplama Malzemesinin Bulanık Kümeler Kullanılarak Seçimi	179
Selection of Flooring Material in Office Spaces Using Fuzzy Sets Esra Eres Yalçın, Ferhat Pakdamar Research Article	

Media Architecture: Instagram versus Archigram

Gülşah Güleç¹

ORCID NO: 0000-0002-8041-2018¹

¹Gazi University, Faculty of Architecture, Department of Architecture, Ankara, Türkiye

Media and architecture have always been closely related, but in recent years, they have become so intertwined that the boundaries between them have become blurred. This has led to the emergence of the term "media architecture." Various exhibitions, discussions, and seminars have been organized to explore the ever-changing relationship between media and architecture in the new 21st-century landscape, which seems to be characterized by digital revolutions. These organizations emphasize integrating digital media systems, particularly in building exteriors. Accordingly, they offer a technical and technological understanding of media architecture. However, media architecture also refers to integrating media technologies into architectural theory and practice, resulting in buildings designed and published as images in printed and non-printed media. In this regard, the paper relates "media architecture" to "architecture without architecture" because both terms refer to the possibility of architectural practice without building a physical structure. The paper explores the term "architecture without architecture" by relating it to the process of creating an image rather than an object. In this way, architecture becomes image-making. Nevertheless, "architecture without architecture" is often defined as building anonymously. While this is a reliable definition, the paper discusses "architecture without architecture" alongside its other meanings, which reveal the embodied aspects of digital media in producing architectural objects and images. This means that people with the ability and access to new digital media tools and technologies can create architectural images, even if they are not architects, designers, or professionals. It broadens the terminological and technological limits of "architecture without architecture" beyond traditional, anonymous structures to include non-traditional, anonymous images. In this context, the paper focuses on Instagram and Archigram as "media architecture". The aim of the paper is to argue that media is not only changing the way architecture is represented, but also the way it is produced, reproduced and consumed. The paper's originality lies in its discussion of Instagram and Archigram, revealing the evolving relationship between media and architecture. Furthermore, the paper emphasizes that, despite belonging to different times and cultures, Instagram and Archigram exemplify "architecture without architecture" by highlighting images in architectural representation. Both remind us that architecture is not just about buildings, but also about images of buildings. It is a critical part of the practice of architecture; "image-making". However, Instagram (non-printed) and Archigram (printed) are different mediums through which different meanings are created in architecture. While the former (Instagram) blurs the boundaries between the real and the virtual, the latter (Archigram) creates the virtual as an alternative to the real. Despite their differences, the paper discusses the similarities between Instagram and Archigram, as they both refer to "media architecture," revealing that architecture not only represents, but also realizes itself through media, without constructing buildings. So, it is crucial to understand the new dynamics and realities of media in order to understand the new reality of architecture.

Keywords: Archigram, Instagram, Media Architecture, Social Media, Social Media Architecture

Received: 30.07.2025

Accepted: 05.01.2026

Corresponding Author:

gulsahgulec@gazi.edu.tr

Güleç, G. (2026). Media architecture: Instagram versus Archigram. JCoDe: Journal of Computational Design, 7(1), 1-28.
<https://doi.org/10.53710/jcode.1753503>

ROR ID: 059636586



Medya Mimarlığı: Instagram Archigram'a Karşı

Gülşah Güleç¹

ORCID NO: 0000-0002-8041-2018¹

¹Gazi Üniversitesi, Mimarlık Fakültesi, Mimarlık Bölümü, Ankara, Türkiye

Bu makalenin amacı, medyanın mimarlığın yalnızca temsil edilme biçimini değil aynı zamanda üretilme, yeniden üretilme ve tüketilme biçimini de değiştirdiğini tartışmaktır. Makalenin medya ve mimarlık arasındaki değişken ilişkiye odaklanırken bu tartışmayı Instagram ve Archigram üzerinden yürütüyor olması güncelliğini ve özgün değerini ortaya koymaktadır. Bilgi ve iletişim teknolojileri ile bilgisayar teknolojilerinde yaşanan gelişmelerle birlikte medya daha çok dijital medya ve sosyal medya olarak adlandırılan alana doğru kaymıştır. Böylece medya yeni bir alanda kendisini yeniden üretmeye başlamıştır. Ayrıca mimarlığın da yeni bir beğeni anlayışıyla yeniden üretilmesini sağlamıştır. Bugün medyada paylaşılan ve beğeni alan imgelerin bombardımanı ve özellikle Instagram gibi sosyal medya platformlarında sürekli bir akış halinde olması, mimarlığın bir imge üretimi olarak görülmesine yol açmıştır. Makalede mimarlık üretiminin değişimi Instagram (basılı olmayan) ve Archigram (basılı olan) gibi iki farklı temsil ortamı üzerinden ele alınmış; dönemleri ve mimarlığı temsil etme biçimleri birbirinden farklı olsa da bu ortamların mimarlık olmadan mimarlık anlayışını örneklediği tartışılmıştır. Çünkü her ikisi de binaların kendisinin değil onun yerine tasarım fikirlerinin ve imgelerinin üretildiği ortamlardır. Instagram, Archigram'a alternatif olarak ortaya çıkmamıştır; ancak Instagram da Archigram gibi mimarlık ortamına metnin ya da nesnenin değil imgenin hakim olmasını sağlamıştır. Medya sürekli olarak değişiyor olsa da mimarlığın kendisini hala medya aracılığıyla temsil ettiği ve yeniden ürettiği anlaşılmaktadır. Bu yüzden mimarlığın gerçekliğini sorgulayabilmek ve anlayabilmek için medyanın önceliklerini, beğeni düzeyini, değişkenlerini ve gerçekliği yeniden üretme biçimini anlayabilmek büyük önem taşımaktadır.

Teslim Tarihi: 30.07.2025

Kabul Tarihi: 05.01.2026

Sorumlu Yazar:

gulsahgulec@gazi.edu.tr

Güleç, G. (2026). Medya mimarlığı: Instagram Archigram'a karşı. JCoDe: Journal of Computational Design, 7(1), 1-28.
<https://doi.org/10.53710/jcode.1753503>

ROR ID: 059636586

Anahtar Kelimeler: Archigram, Instagram, Medya Mimarlığı, Sosyal Medya, Sosyal Medya Mimarlığı



1. INTRODUCTION

The paper's research question is, what does "architecture without architecture" mean, and how does it relate to "media architecture"? Media and architecture have always been closely related, but in recent years, they have become so intertwined that the boundaries between them have become blurred. This has led to the emergence of the term "media architecture." Various exhibitions, discussions, and seminars have been organized to explore the ever-changing relationship between media and architecture in the new 21st-century landscape, which seems to be characterized by digital revolutions. These organizations emphasize integrating digital media systems, particularly in building exteriors. Accordingly, they offer a technical and technological understanding of media architecture. However, media architecture also refers to integrating media technologies into architectural theory and practice, resulting in buildings designed and published as images in printed and non-printed media.

The paper relates "media architecture" to "architecture without architecture" because both terms refer to the possibility of architectural practice without building a physical structure. It discusses the term "architecture without architecture," which describes the process of creating an image rather than an object. In this way, architecture becomes image-making. This term is famously used by Rudofsky as the curator of the MoMA exhibition *Architecture Without Architects* (1964), in which he attempts to convey a new understanding of architecture. This understanding moves away from modern trends and focuses on architecture's origins and influences. The exhibition presents primitive examples that anticipate heavy technology and models that address practical problems with great ingenuity. It shows his support for the idea that the intuition and knowledge of anonymous builders form the main inspiration for industrial man (Martínez Matos, 2022). So, "architecture without architecture" is about building anonymously. For Rudofsky, anonymous buildings and building techniques by anonymous practitioners exemplify "architecture without architecture" throughout history (Rudofsky, 1964). While this is a reliable definition when discussing the term "architecture without architecture", the paper explores this term alongside its other meanings, which reveal the embodied aspects of digital media in producing architectural objects and images. This means that people

with the ability and access to new digital media tools and technologies can create architectural images, even if they are not architects, designers, or professionals. It broadens the terminological and technological limits of "architecture without architecture" beyond traditional, anonymous structures to include non-traditional, anonymous images.

Today, it is easier than ever to create architectural images thanks to the adoption of artificial intelligence as a tool for image-making. Digital and social media promote these images, allowing people to publish and share them with others in a matter of seconds. In this respect, the paper establishes a relationship between the terms "architecture without architecture" and "media architecture." The paper relies on Sadler's discussion of "architecture without architecture" since he discusses this term in relation to Archigram's "paper architecture," which prioritizes images over objects in architecture during the 1960s and 70s (Sadler, 2005). Nowadays, images are mostly produced, consumed, and reproduced in digital and social media, particularly on Instagram, in the field of architecture. The paper discusses this as a paradigm shift from "paper architecture" to "screen architecture" by comparing Instagram and Archigram, both of which function as mediums for sharing images. It reveals these mediums' characteristics and highlights that, despite their different media tools and technologies, they demonstrate that architecture is a form of media construction and achieves this by constructing images.

In this context, the paper focuses on Instagram and Archigram as "media architecture". The aim of the paper is to argue that media is not only changing the way architecture is represented, but also the way it is produced, reproduced and consumed. The paper's originality lies in its discussion of Instagram and Archigram, revealing the evolving relationship between media and architecture. Furthermore, the paper emphasizes that, despite belonging to different times and cultures, Instagram and Archigram exemplify "architecture without architecture" by highlighting images in architectural representation. For example, Archigram magazines represent utopian designs beyond time, and these designs mostly remain as futuristic and fantastic images in the 1960s and 70s. We encounter even more architectural images (utopian or not) due to the expanding media platforms in the 2010s and 20s. Media today is not restricted to printed media such as newspapers,

magazines, catalogues, journals, etc. It is expanding into non-printed mediums such as digital media and social media. In social media, there is a bombardment of architectural images. The constant flow of images on social media platforms, such as Instagram, leads to architecture being seen and understood as an image production.

The paper argues that there are surprising similarities between Instagram and Archigram, as both are the mediums prioritizing images over text and objects. The members of the Archigram group publish architectural images in the Archigram magazines, and these are not images of architectural objects built on a real site. This is why the practice of Archigram is known as "paper architecture". Today, images of architectural objects, whether built or not, are more likely to be shared on Instagram. We see and experience these images on the screens of our phones, tablets, and computers. The paper describes this phenomenon as "screen architecture."

The methodology of the paper is to compare the terminological and technological framework of Instagram and Archigram by highlighting that both define a medium for sharing information about architecture, even though the former is a non-printed medium associated with "screen architecture" and the latter is a printed medium described as "paper architecture" (See Table 1). Nevertheless, it is surprising that the terms "Instagram" and "Archigram" are very similar. Instagram is a combination of "instant photography" and "telegram," a method of sending text and photographs to others. The term "Archigram" is a combination of "architecture" and "telegram," meaning architecture is also a means of communication. However, advances in information and communication technology are radically changing the way architecture is communicated, and vice versa.

The paper does not claim that Instagram is an alternative to Archigram as a medium for communicating and representing images. Archigram is a magazine published specifically to share architectural ideas and images designed by the members of the Archigram group, such as Peter Cook and Ron Herron, in the 1960s and 70s. Instagram, on the other hand, is a medium that is not specifically created to share or publish architectural images, but rather to foster social relationships between people in the 2010s. We see that Instagram is becoming a platform for

promoting architectural images, especially those designed by famous architects of the 2020s.

The medium is the message, as McLuhan suggests (McLuhan, 2006). When the medium is Archigram, we are confronted with architectural drawings, illustrations and collages. With these materials, Archigram magazines give us the message of an architecture of fantastic buildings and cities. When the medium is Instagram, we are often exposed to architectural photographs and renderings. With these renderings, the Instagram posts give us the message of an architecture of not always fantastic, but fetishistic buildings. Yet both remind us that architecture is not just about buildings, but also about images of buildings. It is an important part of the practice of architecture; "image-making". As the paper argues, Instagram and Archigram are the mediums that lead to images being seen not as virtual but as real constructions in architecture. Advances in computer technology and media, and more recently in artificial intelligence, make images look even more real. As a result, the medium through which architectural images are represented is constantly changing. The paper focuses on this change by comparing Instagram, a social media platform, and Archigram, a printed medium, revealing that they both refer to "architecture without architecture."

2. ARCHITECTURE WITHOUT ARCHITECTURE

The term "architecture without architecture" is derived from Sadler's seminal work about the practice of Archigram, which is actualized itself not on the construction site but on paper. He describes the practice of Archigram as "architecture without architecture" because the members of this group construct ideas and images rather than objects, and they disseminate images, which illustrate the present and future dynamics of architecture, through the Archigram magazines of the 1960s and 70s (Sadler, 2005). The paper argues that "architecture without architecture" is a relevant term also to describe the status of architecture in the 2010s and 20s. It is precisely because of today's advanced computer technology, not only in the practice of architecture, but also in the perception and communication of architecture, that "the object" is mainly replaced by "the image".

It is a fact that architecture is not limited to buildings. It also involves the images of buildings. The images are a means of communication

between city, architecture and people. But when architecture is reduced to images, it becomes a flattened practice. Nevertheless, architecture relies on the recognition of a mass of famous pictures, as Rattenbury explains. Sometimes these pictures are more iconically famous and even more satisfyingly architectural than the buildings. They are indeed iconic, not only as a picture of architecture, but of architecture itself. Images (or pictures, as Rattenbury calls them) are media constructions that allow buildings to exist even when they are not constructed (Rattenbury et al., 2002). Moreover, images allow constructed buildings to continue to exist even after they have been damaged or demolished.

Architecture has a virtual existence due to its images. With the advancements in the communication tools and technologies of the 20th century, images are produced, reproduced and consumed through newspapers, magazines, journals, exhibitions, catalogues and advertisements. As Colomina discusses, the advent of photography has expanded the audience for architecture enormously. The audience is not only the user, but also the tourist in front of a building, the reader of a magazine, the viewer of an exhibition, etc., who sees the building (or the image of the building), gives it meaning, and consumes it (Colomina, 2002).

Throughout the 20th century, architectural photography is largely confined to the printed media. In the 21st century, however, and particularly in the 2010s and 20s, it is being (re)produced and consumed by masses of people who are not necessarily professionals, but who use computers, tablets, phones and other technological devices, through the proliferation of non-print media, namely digital and social media. Social media, as an accessible platform for everyone, leads images to be published and shared instantly around the world. Drawings, collages and illustrations in printed media, such as Archigram magazines, are still used as virtual images for communication, but today new virtual images made of pixels and posts in non-printed media, such as Instagram, are more relevant for communication in architecture.

The changing relationships between media and architecture offer new ways of communication between buildings, cities and people. So much so that we are now talking about “media architecture” to indicate that media is embedded in the practice of architecture. Archigram and

Instagram are both media platforms; however, Archigram magazines are published specifically for the dissemination of architectural images, while Instagram is used as a platform more for socialization. The paper does not discuss Instagram as an alternative to Archigram. Instead, it discusses the characteristics of these mediums that represent architectural productions. The paper emphasizes that Archigram is a printed magazine, and Instagram is a non-printed social platform. Despite their differences in meaning and media tools and technologies, both platforms exemplify their own time and culture. Both of these platforms are discussed in the paper as “architecture without architecture”, as they define a medium that prioritizes “the image” over “the object”, whether printed or non-printed.

3. MEDIA ARCHITECTURE

“Media architecture” is a relatively new term that emerged in the 2000s. The relationship between “media” and “architecture” is not just about building things, but also about shaping, discussing and rewriting intellectual practices in the digital world. Moreover, media leads an interdisciplinary approach to be adopted in the disciplinary field of architecture (Lindsay et al., 2025). However, the term “media architecture” is mostly used to refer to facades, applications, social media, screens, projections and responsive environments. Through these communication tools and technologies, Junte suggests that media architecture is shaping our cities. Yet it is beyond designing buildings and cities, it is also a way of imagining our lives (Junte, 2021).

Wiethoff and Hußmann also suggest that media architecture is a new term that means using information as a construction material such as glass, wood, or concrete in the built environment. Due to media architecture, we can access information through screens and other technologies in cities without using personal devices. So, media architecture is about making information accessible to everyone in a public location (Wiethoff & Hußmann, 2017).

Fischer and Hornecker define media architecture as the construction of a media facade as an interface between the building and the city. Since contemporary architecture communicates with the city and its inhabitants through screens, they associate media architecture with screen culture (Fischer & Hornecker, 2017). Media enables buildings to

be interactive forms of information and communication. In other words, buildings communicate with people through screens and other media technologies. This recalls Virilio's theory of the aesthetics of disappearance, as the screen replaces space, or space hides behind the screen and disappears. According to Virilio, media architecture refers to buildings with facades made entirely of screens. The screens that display images become the walls of buildings. Real space is therefore replaced by virtual space in architecture. These transformations of space make architecture disappear (Virilio & Ruby, 1993).

We perceive not only architecture but the world through screens, or the ephemerality of the images on these screens. As McLuhan says, media changes the way we perceive the world (McLuhan, 2006). Media changes our everyday routines, desires, behaviors, clothing, buildings, cities, and so on (Junte, 2021). Architecture is also changing and evolving with the media, not because its primary purpose of building shelter for people is changing, but because the media changes the ways of communicating with people and the built environment. As Tovar states, keeping up with the world of architecture, seeking inspiration, discovering new processes or materials, require hours of searching through magazines, talking to colleagues, and traveling. But with the improvements in transportation infrastructure, technology, and the advent of the Internet, the world is becoming more connected and everything is accelerated. This allows for the emergence of new terms such as "Instagrammable" and "Instagram friendly" design, which refer to a new architecture, especially for audiences who experience buildings not in the built environment, but in a new environment such as social media platforms (Tovar, 2025). These platforms allow users to connect, share and engage in various ways at accelerated speeds and scopes. The possibilities afforded by social media have a significant import for architectural practice as well as for the political communication of spatial imaginings of the future (Alaily-Mattar & Jones, 2025).

Social media platforms, particularly Instagram, have emerged as powerful mediators between individuals and their built environments, reshaping not only spatial perceptions but also temporal interactions with architecture. Since its launch in 2010, Instagram has attracted over 1 billion active users, who share more than 100 million photos and videos daily. Its visually driven interface, featuring posts, accounts,

filters, hashtags and stories, makes it a prominent tool for visual storytelling and social interaction. Instagram not only redefines the presentation of architecture but also transforms the way users experience, interpret and contextualize architectural spaces across different times and places. Architects are increasingly designing with Instagram in mind, creating “Instagrammable” moments that capture attention and drive engagement. Digital representations on Instagram can create familiarity with spaces users have never physically visited, influencing expectations and interpretations while disconnecting them from the temporal narratives of these spaces. The platform’s emphasis on visual content often leads to a disembodied experience, where multisensory aspects of architecture, such as the play of light throughout the day or the aging of materials, are overlooked (Wagiri et al., 2024). Hence, social media platforms, Instagram in particular, lead us to see and understand architecture as a practice that creates amazing images.

On the other hand, Pallasmaa reminds that the task of architecture is not to shock, to amaze or to entertain, but to give us a foothold in the realm of the real (Pallasmaa, 2011). Nevertheless, architecture today seems to create amazing and shocking images that are detached from reality. We are constantly exposed to these images through digital and social media, and the shocking effect of the images reinforces the state of distraction (Beasley, 2015). According to Benjamin's theory, buildings are truly experienced in a state of distraction, not in a tourist-like state of concentration. Benjamin defines distraction as a condition that governs the everyday experience of architecture. But concentration leads to seeing buildings only as objects separated from everyday life. In this regard, he says: “Buildings are appropriated in a twofold manner: by use and by perception, or rather, by touch and sight. Such appropriation cannot be understood in terms of the attentive concentration of a tourist in front of a famous building.” (Benjamin, 1999).

Yet concentration is usually seen as a positive condition and distraction is seen as a negative condition. This dichotomy is still relevant today, as the term distraction is used negatively to describe the state of people when they experience architecture or other forms of art such as film and photography in a distracted condition (Beasley, 2015). Today, we are in a constant state of distraction due to the bombardment of

images on the screens of our computers, phones or other smart devices. It is the new media that makes us the distracted people of the new century. Manovich defines new media as the Internet, websites, computer multimedia and virtual reality (Manovich, 2001). We are all distracted by these new media tools and technologies. But distraction here does not have the same meaning with the term described in Benjamin's theory. In the 21st century, distraction paradoxically has the meaning of concentration in that theory, which refers to a tourist gaze and experimentation. We usually experience architecture as tourists, taking pictures in front of buildings and posting them on social media to create memories.

It seems that Instagram, as one of the most commonly used social media platforms, has the ideal of creating a picture-perfect society (Fiocco & Pistone, 2020). People use this platform not only to show their lives, but also to advertise things, goods, other people, their work, experiences, environments and so on. People's tendency to share, advertise, use and consume almost everything in their daily lives is changing the way we experience architecture, in that the architectural object (building, space, structure, etc.) seems to be replaced by the architectural image. Rather than experiencing "the object", we now experience "the image of the object". We see and use the image to experience space, to share it with our colleagues, friends and other people, and finally to consume it without actually seeing it. This is why we call it "media architecture", to refer to the new reality of buildings and spaces that do not even need to be built to be experienced. Our memories of built environments are created by the images of those environments that are shared in the media.

As the paper discusses, Instagram and Archigram define their own specific environments, disseminating architectural ideas and images to the world through screen, that is, posts, renderings, photographs, and through paper, that is, drawings, illustrations, collages. Instagram is an interactive, but of course not an alternative platform to Archigram for sharing and disseminating architectural images. As with Archigram magazines, Instagram also allows images to be seen as real practices, reminding us that architecture is the practice of "image-making". The paper discusses Instagram and Archigram as "media architecture" because they show us that media is not only a platform for representing, but also for producing, reproducing and consuming

images in architecture. Furthermore, both share images through their specific printed (Archigram) and non-printed (Instagram) platforms to be consumed by masses of people. Consumption is the key to these platforms, both of which serve popular images for popular culture. However, Instagram and Archigram do not use the same tools and technologies, nor do they have the same architectural language. It is therefore important to understand both the differences and the similarities between them in the ever-changing atmosphere of architecture.

4. ARCHIGRAM AND ARCHITECTURE

Archigram is a London-based architectural magazine that appeared irregularly in 9 issues between 1961 and 1970. It is also known as the famous group of avant-garde architects such as Peter Cook, David Greene, Cedric Price and Ron Herron (Sadler, 2005). As Banham notes, Archigram is in the image business, and they are blessed with the power to create some of the most compelling images of their time (Banham, 1965). They sweep away the differences between buildings and media constructions, or in other words, the real and the virtual. This is why Gannon suggests that Archigram's drawings are more real than images of virtual buildings (Gannon, 2008).

For Archigram, image is the real construction (Sadler, 2005). They are interested in designing the images of plug-ins, geodesics, plastics and inflatables for the world of the 1960s and 70s, which is in a constant state of flux (Steiner, 2009). According to Rattenbury, these iconic and fantastic pictures suggest a new way of looking at the world, as in the picture of *The Walking City*, the colored version in the desert. These pictures, or images, designed by Archigram do not depict a static world but a dynamic one with objects of popular culture such as electronics, advertising, vehicles, clothes, etc. (Rattenbury et al., 2002).

The images published in the Archigram magazines represent the shift from high to low (or popular) culture in the post-war world. As such, the members of the Archigram group plug telephones, refrigerators, washing machines, scooters and automobiles in houses. These images inform us about the new era of architecture, where speed, technology, dynamism and movement define everyday life, and where users become consumers. Archigram magazines illustrate the new images of

a new lifestyle by designing images as if they were architectural advertisements (Sadler, 2005).

Architectural magazines not only document the architectural movements of a particular period but also reflect how these movements are perceived and evaluated by society. Magazines play a vital role in promoting, criticizing, and preserving a particular architectural style or project in the public memory, thus ensuring that these structures have a longer-lasting place in the social memory. In this context, newspapers and periodicals significantly impact the history of architecture and that the buildings designed by architects are considered physical entities and phenomena reconstructed in the media and social memory (Irapoğlu et. al., 2025).

Archigram magazines are among the publications that has a special place in the social, spatial and cultural history of architecture. Güneri states that Archigram magazines are the medium for understanding architecture not only as an architectural, but also as a cultural practice (Güneri, 2019). The Archigram group uses an ironic and caricaturistic language in the magazine to represent the changing nature of culture, cities and architecture (Güneri, 2020). This language reflects a cultural shift from production to consumption and communication (Steiner, 2009). One of the main roles of architecture is to communicate with people, the city and the built environment. It is also the role of the media to create communication between people and architecture. This is the common ground between media and architecture in that they communicate with people. The medium used for communication may vary, but the fact is that Archigram magazine is a popular medium that disseminates utopian architectural ideas and images to an international audience, mostly through drawings and illustrations.

Whether these images are defined as iconic, fantastic, ironic, caricaturistic or utopic, Archigram designs cities and buildings to be presented on paper, not to be built on the ground. However, they design the most memorable and remarkable images of the 1960s (Sadler, 2005). These are the blueprints of the utopian images of architecture. Archigram's utopian images define a new terrain in architecture, in which information and communication become a new material with the power to reshape social arrangements, in which city becomes a continuous construction site in the most literal sense, in

which things and people vibrate and oscillate around the globe in an ecstatic consumption of energy. When we see architecture as a means of communication, we understand that the built form is only one form of expression. So, Archigram is also a form of expression through which communication between architecture and people is built. Archigram creates images rather than objects to communicate with people about the present and the future of architecture. Through these images, Archigram shows that there is no difference between architecture and communication. The dominant culture is American culture in the post-war world. Archigram thus uses the images of American popular culture to highlight consumerism and Americanism in the world of architecture. Nonetheless, the last issues of Archigram point out to the fact that that printed media alone is insufficient for conveying architectural messages to people. So, the members of the Archigram group think that they need to find new ways of creating communication between architecture and people (Steiner, 2009).

With advances in information and communication technology and media, it seems that architecture today has various ways of communicating with people. In particular, social media allows new architectural ideas, messages, trends and images to be shared instantly with people around the world. The new ways of sharing and communicating are mostly achieved through screens, not paper. Architecture is therefore experienced through screens and images. The virtual world of images becomes the medium for seeing and experiencing the real world. So, today, we need to understand architecture not just as a building or a material fact, but as “an image effect” created through the media.

5. INSTAGRAM AND ARCHITECTURE

Instagram is one of the most commonly used media platforms established in 2010, and now it has millions of active users all around the world. It is used also as a platform for representing architectural works, architects, designers, cities and buildings in the world. As Wilkinson notes, buildings are mostly photographed with smartphones, and their most photogenic images, with few clues about their internal or external relationships, are instantly shared with the world on social media. It becomes difficult to criticize these buildings in terms of their spaces or contextual relationships. When architectural criticism is

stripped of actual users, spaces, and context in general, it is reduced to “like” or “dislike” on social media, by commenting only on the external views of buildings (Wilkinson, 2015). Social media users see and experience famous buildings through their famous photographs, which are repeatedly published and shared on social media. These photographs begin to define iconic images of buildings that are recognizable to everyone, whether or not they are involved in the profession of architecture.

The photogenic and photorealistic images of buildings published on social media lead people to perceive them as if they were built. So, it almost becomes irrelevant for today’s architecture whether it is built or not. Because the computer-generated images of buildings look like photographs of buildings that we think are actually built. Furthermore, these images look more real than the buildings themselves. Social media, particularly Instagram, is the medium through which realistic images are instantly shared with masses of people. It changes the ways of seeing, perceiving and experiencing architecture. It creates instant communication between architecture and people, but this way of communicating blurs the boundaries between “the real” and “the virtual”.

In this regard, Goffi states that we often cannot be sure whether we are looking at a real image, for example a photograph or a drawing of a building. Computer-generated drawings and renderings usually look like photorealistic images (Goffi, 2007). But, as Grillner suggests, architectural photography captures the object, whereas architectural drawing captures the material fact, such as the exact location of the wall or the extension of the floor (Grillner, 2007).

Architectural photography paves the way for buildings to be seen as images rather than objects. Social media promotes this way of seeing, as it prioritizes images over objects. This reminds Archigram’s approach to architecture, through which the members of the Archigram group design images rather than objects to represent their visionary architectural projects. Instagram’s approach is slightly different in that it results in architectural objects being reduced to images in such a way that images begin to represent themselves apart from the objects. Images have their own reality, as they do not need to represent objects. They can even be more real than objects.

Pallasmaa emphasizes that buildings are often seen as objects that are not embedded in a physical, social and cultural context. This way of seeing leads them to be perceived only as aesthetic objects or images. There is a tendency in contemporary architecture to see buildings as seductive images. But buildings cannot be reduced to images as they are repositories of our daily lives, memories and sensual experiences (Pallasmaa, 2011).

Nevertheless, social media allows images of buildings to become even more seductive than the buildings themselves. We usually sense and experience architecture through images, not buildings or objects in bodily presence. We are constantly exposed to popular images of popular buildings on Instagram. Whether we visit these buildings or not, their images become recognizable to us. When we have the opportunity to visit them, we try to take the most photogenic picture to document it on our social media accounts. It is the new “popular culture” of our time. We tend to experience buildings through their images, even when we see these buildings in their own location. Architects therefore prioritize designing the most photogenic buildings for today’s “screen culture”. So, it is the new tendency of architects to create an image effect on social media, which is likely to result in their buildings being shared and experienced by masses of people, making them a trending topic.

In fact, architects have always tended to design photogenic buildings, but it is probably only in the 21st century that this has been emphasized as a priority of architecture. This is why contemporary architects design buildings as if only their facades and exteriors are worth experiencing. As a result, the built environment is flattened and turned into a giant selfie stage (Fiocco & Pistone, 2020). As Kushner explains, taking a selfie in front of a building carries weight. It carries a different kind of weight than seeing a building or reading about a building in an architectural magazine. It has become a part of our personal history. It becomes a place that people want to visit, that they want to see with their own eyes, and most importantly, it becomes a visual story that can be shared on social media (Kushner, 2015).

Thus, a new term emerges: "Instagrammability." This term is not only about making something photogenic, but also about creating a scene

where people can place themselves to be photographed. Instagrammability is becoming part of our vocabulary, and an important way of thinking and imagining buildings (Wainwright, 2018). We are accordingly witnessing a substitution between “the object” and “the image”, and between “the real” and “the virtual”. As Virilio suggests, it is difficult to believe in the stability of the real, in the fixation of a visuality that is constantly fleeing. The public space of the building disappears behind the instability of a public image (Virilio & Ruby, 1993). Today, it becomes possible to reinterpret “instability” as “instagrammability” when we think of the constant flow of virtual appearances (and disappearances) of buildings, or rather, images of buildings on social media, accelerating the processes of production, reproduction and consumption in architecture.

Fiocco explains that social media is leading to a shift from a functional understanding of design to a formal and commercial one. This affects almost all types of design, including architecture and urban planning. The built environment is becoming a space populated by social media users, who feel the need to self-document their lives by using these spaces as backgrounds for their selfies. These are called “Instagrammable”, or “Instagram-friendly”, spaces in cities. As Fiocco notes, these spaces are mostly designed with transparent, reflective, shiny and slippery materials that prioritize “photographability” over “functionality”. In other words, they are designed to be photogenic for Instagram (Fiocco & Pistone, 2020).

There is a constant flow of images on social media that we are often exposed to in our daily lives. Instagram, in particular, leads us to believe that architecture needs to create stunning images. We see on Instagram that these images become backgrounds for the selfies of the social media users. There has always been an interactive relationship between media and architecture, so much so that media determines architectural trends, styles and innovations. It is also a means of communication in architecture. If the media is an Archigram magazine, architecture communicates with people through paper. But if the media is Instagram, it is screen that creates communication between architecture and people. Whether on screen or on paper, Instagram and Archigram communicate through images and imaginary visions. Since the media prioritizes “the image” over “the object” as a means of communication, the paper discusses Instagram and Archigram as

"media architecture." However, as the paper emphasizes, Instagram and Archigram have their own specific mediums and conditions.

6. INSTAGRAM VS ARCHIGRAM

Instagram and Archigram, as the mediums for disseminating architectural ideas and images, belong to different times, as Instagram is advanced in the 2010s and has had a widespread use in the 2020s, and Archigram is published in the 1960s and 70s. Despite the similarities in their names, Insta-gram and Archi-gram, which refer to information and communication technologies such as the telegram, these are the mediums of different lifestyles and ideologies.

Archigram appears as a printed magazine at a time when hippies and anarchists are challenging the status quo. It is also a time when societies are confronted with the advance of new technologies. With the impact of anarchist movements and technological advancements, Archigram creates a new language that interrogates the differences between high and low culture in architecture. Accordingly, Archigram magazines promote a popular culture in between, declaring that architectural designs need to adapt themselves to the emerging electronic tools and technologies. Archigram is indeed an ideological magazine that informs people about the new lifestyles of societies. Although the Archigram magazine is based in London, it illustrates the American lifestyle, which is largely established on the consumption culture. In this context, pop figures, consumption culture, new lifestyle, electronic technologies, popular culture, Americanization, transportation technologies and movements are some of the leading terms that define the new architectural language of Archigram. By using this language, the members of the Archigram group such as Peter Cook, Ron Herron and Cedric Price publish texts, drawings, illustrations and collages to share their projects with the world through the Archigram magazines. It is through the printed media that these architects disseminate the images of their projects.

Instagram, on the other hand, is being advanced in a different context, where buildings are mushrooming in cities and cities are becoming more crowded and connected spaces in the world. Advances not only in transportation, but also in information and communication technologies, and the internet are connecting people all over the world.

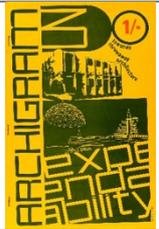
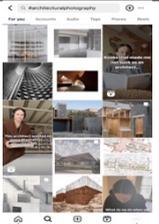
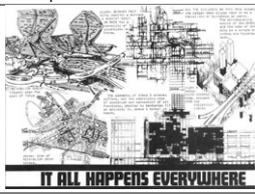
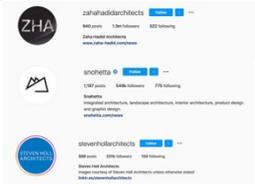
But there is also a growing sense of loneliness and isolation in societies. This is why Instagram and other social media platforms such as Facebook, Twitter and LinkedIn are being developed to promote people's social relationships. Apart from people's need to socialize, these platforms are also used for professional needs, careers, networking and advertising. However, it seems that social media is weakening real social relationships as it separates its users from real life by trapping them in front of screens. In addition, social media, particularly Instagram, encourages more and more consumption by influencing and advertising. On Instagram, we see pictures of new designs of phones, computers, clothes, houses or cars, and we are instantly influenced to buy them, even if we do not actually need them in our daily lives. Instagram is leading the way for consumption culture to become the dominant culture of the 2010s and 20s. We can say that Americanization is still dominant in our daily lives. As such, selfies of people in Starbucks and shopping malls, the popular spaces of American culture, dominate social media platforms. These images define the popular spaces of our time on Instagram, as in the pop figures and images in Archigram.

As the paper argues, Instagram has surprising similarities to Archigram in that both media platforms promote popular culture and consumer culture. However, Instagram is a non-printed platform, accessible to anyone to share and publish, whereas Archigram is a printed platform, constituted by a group of architects who publish design projects and imaginary places. In this respect, Instagram is seen as a more democratic media platform, open to people who are not necessarily professionals, but who still have opinions about architecture to share. The users of Instagram share their opinions mainly through images. So, another similarity between Instagram and Archigram is that they prioritize images over objects. Whether they are drawings, collages, renderings or photographs, they are virtual images that represent real objects, or objects that are imagined to be real. When we see these images in the Archigram magazines, we know that they are virtual. But when we see them on Instagram, we often cannot be sure whether they are real or virtual. Instagram paves the way for blurring the boundaries between reality and virtuality, but Archigram exposes the differences between them. We see speculative images in the Archigram magazines, as the members of Archigram create an alternative reality, usually by publishing images of utopian buildings and cities in the

magazines, beyond the technological limits of the time. But, on Instagram, we are confronted with even more speculative images, or more accurately, seductive images, apart from their utopian or non-utopian qualities, as architectural photography, computer technology and, more recently, artificial intelligence are advancing in ways that often deceive us about the reality of building renderings and photographs.

Instagram and Archigram show us that architecture is not limited to real constructions, that is, buildings or other structures. It is also about constructing virtual images. Rattenbury, therefore, discusses architecture as "media constructions" (Rattenbury et al., 2002). Media provides another construction site for architecture. Instagram is a non-printed medium that leads to the construction of images on screen, and Archigram is a printed medium that leads to the construction of images on paper. So, we can say that the former represents "screen architecture", while the latter represents "paper architecture". However, both media platforms remind us that architecture is not only involved in "building", but also in "image-making". It is not necessary to build an architectural design to be real, it is already real when it is imagined, and its images are represented in media. When these images are represented on Instagram, we tend to criticize them in terms of their "Instagrammability". But when they are represented on Archigram, we tend to criticize them in terms of their "imaginal visionary". We see on Instagram that building images are usually flattened as the backgrounds for the selfies of people and criticism is limited to these images; however, criticism of buildings is expected to cover their social, spatial, functional, and environmental relationships. Instagram thus defines a new type of criticism that can be considered a non-critical approach to architecture. On the other hand, Archigram is a medium that criticizes the existing static architectural language through designing dynamic images of buildings, spaces and cities for the magazines. These are not only dynamic, but also utopic images. As in the Archigram magazines, we also encounter utopic images on Instagram posts and accounts. But these images are usually photogenic and not necessarily based on a utopian imaginary. Rather, they are based on the Instagrammability of spaces and cities (**Table 1**).

Table 1: Instagram vs Archigram (created by the author). This table can be improved by adding new concepts and images describing Instagram and Archigram as specific modes of media.

Archigram	Instagram
	
Printed media	Non-printed media
	
Paper architecture	Screen architecture
	
Architectural imaginary	Architectural photography
	
Imaginal visionary	Instagram friendly
	
Blueprint	Screenprint
	
Architectural drawing	Architectural rendering
	
Utopia-in-architecture	Insta-architecture

Instagram and Archigram create different meanings in architecture by using different materials and technologies. The paper discusses these

differences by comparing the terminological and technological framework of Instagram and Archigram, such as "screen architecture" versus "paper architecture," "non-printed media" versus "printed media," "architectural photography" versus "architectural imaginary," "Instagram-friendly" versus "imaginal visionary," and "architectural rendering" versus "architectural drawing" (See Table 1). Nevertheless, Instagram and Archigram have similar aspects, as well as different characteristics. For example, they both promote popular culture by prioritizing images over objects in architecture. These images are popularized by media environments.

Therefore, the paper focuses on Instagram and Archigram to reveal the changing relationship between media and architecture. Throughout the paper, we understand that architecture exists not only on physical ground, but also on nonphysical ground, namely, media. The merge of nonphysical media and physical space enhance the state of in-betweenness regarding dichotomies such as natural-artificial, real-virtual and material-immaterial in architecture (Başarır & Demir, 2024). On the other hand, social media provides an emancipatory ground for architecture, leading us to question the limits of architectural photography and architectural criticism, which are supposed to be carried out only by professionals (Güzer, 2020). Nowadays, anyone can be a photographer or a critic on social media, so much so that we are now talking about "Insta-architecture". But it is crucial to be able to distinguish between media platforms, as in the case of Instagram and Archigram, because they are the platforms that represent different realities about our everyday lives, social relationships, cities, spaces, and buildings.

7. CONCLUSION

Media and architecture have always had close relationships. In that, media determinates new styles, trends and materials in architecture. Architectural objects, if they are designed according to the new trends, are highlighted to such an extent that we are often exposed to images of these objects in printed and non-printed media. With advances in information and communication technologies, media is now expanding into non-printed media such as digital media and social media. Computer technology supports media to be re-generated in a new environment known as social media. Accordingly, the relationships

between media and architecture are changing in such a way that media also re-generates architecture.

In this context, the paper argues that Instagram, as one of the most popular social media platforms in the world, paves the way for architectural images to be flattened through the screens of phones and computers. It is a new way of generating architectural images in media. It is instant and interactive, meaning that these images are instantly shared with people all over the world, and they have the opportunity to “like” or “dislike” images that they see while browsing among millions of other images. It is also the new way of criticizing architecture in the world of the 21st century. Instagram leads us to criticize architectural objects through their “instant image effects”.

Architectural images published on Instagram do not usually inform us about the functions or the social, spatial and environmental relationships of buildings. Nevertheless, we see the exteriors or the interior images of buildings, and these images allow us to experience the buildings that they represent. This is why images shared on social media are beyond “architectural representations”. As the paper discusses, these are “architectural reproductions” that create a new reality, changing the way we see, perceive and experience architecture.

In the architecture of the 21st century, images are sometimes more real than objects because computers and, more recently, artificial intelligence technology are used to create photorealistic images. This reminds Virilio’s famous quote that “architecture will continue to exist, but in a state of virtual disappearance” (Virilio & Ruby, 1993). Before the advent of digital media and social media, architecture also represents itself in a virtual environment. Architectural images, whether they are photographs or not, are virtual images. For example, drawings, illustrations and collages published in the Archigram magazines are the virtual representations of the Archigram projects. However, the paper argues that Instagram (non-printed) and Archigram (printed) are different mediums through which different meanings are created in architecture. While the former (Instagram) blurs the boundaries between the real and the virtual, the latter (Archigram) creates the virtual as an alternative to the real.

Despite their differences, the paper discusses the similarities between Instagram and Archigram in that they both refer to "media architecture." That means architecture not only represents, but also realizes itself through media, without constructing buildings. Media provides an environment for architecture to construct images of buildings. This is discussed as "architecture without architecture" throughout the paper. The discussions in the paper will hopefully help us to see and understand the changing relationship between media and architecture. Instagram is not an alternative media platform to Archigram, but both of these platforms show us that images dominate text and objects in architecture. Although media is changing radically, architecture still represents and realizes itself in the media. So, it is crucial to understand the new dynamics and realities of media in order to understand the new reality of architecture.

Conflict of Interest Statement

The manuscript entitled "Media Architecture: Instagram versus Archigram" has not been published and is not under consideration for publication elsewhere.

AI Use Disclosure

The author declares that AI or AI-assisted tools were not used in the preparation of this manuscript.

References

- Alaily-Mattar, N., Jones, P. (2025). Representing spatial futures in the age of social media: Unpacking the case of The Line. *Archnet-IJAR: International Journal of Architectural Research*, 19(2), 434–449. <https://doi.org/10.1108/ARCH-06-2024-0235>
- Banham, P. R. (1965). A clip-on architecture. *Design Quarterly*, 1(63), 1-29. <https://doi.org/10.2307/4047309>
- Başarır, S. B., Demir, Y. (2024). Postdigital augmented spaces: A conceptual framework. *VLC arquitetura*, 11(2), 173-189. <https://doi.org/10.4995/vlc.2024.21425>
- Beasley, O. (2015). *In search of distraction: Representing Benjamin's everyday experience of architecture*. University of Westminster.
- Benjamin, W. (1999). The work of art in the age of mechanical reproduction. In H. Arendt (Eds.), *Illuminations* (pp.211-244). Pimlico.

- Colomina, B. (2002). Architectureproduction. In K. Rattenbury (Eds.), *This is not architecture: Media constructions* (pp. 207–221). Routledge.
- Fiocco, F., Pistone, G. (2020, June 17). *Good content vs good architecture: Where does 'Instagrammability' take us?* Arcdaily. <https://www.archdaily.com/941351/good-content-vs-good-architecture-where-does-instagrammability-take-us>
- Fischer, P. T., Hornecker, E. (2017). Media architecture for shared encounters. In A. Wiethoff and H. Hußmann (Eds.), *Media architecture: Using information and media as construction material* (pp. 5-24). De Gruyter.
- Gannon, T. (2008). Return of the living dead: Archigram and architecture's monstrous media. *Log*, 1(13/14), 171-180. <http://www.jstor.org/stable/41765245>
- Goffi, F. (2007). Architecture's twinned body: Building and drawing. In M. Frascari, J. Hale & B. Starkey (Eds.), *From models to drawings: imagination and representation in architecture* (pp. 88-98). Routledge.
- Grillner, K. (2007). Fluttering butterflies, a dusty road, and a muddy stone: Criticality in distraction. In J. Rendell, J. Hill, M. Dorrian & M. Fraser (Eds.), *Critical architecture* (pp.135-142). Routledge.
- Güneri, G. D. (2019). Reading architectural utopia(nism)s: A proposal. *Metu Journal of Architecture*, 36(1), 85-106. <http://dx.doi.org/10.4305/metu.jfa.2018.2.5>
- Güneri, G. D. (2020). Peter Cook beyond Archigram: Towards a critical utopianism. *Prostor*, 1(59), 130-141. [https://doi.org/10.31522/p.28.1\(59\).8](https://doi.org/10.31522/p.28.1(59).8)
- Güzer, A. (2020). Bir mimarlık eleştirisi ortamı olarak sosyal medya. In G. Kaymak Heinz & D. Yaşar (Eds.), *Mimari yansımalar: Şengül Öymen Gür'e armağan* (pp. 29-42). Yem Yayınları.
- İrapoğlu, N., Topdağı Yazıcı, B. (2025). The role of media in architectural studies: An analysis of research on newspapers and periodicals. *Megaron*, 20(3), 325–345. <https://doi.org/10.14744/megaron.2025.17048>
- Junte, J. (2021, March 26). *How media architecture is shaping our cities – and with it our lives*. Arcdaily. <https://www.archdaily.com/959178/how-media-architecture-is-shapingour-cities-nil-and-with-it-our-lives>
- Kushner, M. (2015, March 10). *Why the buildings of future will be shaped by you?* TED Talks. <http://www.youtube.com/watch?v=hhaONsYXS5c>

- Lindsay, G., Sawyer, M., Alaily-Mattar, N. (2025). Architecture in the age of social media: Introduction to the special issue. *Archnet-IJAR: International Journal of Architectural Research*, 19(2): 311–317. <https://doi.org/10.1108/ARCH-03-2025-0114>
- Manovich, L. (2001). *The language of new media*. The MIT Press.
- Martinez Matos, A. (2023). Bernard Rudofsky's curatorial innovation at MoMA: Architecture Without Architects, 1964. *Constelaciones*, 1(11), 35-53. <https://doi.org/10.31921/constelaciones.n11a2>
- Mcluhan, M. (2006). *The medium is the message*. Gingko Press.
- Pallasmaa, J. (2011). *The embodied image: Imagination and imagery in architecture*. Wiley Publications.
- Rattenbury, K., Cooke, C. & Hill, J. (2002). Iconic pictures. In K. Rattenbury (Eds.), *This is not architecture: Media constructions* (pp. 57-90). Routledge.
- Rudofsky, B. (1964). *Architecture without architects: An introduction to nonpedigreed architecture*. The Museum of Modern Art.
- Sadler, S. (2005). *Archigram: Architecture without architecture*. The MIT Press.
- Steiner, H. A. (2009). *Archigram: The structure of circulation*. Routledge.
- Tovar, E. (2025, January 28). *Social media-friendly design: Is architecture adapting to viral trends and algorithms?* Arcdaily. <https://www.archdaily.com/1025972/social-media-friendly-design-is-architecture-adapting-to-viral-trends-and-algorithms>
- Virilio P., Ruby, A. (1993). *Architecture in the age of its virtual disappearance*. Princeton Architectural Press.
- Wagiri, F., Wijaya, D. C., Sitindjak, R. H. I. (2024). Embodied spaces in digital times: Exploring the role of Instagram in shaping temporal dimensions and perceptions of architecture. *Architecture*, 1(4), 948–973. <https://doi.org/10.3390/architecture4040050>
- Wainwright, O. (2018, November 23). *Snapping point: How the world's leading architects fell under the Instagram spell*. The Guardian. <https://www.theguardian.com/artanddesign/2018/nov/23/snapping-point-how-the-worlds-leading-architects-fell-under-the-instagram-spell>
- Wiethoff, A., Hußmann, H. (2017). Introduction. In A. Wiethoff and H. Hußmann (Eds.), *Media architecture: Using information and media as construction material* (pp. 1-2). De Gruyter.

Wilkinson, T. (2015). The polemical snapshot: Architectural photography in the age of social media. *Architectural Review*, 1(11), 91-97. <https://www.architectural-review.com/essays/photography/the-polemical-snapshot-architectural-photography-in-the-age-of-social-media>

Representation and Interpretation of Multi-Agent Systems through Deleuzian Thought

Aysel Merve Baron¹

ORCID NO: 0000-0001-7958-2733¹

¹Istanbul Technical University, Graduate School, Department of Informatics, Istanbul, Türkiye

This study combines multi-agent systems and Deleuzian thought with an interdisciplinary approach, aiming to bring together the explanatory world of the natural sciences and the world of meanings of the social sciences. The study first analyzes the conceptual framework of Deleuzian thought and the working mechanisms of swarm behaviors in multi-agent-based systems. In this context, the concepts of machine, assemblage, rhizome, and flow, which appear in the Deleuzian thought system of the twentieth-century French philosophers Gilles Deleuze and Felix Guattari, were focused on mainly. Subsequently, the relationships between Deleuzian thought and multi-agent systems are examined and interpreted through animated representations created using the Java language in Processing, a graphical programming software. After scrutinizing the representations created in the study, it was concluded that multi-agent systems are compatible with this system of thought, as agents themselves are capable of incorporating the concepts of Deleuzian thought within their working mechanisms. In this regard, the study concluded that multi-agent systems can be considered as ontological frameworks, philosophical systems of thought. Here, the study contributes to social sciences and design research by offering a computationally grounded lens through which concepts of a thought system can be represented, observed, and interpreted in action. By demonstrating how multi-agent systems embody machinic assemblages, emergent flows, and rhizomatic relations, the study provides a methodological approach that enables philosophical concepts and contemporary social theories to inform structure and inspire new forms of creative and analytical inquiry.

Received: 09.12.2025

Accepted: 22.01.2026

Corresponding Author:

baron24@itu.edu.tr

Baron, A. M. (2026). Representation and interpretation of multi-agent systems through Deleuzian thought. *JCoDe: Journal of Computational Design*, 7(1), 29–52.

<https://doi.org/10.53710/jcode.1839208>

ROR ID: 059636586

Keywords: Multi-Agent Systems, Simulation, Swarm Behavior Modeling, Deleuze, Computational Social Theory



Deleuzeyen Düşünceyle Çoklu-Etmen Sistemlerinin Temsili ve Yorumlanması

Aysel Merve Baron¹

ORCID NO: 0000-0001-7958-2733¹

¹İstanbul Teknik Üniversitesi, Lisansüstü Eğitim Enstitüsü, Bilişim Anabilim Dalı, Mimari Tasarımda Bilişim, İstanbul, Türkiye

Bu çalışma, disiplinler arası bir duruşla fen bilimlerinin açıklamalar dünyasıyla sosyal bilimlerin anlamlar dünyasını bir araya getirmek amacıyla, çoklu-etmen sistemleri ve Deleuzeyen düşünceyi birlikte ele almaktadır. Çalışmada, öncelikle Deleuzeyen düşüncenin kavramsal alt yapısı ve çoklu-etmen tabanlı sistemlerdeki sürü davranışlarının çalışma mekanizmaları çözümlenmiştir. Bu bağlamda, yirminci yüzyıl Fransız filozofları Gilles Deleuze ve Felix Guattari'nin Deleuzeyen düşünce sisteminde yer alan makine (machine), asamblaj (assemblage), rizom veya köksap (rhizome), akış (flow) kavramları üzerinde durulmuştur. Ardından, Deleuzeyen düşünce ile çoklu etmen sistemleri arasındaki ilişkiler, grafik programlama yazılımı Processing'de Java dili kullanılarak oluşturulan hareketli animasyon temsiller aracılığıyla incelenmiş ve yorumlanmıştır. Çalışmada oluşturulan temsiller incelendikten sonra, etmenlerin kendilerinin çalışma mekanizmalarına Deleuzeyen düşüncenin kavramlarını dahil edebildikleri gözlemlendiği için, çoklu ajan sistemlerinin bu düşünce sistemiyle uyumlu olduğu sonucuna varılmıştır. Bu bağlamda, çoklu-etmen sistemler ontolojik bir çerçeve, felsefi bir düşünce sistemi olarak ele alınabilir karakterdedirler. Bu çalışma, bir düşünce sisteminin kavramlarının eylem içerisinde temsil edilebileceği, gözlemlenebileceği ve yorumlanabileceği hesaplamaya dayalı bir bakış açısı sunarak sosyal bilimler ve tasarım araştırmalarına katkıda bulunmaktadır. Çalışma, çoklu etmenli sistemlerin Deleuzeyen düşüncedeki makine topluluklarını, beliren akışları ve rizomatik ilişkileri nasıl bünyesinde barındırdığını ortaya koymaktadır. Bu sayede felsefi kavramların ve çağdaş sosyal teorilerin araştırma yapısını şekillendirmesine ve yeni yaratıcı ile analitik inceleme biçimlerine ilham vermesine imkân tanıyan bir yaklaşım sunmaktadır.

Teslim Tarihi: 09.12.2025

Kabul Tarihi: 22.01.2026

Sorumlu Yazar:

baron24@itu.edu.tr

Baron, A. M. (2026). Deleuzeyen düşünceyle çoklu-etmen sistemlerinin temsili ve yorumlanması. *JCoDe: Journal of Computational Design*, 7(1), 29–52. <https://doi.org/10.53710/jcode.1839208>

ROR ID: 059636586

Anahtar Kelimeler: Çoklu Etmen Sistemleri, Simülasyon, Sürü Davranışı, Modellemesi, Deleuze, Hesaplamalı Sosyal Teori



1. INTRODUCTION

While the natural sciences seek to progress through making explanations focused on causality, the social sciences seek to progress by creating meanings and understanding human-related matters (Klüver & Klüver, 2011, pp. 66-75). For example, while there is a singular explanation for the molecular structure of water (two hydrogen atoms, one oxygen atom), the meanings water carries with it are subjective, relative, and numerous. In this regard, Deleuze and Guattari (1994) argue that the social sciences (particularly philosophy) progress not through discoveries but through conceptual creations. The value of a philosophical thought system does not depend on how verifiable or falsifiable it is.

When we turn our attention to contemporary design fields, we see that design is often situated at the intersection of social and natural sciences. Design draws on many different disciplines, such as art, history, philosophy, physics, chemistry, biology, etc., while simultaneously existing in both the world of meanings and the world of explanations. The designer, starting from existing numerous and subjective concepts, creates new concepts/ideas that contribute to human life in meaningful and functional ways, while also having to focus on the inevitable parameters of the physical world—its objective explanations (e.g., the technical aspects of heat, light, materials, and so on). The ill-defined nature of design problems, the inability to adequately explore the solution space and the potential for divergence to infinity, the simultaneous presence of multiple undefined functions and requirements, the responsibility for creativity and innovation, etc., confront the designer with high levels of uncertainty and complexity (Maier & Fadel, 2006). To cope with this complexity today, we often see contemporary design adopting interdisciplinary, innovative, and generative design approaches inspired by evolutionary studies in modern biology. In this context, generative design systems enable complex computational capabilities that support design processes, paving the way for the consideration of a broader and more complex solution space (Singh & Gu, 2012). For instance, while traffic in an urban context involves highly chaotic and dynamic conditions, traffic lights can be optimized by modelling drivers' social behaviors as if they were an ant colony, based on local rules and conditions (see Hoar et al., 2002). Indeed, by making complex phenomena amenable to analysis

through simple rules, evolutionary approaches provide us with decentralized, interactive, and bottom-up multi-simulation environments. However, these multi-simulation environments and the idea of explaining (and perhaps even making sense of) complexity through simple rules represent an effort to create ideal conditions. When it comes to humans, society, and individuals, various layers such as culture, politics, thought structures, and social norms, which we would particularly expect to encounter, get ignored under these ideal conditions. For this reason, in simulations of evolutionary approaches seeking solutions to structural or organizational problems, we encounter an idealized and sterile environment that models complex behaviors. So, what if we step outside the conventional norms, focus on the world of meanings, and open up a discussion about the simulation environments and existing representation mechanisms provided by evolutionary approaches? What pertains to human behavior, society, and the individual belongs more to the world of meanings than to explanations. From this perspective, this study adopts an interdisciplinary stance and aims to reveal representational possibilities offered by evolutionary approaches on an interpretive level. To do so, the study focuses on the logic behind modeling swarm behavior in multi-agent systems, a subfield of evolutionary approaches, along with the Deleuzian thought system. Firstly, the conceptual structure of Deleuzian thought and the working mechanisms of multi-agent systems were construed in the study. Then, the reciprocal relationships between Deleuzian concepts and multi-agent systems were examined through the representational simulations created in the Processing environment.

2. MULTI-AGENT SYSTEMS

Encompassing studies focused on swarm intelligence or swarm behavior, multi-agent systems emerge towards the end of the twentieth century, as complex generative systems simulated in virtual environments containing numerous simple autonomous entities/agents (Singh & Gu, 2012). Preceding the idea of designing autonomous entities in a computer environment, Italian neuroscientist Valentino Braitenberg first imagined autonomous, intelligent, and interacting fictional vehicles together with the rules governing their movement and communication in his science-fiction book *Vehicles: Experiments in Synthetic Psychology* (1984). Inspired by Braitenberg's

autonomous vehicles, Craig Reynolds simulated the coordinated movements of bird flocks and fish schools in a three-dimensional virtual environment in 1986. As shown in **Figure 1**, the combined behavior of the agents in Reynolds' Boids¹ model and their relationships with each other within the group are based on three fundamental rules (Reynolds, 1987; 1999):

Separation: Stay a certain distance away from your neighbors.

Alignment: Move at the same speed and direction as your neighbors.

Cohesion: Move toward the average position of your neighbors.

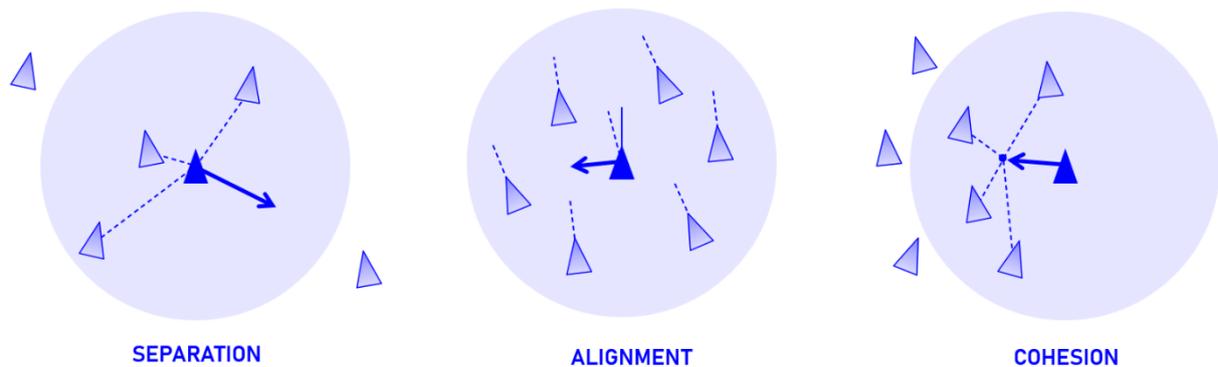


Figure 1: The behavior rules of agents in the Boids model (by the author based on Reynolds, 1999)

Reynolds (1999) also examined the individual behaviors of the agents in detail and listed them as the following: seek and flee; pursue and evade; wander; arrival; obstacle avoidance; containment; wall following; path following; and flow field following. He indicates how artificial life simulations of various living organisms can be created through combinations of simple agent behaviors, and thus, real-world problems such as an emergency evacuation of crowds can be represented and simulated in virtual environments via multi-agent systems (Reynolds, 1999). In the literature, there are many studies that continue Reynolds' work by focusing on the expression and development of algorithms through various combinations of simple behaviors and boids rules (e.g., Delgado-Mata et al., 2007; Olfati-Saber, 2006). Within the scope of the studies conducted, the main application areas of multi-agent systems include artificial intelligence, robotics, computer networks, telecommunication, traffic and transportation, security, e-commerce, business and information management, medical fields, manufacturing sector, and the film and gaming industries (Dorri et al., 2018; Jennings et al., 1998). Today, evolutionary approaches

¹ "Boids" is an abbreviation for the phrase "bird-like (bird-oid) objects."

inspired by agent-based swarm behaviors are frequently adopted for the purpose of generating highly efficient approximate solutions in optimization, design, and engineering problems in fields such as architectural design (Magdy & Eldaly, 2020), urban studies (Kaynarkaya & Çağdaş, 2020), and even fine arts (Choi & Ahn, 2019).

3. DELEUZIAN THOUGHT SYSTEM

Deleuzian thought, constructed by the twentieth-century French thinkers Gilles Deleuze and Felix Guattari, is essentially a philosophical system that emphasizes new ideas, new forms of thought, and the potential of different perspectives (May, 2005). Deleuze and Guattari (1994) draw attention to the chaotic nature of reality, arguing that thought systems introduce impressions of order to enable us to make sense of this chaotic reality and that objective truth can never be attained—nor is it necessary. Philosophy has progressed not through discoveries but through conceptual creations. Although the thinkers of the past believed that they discovered the objective truth about reality, each of them actually created different ontological frameworks as byproducts of completely different cultures and eras. In fact, Deleuze and Guattari also construct their own thought systems by creating numerous, varied, and polysemantic concepts (May, 2005).

Building on this epistemological stance, Deleuzian thought can be situated in close affinity with perspectives emerging from nonlinear systems and chaos theory, where reality is understood as fundamentally dynamic, unstable, and resistant to totalizing explanation (DeLanda, 2002). Here, chaos does not signify randomness devoid of structure but instead refers to a condition in which order is provisional, situational, and continuously renegotiated. This point of view contrasts with classical Euclidean and Hegelian frameworks, which emphasize linear causality, hierarchical organization, and teleological resolution. Rather than reconciling difference with synthesis or equilibrium, Deleuze and Guattari (1994) emphasize becoming, multiplicity, and transformation as primary ontological conditions. In this regard, computational systems, such as multi-agent systems, can be interpreted not as instruments for prediction, control, or optimization, but as environments in which unstable relations, emergent tendencies, and nonlinear trajectories unfold. On this basis, this study focuses on the concepts of machine, assemblage, rhizome,

and flow, which explicitly express processes of becoming, relational organization, and non-hierarchical transformation in Deleuzian thought (see **Figure 2**).

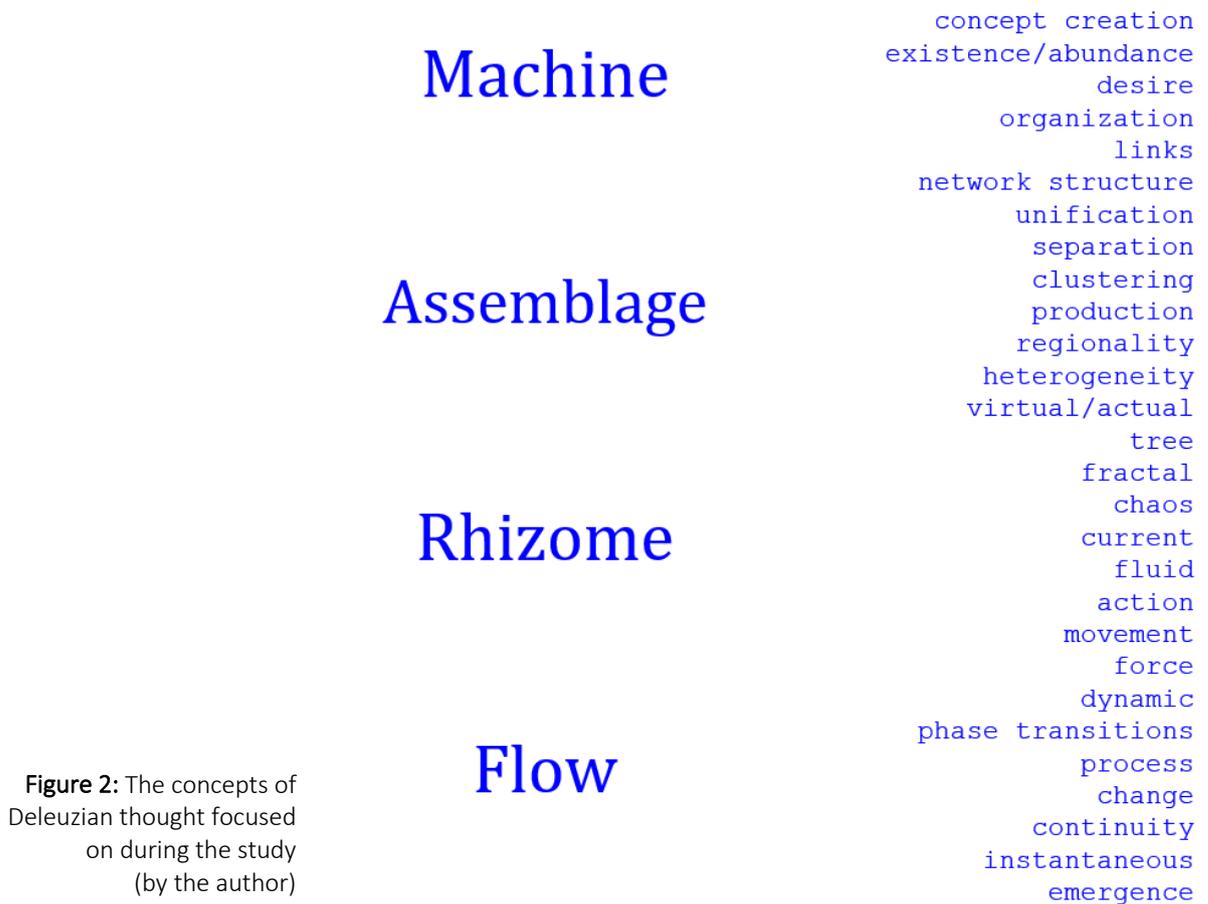


Figure 2: The concepts of Deleuzian thought focused on during the study (by the author)

In the first volume of their book *Anti-Oedipus: Capitalism and Schizophrenia* (1983), where they discuss the political reality of modern Western society, Deleuze and Guattari lament how the foregrounding of the individual subject that emerged with modernity (especially after Marx and Freud) eliminated new perspectives and led to singular points of view. In this context, Deleuze and Guattari (1983) move beyond the thinkers such as Thomas Hobbes, John Locke, and Jean-Jacques Rousseau in the classical liberal tradition, who always viewed things through the lens of the individual. Instead, they suggest that we look at the world through the concept of the *machine*. In Deleuzian thought, everything in the chaotic reality of the world is a machine. Machines are entities with variable desires, inclined to establish connections with other machines, flexible, fluid, and capable of evolving and adapting—

they are everything. Individuals are machines; groups, communities, societies, states, populations, and political movements are also machines. A machine has no rigid, static goals; it can change its desires and objectives at will. The machine connects with other machines to actualize its ideas and momentary desires, and it is generative to the extent of these connections. Deleuzian thought also opposes Freud's association of desire with deprivation in psychoanalysis (Deleuze & Guattari, 1983). According to them (Deleuze & Guattari, 1983), people do not desire when they feel a lack of something in their lives. Desire is a natural process of experience, and at the core of life lies the constant production of variable desire. Here, desire emerges not as a transcendental concept buried in the depths of the individual's subconscious, but as a social force that drives the connections between machines. And besides, the machine, in Deleuzian thought, consists of *assemblages*. Assemblage corresponds to qualitative and quantitative arrangements, combinations, and clusters, but it does not denote a flawless, Hegelian unity created by the mutual fusion of parts. In Deleuzian thought, an assemblage is a fragmented heap whose parts do not form a unified whole. DeLanda discusses how, even within an assemblage, the components possess a distinct autonomy, a certain degree of self-governance, separate from the whole that they form (2006, p. 253). Here, while machines are composed of assemblies, assemblies are also composed of machines.

The *rhizome* is conceptualized in Deleuzian thought in opposition to the hierarchy-oriented modes of thinking that dominate traditional structuralist thoughts. According to Deleuze and Guattari (1987), the representation of the tree, with which classical Western philosophy identifies itself, is entirely dogmatic, linear, and single-perspective. For Deleuze and Guattari (1987), the tree is a highly static, rigid, top-down system with well-defined components, each performing specific functions. Deleuzian thought, however, deconstructs the tree representation and views the world through the rhizome concept. The rhizome is an extremely chaotic and unpredictable root structure in botany (see **Figure 3**). Rhizomes do not grow in a single direction like trees and are not anchored on to the ground. They have no distinct beginning, end, or middle. At any time, a new root can sprout from any part of it in a completely different direction, and then other roots from other parts in other directions. There are roots connecting to these root networks to each other and other roots connecting to both of these

networks to countless other root networks. If a part of the rhizome is cut off, what remains is still a rhizome. What is left behind is also a rhizome. Moreover, in Deleuzian thought, everything in the universe has a rhizomatic structure: ant colonies, ecosystems, different cultures, urban settlements, thought systems, books, films... Therefore, the rhizome is a concept that truly represents the entirety of thoughts, ideas, social movements, and machinic relations (Deleuze & Guattari, 1987).

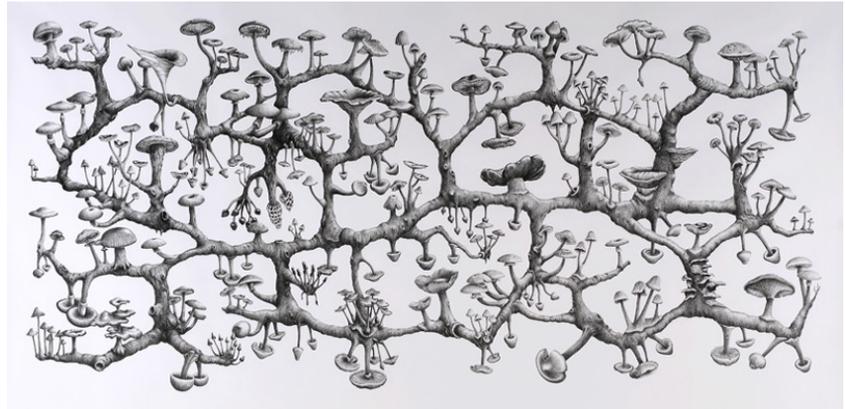


Figure 3: Mycelium Rhizome
(Giblett, 2009)

The concept of flow in Deleuzian thought, similar to the concept of the machine, aims to bring a new perspective to social theory by focusing on the fact that everything in the universe is in motion. Deleuze and Guattari (1987) initially think about the concept of flow in terms of the transfer of goods, services, and money in the world of economics and finance and the movement of commodities such as oil, electricity, and coffee between countries and even cultures (see also Smith, 2012). Considering the continuity of movement in the universe at different levels and forms, Deleuze and Guattari (1987) argued that the concept of flow is actually distinguishable throughout all social reality, alongside and simultaneously with the concept of machine, assemblage, and rhizome. In Deleuzian thought, everything is in a state of movement and flow. It is possible to speak of the flow of everyday life, the flow of labor, human migration to cities and countries, the migration of animal herds, traffic flows in cities, socio-cultural currents, the transmission of genetic information from generation to generation in living beings, and many other states of flow. According to Deleuze and Guattari (1987), in order to understand how a society functions, it is necessary to understand flows, the forces that direct the movement of flows between different poles, how different flows interact with each other,

and how flows are shaped and transformed under the influence of machines' territorializations. At this point, the rhizomatic nature of flow and the territorializations arising from the interactions between machines and flows become apparent. The machine becomes a critical part of the rhizomatic flow as it establishes connections and creates territories. Deleuze and Guattari explain this complex process by using the example of the wasp and the orchid (1987, pp. 10, 12, 293-294). The reproductive process of two orchids pollinating each other can be thought of as a flow between orchids. However, a specific type of wasp plays a very important role in this process. The wasp, which carries the pollen from one orchid to another, becomes a critical part of the flow. Here, the wasp has no fixed identity as it defines itself by the connections it has while carrying the pollen. At that moment, both the goals, desires, and connections the wasp had a week ago and what it will do after this pollen-carrying process are completely irrelevant: the wasp has become deterritorialized. At this point, the wasp is no longer a fixed subject but a movement, a thing in motion, an action unfolding within a larger circulation. It has become part of the flow of reproduction, absorbed into the orchid's own material and semiotic trajectory. It has become an extension of the orchid's reproductive apparatus. Here, what emerges is a rhizome formed between the orchid and the wasp, establishing connections with countless roots in their surroundings, a transient network of connections linking the wasp and the orchid to the innumerable other forces, bodies, and environments that condition this encounter.

4. VISUAL REPRESENTATIONS AND THEIR INTERPRETATIONS

After structuring the conceptual framework of the study, general characteristic features and behavioral mechanisms of the agents were first examined in relation to concepts from Deleuzian thought, and visual representations of these relationships were created in the Processing environment. Afterwards, various multi-agent system representational simulations based on Craig Reynolds' boids behavior model were created in Processing, and the correlations between these representations and Deleuzian thought were discussed. Processing is a simple graphics programming software mainly built on the Java programming language, used in the context of visual design and digital arts, serving as an electronic sketchbook (see Fry & Reas, 2022). The representations in the study were created by dismantling,

deconstructing, adding to, removing from, modifying, and combining fragments of open-source text-based codes that are commonly found in the public domain.

Across all simulations developed in this study, system behavior emerges from a decentralized update structure in which agents operate without global coordination or centralized control. Each agent retains its own state variables, such as position, velocity, and acceleration, and changes/updates its motion through an iterative perception-action loop that runs every frame. At each iteration, agents perceive local conditions within a finite spatial neighborhood, assess situational constraints, and compute steering responses, which are then incorporated into their motion. Collective patterns thus emerge from the accumulation of locally situated decisions rather than from predetermined trajectories or externally imposed objectives. Although the simulations follow a similar architectural logic, different parameter sets were used to emphasize different conceptual relations between multi-agent dynamics and Deleuzian thought. These parameters do not function as variables to be optimized or compared quantitatively; instead, they structure the conditions under which shifts in organization, relational structure, and flow can be observed. In this sense, parameter adjustment is both exploratory and interpretive, enabling the enactment of concepts such as assemblage, rhizomatic connectivity, and distributed agency through computational processes.

4.1 Agent Scale

On the scale of agents, the characteristic features of agents correspond to the features of machines that appear in Deleuzian thought. An agent perceives its environment and other agents and decides for itself how to behave based on the information it acquires (autonomy). Agents have control over their own desires and actions in their environment; they can take initiatives (independence). Agents communicate with each other through their own languages and can organize themselves by gathering together (sociality). Agents can adapt to changes; they evolve; and their desires and wishes can change (adaptation). They respond to their environments behaviorally through their dynamic desires based on the information they receive from it (responsiveness). Unless subjected to external intervention, agents are in a state of constant motion and flow; their movements are flexible and dynamic (mobility).

An agent perceives its environment and decides how to behave according to its own desires based on the information it acquires about the environment (**Figure 4**). These behaviors, which it converts into action by making decisions, cause situational changes in the environment. These situational changes also alter the information the agent acquires about the environment. The agent makes new action decisions by perceiving constantly changing information during the course of its behavior. In environments where numerous agents are present at the same time, each agent affects the conditions in the environment. Therefore, environments with multi-agents embody highly complex, dynamic, and constantly changing unpredictable multi-states. Deleuzian machines also respond to variable environmental conditions with variable behavioral responses in line with variable desires and wishes, while at the same time changing the environment itself. Hence, the environmental relationships, actions, and decision-making processes of agents are the same as those of Deleuzian machines.

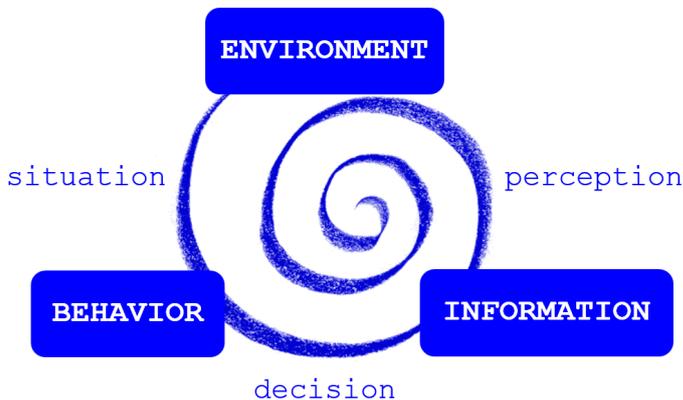


Figure 4: An agent’s relationship with its environment (by the author)

The way that desires and wishes of agents change directly corresponds to the production of desire in Deleuzian thought. For agents, desire does not arise from the lack of something, as in Freudian desire. Desire is a natural process of the agent’s experience of its environment; it does not lie in the depths of the unconscious, it constantly changes, and it directs the agent’s movement. As Deleuzian thought also points out, desire appears as a force that drives the continuous movements of machines and their connections with each other. For example, **Figure 5** shows the free-body diagram of an agent’s movement toward its desired target. Here, a steering force (\vec{R}) arises from the magnitude and

direction of the difference between the desired velocity vector at the moment the agent perceives the target and the instantaneous velocity vector. This steering force leads the agent to follow a parabolic path and reach the target by slowing down. The desired velocity is calculated based on the distance between the target and the current position of the agent and the maximum velocity specified in the simulation.

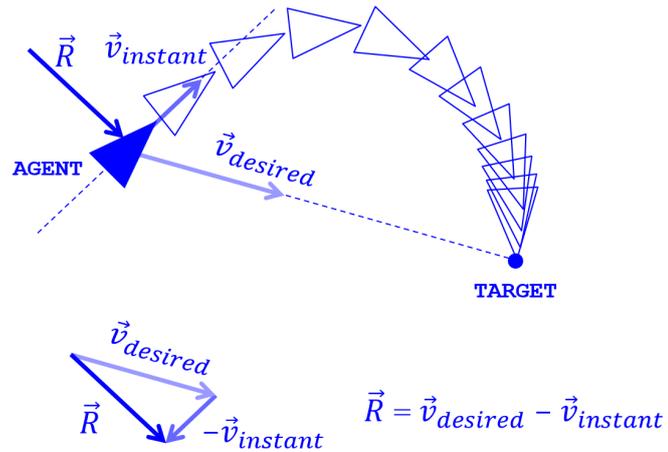


Figure 5: The movement of an agent directed toward a target (by the author)

The simplified function for the movement of an agent directed toward a target in Processing then would be as the following:

```
PVector desiredVelocity=PVector.sub(target, position);
desiredVelocity.setMag(maxVelocity);
PVector steeringForce=PVector.sub(desiredVelocity, velocity);
steeringForce.limit(maxForce);
return steeringForce;
```

Here, the `PVector.sub(x, y)` command takes the vector difference between x and y, while the `setMag` and `limit` commands constrain the scalar magnitudes to the maximum magnitudes (float `maxVelocity`, `maxForce`) predefined in the code so that the motion is observable.

Figures 6 and **7** show snapshots taken from dynamic representations created based on this algorithm. The representation in **Figure 6** simulates simple search and variable target-reaching behavior in agents. First, 20 random targets are assigned in the virtual environment, and approximately 500 agents that desire to reach the target closest to themselves are released into the environment at the mouse cursor's location by holding down the right mouse button. At the beginning of the simulation, the agents move toward their desired

goals. In the meantime, pressing the spacebar on the keyboard removes existing targets from the environment and simultaneously assigns 20 new targets at random locations. Agents do not choose to remain stationary at the goal they have reached. They also do not move toward another goal in the direction they are travelling in response to this change. Instead, they decide new desired targets for themselves. As in Deleuzian machines, agents reproduce their desires and behave flexibly when facing changes. Although the agents' goals are assigned by the programmer, random or not, while coding the system, the agents do not have rigid and static goals. They can change their desires and goals at any time.

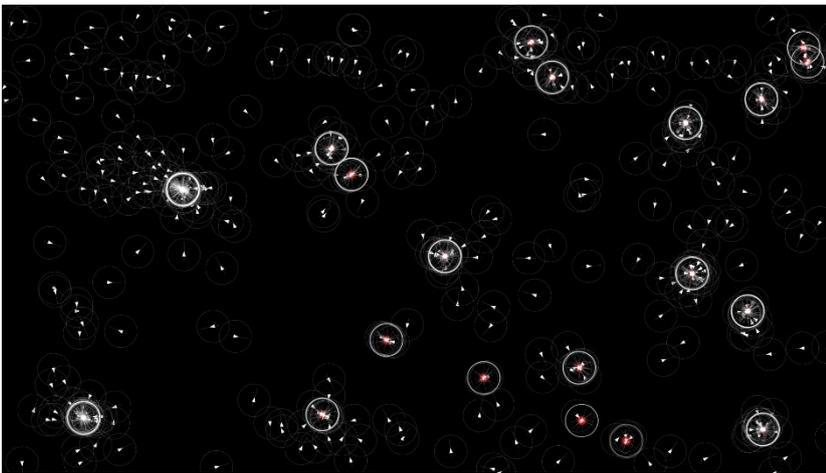


Figure 6: Seek and arrive at goal variations (by the author)

In the representation shown in **Figure 7**, the avoidance movement of the agents around static and node-based obstacles has been simulated, this time including the boid-like behaviors. At the beginning of the simulation, approximately 2000 agents are randomly released into the environment. After a while, the system exhibits a form similar to bird flocks or fish schools, following the Boids model's rules. In the simulation, any number of obstacles can be placed at the locations of the cursors via left-click mouse input. Any agent encountering an obstacle changes its direction of movement in order to steer away from the obstacle. If the other agents in the new direction of movement are not affected by the obstacle, they continue to move in their primary direction. In this case, the agent that changed its direction of movement changes its direction again due to the boid rules and continues to move in harmony with the other agents. When the boid rules are not included in the system, agents simply move away from the

obstacle and continue moving in this new direction until they encounter another obstacle. When the boid rules are included in the system, agents set aside their individualities, just as in Deleuzian thought. Hence, not only are the agents themselves machines, but the system itself also acts as a Deleuzian machine. Moreover, the machine is composed of assemblages, and the components that make up the assemblage, in other words, the agents, can move from one assemblage to another.

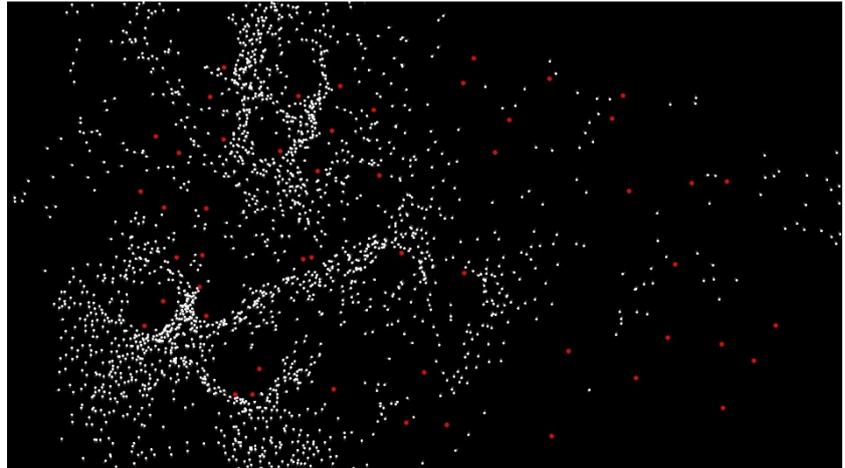


Figure 7: Obstacle avoidance
(by the author)

4.2 System Scale

Following the case of obstacle avoidance, the focus of the study moved from the agent scale to multi-agent systems following the Boids model. **Figure 8** shows a dynamic and user-interactive multi-agent system simulation created during the study. On the upper left corner of the simulation, the basic parameters affecting the boid rules in the algorithm are indicated via a slider-based user interface. Here, moving a slider to the right increases the effect of the relevant parameter on agent behavior, while moving to the left decreases it. The parameters are, in order, as the following: separation, alignment, cohesion, maximum velocity, and maximum force. Here, separation refers to the distance between agents; alignment refers to agents moving at the same velocity and direction; cohesion refers to the tendency to create clusters; and maximum velocity and maximum force, as mentioned in the previous subheading, refer to the limits of the magnitude of the agents' movements. By combining various parameters using the slider interface in this interactive boid-like simulation, plenty of different representations of multi-agent system behavior can be created. In the

context of Deleuzian thought, it has been observed that the maximum force value increases the production of desire, because agents seek new groups/clusters at higher forces. Additionally, agents can change the direction of their movement more quickly and move from one cluster to another more easily at high force values. This ability to easily change the direction of movement increases the variability of desires and wishes within the system. Thus, we encounter a highly mobile, heterogeneous, and dynamic system. The agents are in a constant state of search, and there are non-hierarchical, flexible relationships between the clusters that constantly form and disintegrate. This multi-agent dynamic system contains fragmented agent clusters, and the agents within these clusters possess autonomy separate from the whole they form. As in Deleuzian machines, in addition to the variable relationships and connections between agents, there is also a flexible and variable structure within the agents themselves.

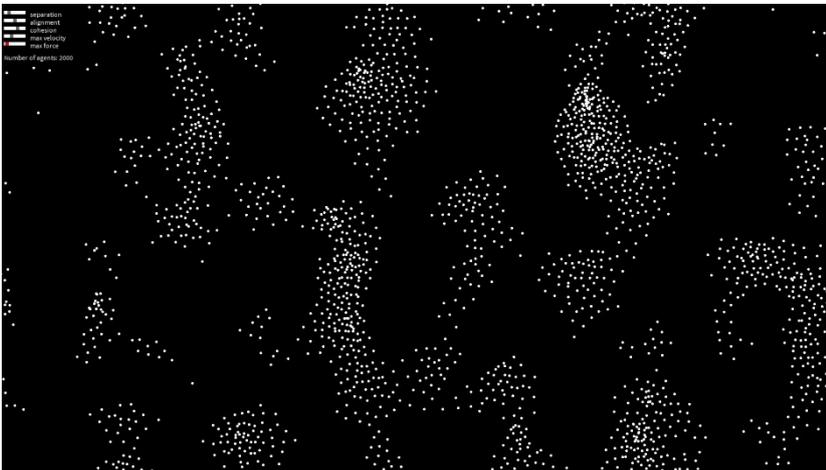


Figure 8: Interactive Boids model (by the author)

In the study, the relationship networks between multiple agents were also examined through the representations created without (**Figure 9**) and with (**Figure 10**) boids rules included. In both cases, the networks revealed decentralized, horizontal, multi-connected structures that contained no hierarchies and were heterogeneous, flexible, and dynamic. Here, these networks show identical character to the rhizome in Deleuzian thought. In other words, rhizomatic relationship networks always exist independently of boid rules among multiple agents. When boid behaviors are incorporated into the system, these rhizomatic relationship networks become more heterogeneous as the clustering emerges. In both systems, relationships get established, then broken,

and re-established, and the networks are fragmented and re-created continuously.

Figure 9: Rhizomatic relations between agents without boid rules (by the author)

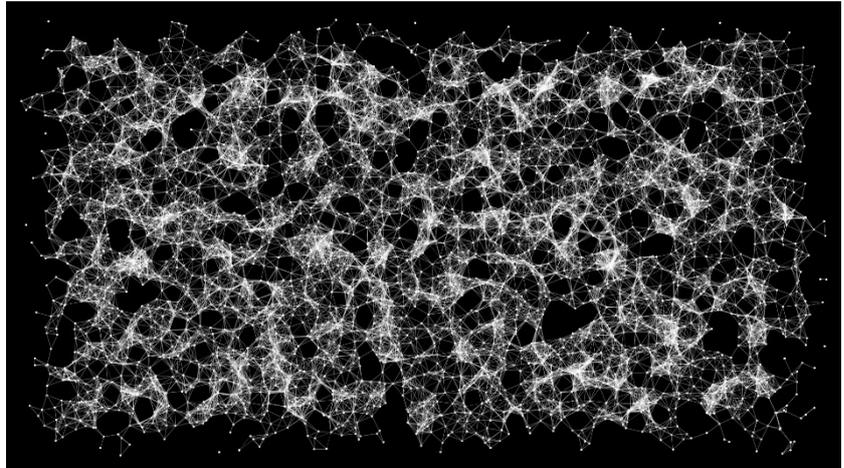
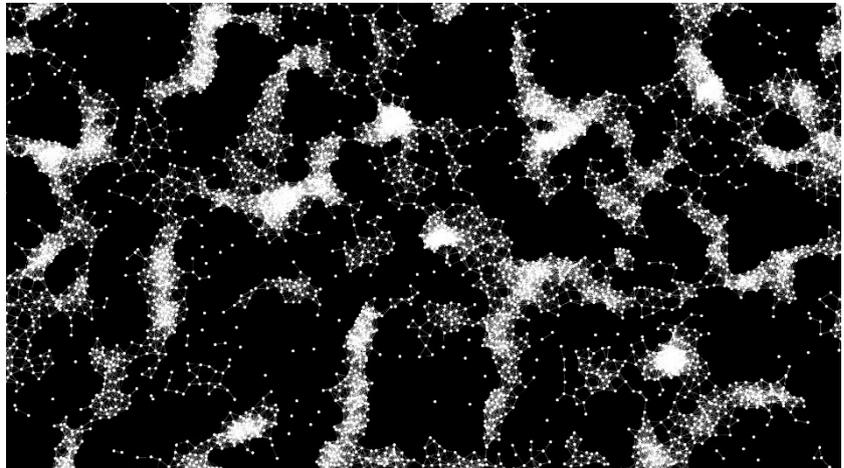


Figure 10: Rhizomatic relations between agents with boid rules (by the author)



A multi-agent system is always in a state of motion and flow. Here, as in the flow concept from the Deleuzian thought, the forces directing the flow of motion, how different flows interact with each other, and how the flow is shaped and transformed under the influence of clusters of agents become significant. Furthermore, the flow of relational information between agents and the flow of situational information between agents and environment also reveal that the system's behavioral mechanisms embody a flow characteristic. **Figure 11** shows a snapshot of the representation created in the study by focusing on the flow motion of multiple agents. The flow motion in multi-agent systems has an inherent temporal dimension. As agents continue their movements within the system, desires are generated based entirely on

momentary situations, and forces that direct the action emerge. Neither the past nor the future has any significance for multi-agent systems, yet the time in the instantaneous state/situation is far too multi-layered to be merely the present. The constantly renewing instantaneous states of the agents in the simulation can be seen on the left side of **Figure 11**. Meanwhile, on the right, the layers of traces generated resulting from the agent's movement from its inception up to that moment are visible (**Figure 11**). Here, agents become a critical part of the rhizomatic flow as they establish connections and create clusters. In this process, agents have no fixed identity; they define themselves through the connections they sustain. Temporally, both the goals, desires, and connections they had before that moment are irrelevant, and what they will do after their instantaneous movement ends is also irrelevant. At this point, the agent has essentially become absolute movement itself, an action. Hence, for the agent, what is at stake on the ontological plane is not being, but becoming.

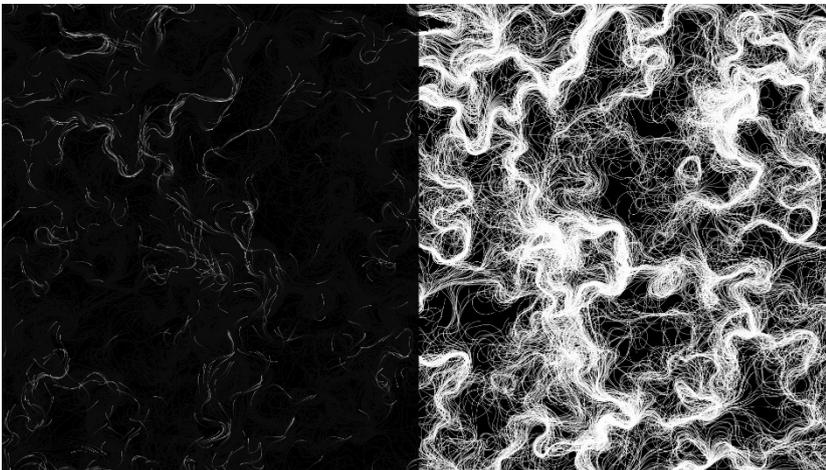


Figure 11: Flow and non-linear time in multi-agent systems (by the author)

Table 1 brings together the conceptual correspondences revealed throughout the study by connecting key Deleuzian concepts with multi-agent system dynamics. The synthesis emphasizes how specific computational principles generate ontologically resonant behaviors at both the agent and system levels. Local autonomy is manifested as self-directed action without centralized control, while dynamic clustering results in provisional formations that continuously assemble and disassemble. Distributed relational networks point to non-hierarchical connectivity, and continuous state updates over time lead to emergent trajectories characterized by ongoing transformation. In this sense, the

simulations serve not as representations of predefined philosophical concepts, but as diagrammatic and interpretive environments in which processes of becoming, multiplicity, and relational organization unfold. The correspondences summarized here therefore operate analytically, demonstrating how abstract concepts from Deleuzian thought can be made observable through computational dynamics without being fixed into prescriptive or static forms.

Table 1: Conceptual correspondences between Deleuzian concepts and multi-agent system dynamics (by the author)

Deleuzian Concept	Computational principle in multi-agent systems	Observed relational dynamics
Machine	Local autonomy and situated decision-making	Self-directed action without centralized control
Assemblage	Dynamic clustering and reconfiguration	Provisional formations that continuously form and dissolve
Rhizome	Distributed relational networks	Non-hierarchical connectivity with no privileged origin
Flow	Continuous state update over time	Emergent trajectories and ongoing transformation

5. CONCLUSION

The study has brought together Deleuzian thought and multi-agent systems not to claim that one can be reduced to the other, but to demonstrate how philosophical and computational structures can be placed in a conceptual alignment. By reading behavioral rules and system dynamics through the lens of machine, assemblage, rhizome, and flow concepts from Deleuzian thought, the paper asserted that multi-agent systems can be treated as more than technical apparatus for analysis and optimization. They can also be approached as ontological frameworks through which a philosophy of becoming, multiplicity, and decentralization can be represented and interpreted in action. In doing so, the study positions computation not merely as a tool for generating or evaluating form, but as a mediating framework through which philosophical and sociological theories become representable and analytically legible within design-oriented contexts. In this regard, the simulations developed in the study do not simply visualize “results” of underlying algorithms. They operate as experimental diagrammatic spaces in which Deleuzian concepts can be implemented. On the agent scale, autonomy, decision-making, responsiveness, and variable desires parallel the machinic qualities that

are attributed to social, political, and subjective processes in Deleuzian thought. On the system scale, assemblages and rhizomatic structures are resonant with the formation and disintegration of clusters, the absence of a centralized authority, and the continuous reorganization of relationship networks. Flows of information, motion, and forces circulate across these scales, indicating becoming rather than being. Here, the simulations serve as dynamic representations of a thought system, giving philosophical concepts that are often regarded as purely abstract an apparent and interactive form.

This approach also challenges the conventional uses of multi-agent systems in design fields, where they typically serve as instruments for control, optimization, or problem-solving. Once we interpret these systems through Deleuzian concepts, they become instruments for opening up rather than closing down the solution space. Rather than prioritizing performance metrics or predictive outcomes, the emphasis shifts toward observed relational dynamics and how relationships emerge, dissolve, and reorganize over time under varying conditions. The correlations presented in this study demonstrate that multi-agent systems can serve as conceptual simulations where designers explore how collective formations, relations, and tendencies emerge under various conditions, rather than being mere inspirational metaphors tied to particular applications. Consequently, generative systems, when associated with thought systems from social sciences, can offer designers an opportunity to cultivate analogies that move beyond the simple mimicry of natural systems and open space for concept-driven, creative, and critical thinking.

In this respect, multi-agent systems serve as a translational medium between the explanatory logics of the natural sciences and the meaning-oriented frameworks of the social sciences, allowing each to inform and clarify the other through shared operational structures. For architecture and urban studies, this translational capacity has implications beyond the use of computational systems as design or optimization instruments. It suggests a way of approaching spatial, social, and urban phenomena as relational and processual conditions instead of as optimizable elements or predictable outcomes. When multi-agent systems are interpreted as diagrammatic and ontological frameworks, they enable architectural and urban inquiry into how collective behavior, spatial organizations, and socio-material relations

emerge, persist, and transform over time. Such a perspective focuses on relations in motion and the conditions under which they emerge, rather than reducing these spatial and social dynamics to deterministic, optimizable, or predefined models. In doing so, it leaves space for architectural, urban, and design thinking to remain concerned with emergence, variation, and transformation.

Acknowledgement

I would like to express my gratitude to Prof. Dr. Gülen Çağdaş and Assoc. Prof. Dr. Ethem Gürer for their valuable critiques and feedback during the MBL601 Evolutionary Approaches in Architectural Design doctoral course at ITU, in which this study was first developed.

Supplementary Materials

A video recording showing instances from the simulations developed in the study can be accessed from the https://drive.google.com/file/d/1EJV9yieJ_aNP2JWhMrW-_gDdZacEzHBP/view.

Code Availability

The codes developed during the study are available from the author upon request.

Conflict of Interest Statement

The manuscript entitled “Representation and Interpretation of Multi-Agent Systems through Deleuzian Thought” has not been published elsewhere, and it has not been submitted simultaneously for publication elsewhere.

AI Use Disclosure

The research design, data collection, analysis, and interpretation presented in this study were conducted entirely by the author without the use of artificial intelligence tools. All components of the manuscript, including the conceptual framework, methodological development, literature synthesis, and writing, were produced through the author’s own scholarly work. No generative AI systems were employed at any stage of the study or the preparation of this manuscript.

References

- Braitenberg, V. (1984). *Vehicles: Experiments in synthetic psychology*. MIT Press.
- Choi, T. J., & Ahn, C. W. (2019). Artificial life based on boids model and evolutionary chaotic neural networks for creating artworks. *Swarm and Evolutionary Computation*, *47*, 80–88. <https://doi.org/10.1016/j.swevo.2017.09.003>
- DeLanda, M. (2002). *Intensive science and virtual philosophy*. Continuum.
- DeLanda, M. (2006). Deleuzian social ontology and assemblage theory. In M. Fuglsang & B. M. Sørensen (Eds.), *Deleuze and the social* (pp. 231–249). Edinburgh University Press.
- Deleuze, G., & Guattari, F. (1983). *Anti-Oedipus: Capitalism and schizophrenia* (R. Hurley, M. Seem, & H. R. Lane, Trans.). University of Minnesota Press.
- Deleuze, G., & Guattari, F. (1987). *A thousand plateaus: Capitalism and schizophrenia* (B. Massumi, Trans.). University of Minnesota Press.
- Deleuze, G., & Guattari, F. (1994). *What is philosophy?* (H. Tomlinson & G. Burchell, Trans.). Columbia University Press.
- Delgado-Mata, C., Martinez, J. I., Bee, S., Ruiz-Rodarte, R., & Aylett, R. (2007). On the use of virtual animals with artificial fear in virtual environments. *New Generation Computing*, *25*(2), 145–169. <https://doi.org/10.1007/s00354-007-0009-5>
- Dorri, A., Kanhere, S. S., & Jurdak, R. (2018). Multi-Agent Systems: A Survey. *IEEE Access*, *6*, 28573–28593. <https://doi.org/10.1109/ACCESS.2018.2831228>
- Fry, B., & Reas, C. (2022). *Overview*. Processing. Retrieved November 14, 2025, from <https://processing.org/overview/>
- Giblett, R. (2009). *Mycelium Rhizome* [Pencil on paper]. Galerie Dusseldorf. Retrieved May 24, 2021, from https://www.galeriedusseldorf.com.au/GDArtists/Giblett/RG2006_09/RGiblettRecentWk2006_09/source/21.mycelium_rhizome_lo_res.html
- Hoar, R., Penner, J., & Jacob, C. (2002). Evolutionary swarm traffic: If ant roads had traffic lights. *Proceedings of the 2002 Congress on Evolutionary Computation*, *2*, 1910–1915. <https://doi.org/10.1109/CEC.2002.1004535>
- Jennings, N. R., Sycara, K., & Wooldridge, M. (1998). A Roadmap of Agent Research and Development. *Autonomous Agents and Multi-Agent Systems*, *1*(1), 7–38. <https://doi.org/10.1023/A:1010090405266>
- Kaynarkaya, S., & Çağdaş, G. (2020). Sürü Zekâsı Yaklaşımı İle Metro Hatlarının Değerlendirilmesi [Evaluation of Metro Lines with Swarm

- Intelligence Approach]. *JCoDe: Journal of Computational Design*, 1(3), 17–48. <https://izlik.org/JA86NU28KL>
- Klüver, J., & Klüver, C. (2011). *Social understanding: On hermeneutics, geometrical models and artificial intelligence*. Springer.
- Magdy, H., & Eldaly, H. (2020). Applying swarm intelligence in architectural design. In S. Kamel, H. Sabry, G. F. Hassan, M. Refat, A. Elshater, A. S. A. Elrahman, D. K. Hassan, & R. Rashed (Eds.), *Architecture and urbanism: A smart outlook* (pp. 77–87). Springer International Publishing.
- Maier, J. R. A., & Fadel, G. M. (2006). Understanding the Complexity of Design. In D. Braha, A. A. Minai, & Y. Bar-Yam (Eds.), *Complex engineered systems* (pp. 122–140). Springer.
- May, T. (2005). *Gilles Deleuze: An introduction*. Cambridge University Press.
- Olfati-Saber, R. (2006). Flocking for Multi-Agent Dynamic Systems: Algorithms and Theory. *IEEE Transactions on Automatic Control*, 51(3), 401–420. <https://doi.org/10.1109/tac.2005.864190>
- Reynolds, C. W. (1987). Flocks, herds and schools: A distributed behavioral model. *ACM SIGGRAPH Computer Graphics*, 21(4), 25–34. <https://doi.org/10.1145/37402.37406>
- Reynolds, C. W. (1999). Steering behaviors for autonomous characters. In *Proceedings of the Game Developers Conference* (pp. 763–782).
- Singh, V., & Gu, N. (2012). Towards an integrated generative design framework. *Design Studies*, 33(2), 185–207. <https://doi.org/10.1016/j.destud.2011.06.001>
- Smith, D. W. (2012). Flow, Code, and Stock: A Note on Deleuze’s Political Philosophy. In *Essays on Deleuze* (pp. 160–172). Edinburgh University Press.

From Control to Contingency: Tolerance as a Generator of Digital Space

İpek Kuran Yıldırım¹, Umut Tasa²

ORCID NO: 0000-0002-3790-6231¹, 0000-0003-0754-8012²

¹Yıldız Technical University, Faculty of Art and Design, Art and Design PhD Program, Istanbul, Türkiye

²Yıldız Technical University, Faculty of Art and Design, Interactive Media Design, Istanbul, Türkiye

This study repositions the concept of tolerance in XR-mediated digital space production from a narrow technical flexibility to a multi-layered principle of openness, uncertainty, and generative difference. In contrast to representational, form-centered, and deterministic design approaches, it advocates an understanding of space as a continuously emerging field of interaction and process. Drawing on Deleuze's concepts of becoming and difference and Parisi's account of speculative computation, the research conceptualizes XR space not as a fixed structure but as an evolving topology where deviations and contingencies are productive rather than erroneous. Experimental investigations extend from simulations, interpreted as agent-based systems, to sensor-driven embodied interaction in XR. These experiments reveal tolerance as an operative condition on behavioral, formal, and temporal levels: small parameter shifts or bodily variations generate qualitatively distinct outcomes, transforming unpredictability into creative potential. The findings demonstrate that tolerance is not a residual setting but a systemic bandwidth through which digital environments sustain novelty. The study contributes to architectural discourse by reframing tolerance as a missing conceptual link: an ontological, algorithmic, and experiential principle that sustains difference, enables co-authorship between human and machine, and positions XR-mediated design as an adaptive and processual mode of spatial production.

Received: 20.06.2025

Accepted: 26.09.2025

Corresponding Author:

ipekkuranyildirim@gmail.com

Kuran Yıldırım, İ. & Tasa, U. (2026).

From control to uncertainty:

Tolerance as generator of digital

space. JCoDe: Journal of

Computational Design, 7(1), 53-70.

<https://doi.org/10.53710/jcode.1723>

[991](#)

ROR ID: 059636586

Keywords: Digital Space, Agent-Based Design, Computational Design, Emergence, Algorithmic Flexibility.



Kontrolden Belirsizliğe: Dijital Mekânın Üretiminde Tolerans

İpek Kuran Yıldırım¹, Umut Tasa²

ORCID NO: 0000-0002-3790-6231¹, 0000-0003-0754-8012²

¹Yıldız Teknik Üniversitesi, Sanat ve Tasarım Fakültesi, Sanat ve Tasarım Doktora Programı, İstanbul, Türkiye

²Yıldız Teknik Üniversitesi, Sanat ve Tasarım Fakültesi, İnteraktif Medya Tasarımı, İstanbul, Türkiye

Bu çalışma, XR aracılı dijital mekân üretiminde tolerans kavramını dar bir teknik esneklikten çok katmanlı bir açıklık, belirsizlik ve üretken fark ilkesi olarak yeniden konumlandırmaktadır. Temsile, biçim-merkezli ve deterministik tasarım yaklaşımlarına karşı, mekânın sürekli ortaya çıkan etkileşim ve süreç alanı olarak anlaşılmasını savunmaktadır. Deleuze'ün oluş ve fark kavramları ile Paris'inin spekülâtif hesaplama yaklaşımından yola çıkarak, XR mekânı sabit bir yapı olarak değil; sapmaların ve kontenjanların hata değil üretkenlik kaynağı olduğu evrimsel bir topoloji olarak kavramsallaştırmaktadır. Deneysel incelemeler, ajan-temelli sistemler olarak yorumlanan simülasyonlarından XR'de sensör tabanlı bedensel etkileşime uzanmaktadır. Bu deneyler, toleransın davranışsal, biçimsel ve zamansal düzlemlerde işleyen bir koşul olduğunu ortaya koymaktadır: küçük parametre kaymaları veya bedensel varyasyonlar, öngörülemezliği yaratıcı bir potansiyele dönüştüren niteliksel olarak farklı çıktılar üretmektedir. Bulgular, toleransın artık ikincil bir ayar değil, dijital ortamların yeniliği sürdürülebilirliğini sağlayan sistemik bir bant genişliği olduğunu göstermektedir. Çalışma, toleransı mimarlık söylemine eksik kalmış bir kavramsal halka olarak yeniden dahil ederek katkı sunmaktadır: farkı sürdüren, insan ile makine arasında eş-yazarlığı mümkün kılan ve XR aracılı tasarımı uyarlanabilir ve süreçsel bir mekân üretim biçimi olarak konumlandıran ontolojik, algoritmik ve deneysel bir ilke olarak konumlandırır.

Teslim Tarihi: 20.06.2025

Kabul Tarihi: 26.09.2025

Sorumlu Yazar:

ipekkuranyildirim@gmail.com

Kuran Yıldırım, İ. & Tasa, U. (2026).
Kontrolden belirsizliğe: Dijital
mekânın üretiminde tolerans. JCoDe:
Journal of Computational Design,
7(1), 53-70.

<https://doi.org/10.53710/jcode.1723991>

ROR ID: 059636586

Anahtar Kelimeler: Dijital Mekân, Ajan Tabanlı Tasarım, Hesaplamalı Tasarım, Oluş, Algoritmik Esneklik.

1. INTRODUCTION

Extended Reality (XR)—an umbrella term encompassing Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR)—has rapidly evolved as a medium that merges physical and digital environments into hybrid, immersive experiences. Unlike traditional architectural or screen-based digital models, XR-mediated spaces are not static representations but embodied environments that are continuously reshaped by user interaction, system feedback, and contextual conditions.

Despite this potential, many XR applications continue to reproduce physical environments as digital replicas or rely on conventional representational approaches. Such practices reduce XR to digital mimicry and overlook its capacity as a computational, process-driven, and interactive medium. This tendency reveals a methodological gap: the lack of design frameworks that fully exploit XR’s immersive and dynamic affordances.

Within computational design, this gap becomes particularly evident in the treatment of the concept of tolerance. Often reduced to a technical “margin of error,” tolerance has been framed as a constraint to be minimized rather than as a productive element of design. Yet in computational and adaptive systems, tolerance can be reinterpreted as openness to uncertainty, deviation, and difference—qualities that are central to the creative potential of XR-mediated environments.

This study therefore aims to reposition tolerance as a central design principle in XR-based digital space production. By shifting the discussion from tolerance as a technical parameter to tolerance as a creative and ontological condition, the paper articulates a conceptual and methodological framework grounded in agent-based modeling experiments. In doing so, it demonstrates how tolerance can be operationalized, visualized, and harnessed as a generative mechanism, offering new insights for the design of immersive and adaptive XR environments.

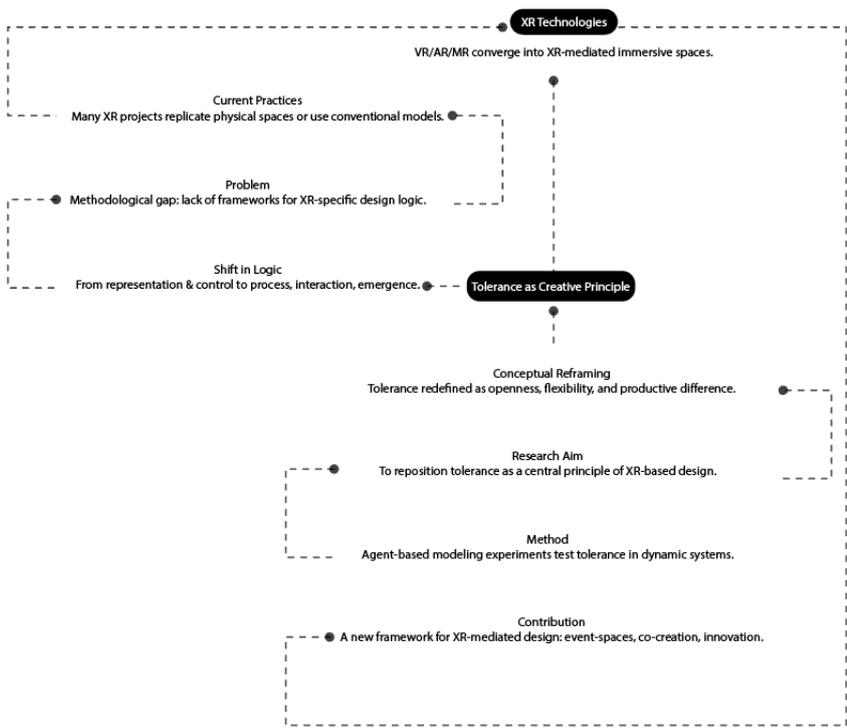


Figure 1: Conceptual cycle of the introduction: from XR technologies to tolerance as a creative principle in XR-mediated digital space.

In summary, the research problem addressed in this article is how tolerance can be repositioned from a marginal technical setting into a central creative principle of XR-mediated spatial experiences. To clarify this conceptual trajectory, **Figure 1** visualizes the logical flow of the study: starting from the emergence of XR technologies and their current practices, it highlights the methodological gap, the shift in design logic, and the reframing of tolerance. The cycle then connects the research aim and methodological choices to the broader contribution of the work, illustrating how tolerance functions not as a residual parameter but as the generative core of immersive digital design.

Building on this framework, the article proceeds in four stages. First, it outlines the philosophical foundations of XR-based digital space through concepts of difference, formation, and process. Second, it examines how tolerance operates within computational models such as agent-based systems. Third, it presents experimental studies that make tolerance visible through formal and spatial variations. Finally, it

discusses how tolerance can be rethought as a creative design tool and ontological principle in XR-mediated environments.

2. TOLERANCE IN AGENT-BASED SYSTEMS: Algorithmic Flexibility and Distributed Generation

In XR-mediated digital environments, space can no longer be conceived as a visual surrogate of the physical world or as a symbolic vessel of cultural forms. When confined to representation, digital space is relegated to the circulation of images and the reproduction of identities, thereby neutralizing its most radical capacity: the generation of productive difference. By contrast, XR introduces a mode of spatiality that is immersive, relational, and processual, continuously reconfigured through embodied interaction, system feedback, and environmental contingencies. Within this horizon, tolerance must be redefined: no longer a narrow margin of technical error, it emerges as an ontological openness, the very condition through which deviation, uncertainty, and indeterminacy become productive forces rather than disruptive anomalies.

The difficulty of articulating such a shift lies in the long philosophical dominance of representational thought. From Plato's metaphysics of Ideas and Aristotle's logic of form and substance to Descartes' cogito, Kant's categorical schemata, and Hegel's dialectical totalities, Western philosophy has privileged the primacy of identity, resemblance, analogy, and opposition. Within this regime, difference has been subordinated to sameness, rendered either as deficiency or deviation. This lineage is broken decisively with the affirmation of difference in itself as a generative force of becoming (Deleuze, 1994). Thought, in this view, is not recognition but production; it does not ask "what is this?" but "what does this do?" In XR, this reversal is not merely conceptual but phenomenological: users encounter environments that do not present pre-coded forms to be recognized but relational systems of forces to be experienced. Tolerance is precisely the interval that sustains such openness, ensuring that variability manifests as creation rather than error.

Deleuze's concepts of repetition, multiplicity, and the virtual radicalize this framework. Repetition is never the return of the same but the inscription of difference in time; each recurrence is singular, irreducible to identity. Multiplicity designates a field of differences that cannot be

subsumed into unity. The virtual is a reservoir of potentials whose actualizations are always partial, contingent, and incomplete. XR environments instantiate these dynamics directly: each gesture, gaze, or interaction actualizes different virtual potentials, generating singular spatial events that resist stabilization. Here, tolerance functions as the system's bandwidth, an elastic margin that allows the passage from the virtual to the actual without predetermination, enabling novelty to emerge as a systemic condition.

This rethinking extends into spatial ontology. Reality can be understood as a continuum of folds, where inside and outside endlessly inflect one another (Deleuze, 1993). Space ceases to be a homogeneous container and becomes a dynamic topology of curvature and transformation. XR environments operate within this register: minor parametric adjustments or behavioral perturbations fold spatial patterns into new configurations. Tolerance is what carries these folds; it is the threshold that allows infinitesimal differences to ramify into qualitative transformations, making instability a productive force rather than a system breakdown.

Luciana Parisi advances this line of thought into the computational domain. Algorithms are not inert mechanisms of calculation but speculative structures oriented toward incalculable possibilities (Parisi, 2013). Her notion of "parametric prehension" casts code as a selective and affective medium that senses, responds, and transforms in relation to data. Computation itself thus becomes a plane of becoming, resonant with the virtual (Deleuze, 1994): each execution condenses potential into actuality without exhausting it. In XR, such logics are rendered experiential, as environments mutate in real time according to the embodied inputs of users. Tolerance here is not error management but the operational latitude through which micro-variations in thresholds or parameters generate emergent, unforeseeable spatialities.

Digital design in this sense is grounded in an open, topological, and computational aesthetic (Parisi, 2013). Similar ambitions have been articulated within architectural practice by figures such as Marcos Novak, Greg Lynn, and Patrik Schumacher. Novak's notion of liquid architectures anticipated the idea that digital space should unfold as fluid, adaptive environments rather than as mimetic reproductions of

physical structures (Novak, 1991). His work expanded the imagination of architecture into immersive, cybernetic, and speculative domains, foregrounding the capacity of the digital to construct entirely new spatial ontologies. Lynn's theorization of animate form reframed architecture as a temporal and process-driven entity, where geometry is not a fixed container but a continuously transforming material responsive to forces and contexts (Lynn, 1999). Schumacher's discourse on parametricism advanced this trajectory by proposing a systemic design paradigm in which variation, adaptability, and correlation between elements replace typological stability as the organizing logic of space (Schumacher, 2009). In parallel, reflections on digital tectonics highlighted the need to reconceptualize the structural and material dimension of architecture under digital conditions (Leach, Turnbull, & Williams, 2004), while Kolarevic emphasized the integration of design and manufacturing through algorithmic processes (Kolarevic, 2003), and Menges explored morpho-ecologies in which material performance and computational logic converge (Menges, 2007). Collectively, these contributions map the contours of a disciplinary shift: from architecture as representation and formal stability to architecture as dynamic, adaptive, and processual production.

Yet a critical tension remains. These contributions extend architectural thought beyond representation and formalism, but their emphasis often rests on stylistic novelty, formal proliferation, or aesthetic paradigms. The underlying question of tolerance—as the active negotiation of uncertainty and deviation—remains underdeveloped. In other words, computational design acknowledges emergence but rarely theorizes the systemic conditions that enable difference to become productive rather than accidental.

It is precisely here that this study turns toward agent-based systems. Unlike parametric or geometric frameworks, agent-based modeling foregrounds uncertainty, relationality, and decentralized decision-making as its operative logics. By generating difference as an inherent and irreducible quality, such systems provide a unique lens for examining tolerance not as a technical constraint but as a generative condition of spatial production.

As illustrated in **Figure 2**, the conceptual trajectory of this section moves from philosophical ontologies of difference, through

computational mediation and architectural translation, toward the methodological operationalization of tolerance in agent-based systems, all within the lived horizon of XR environments. In the following section, agent-based approaches will therefore be introduced as the methodological ground for operationalizing tolerance. By moving from philosophical and theoretical arguments to computational experiments, the study demonstrates how tolerance can be both theorized and made visible as a systemic and creative quality of XR-mediated digital space.

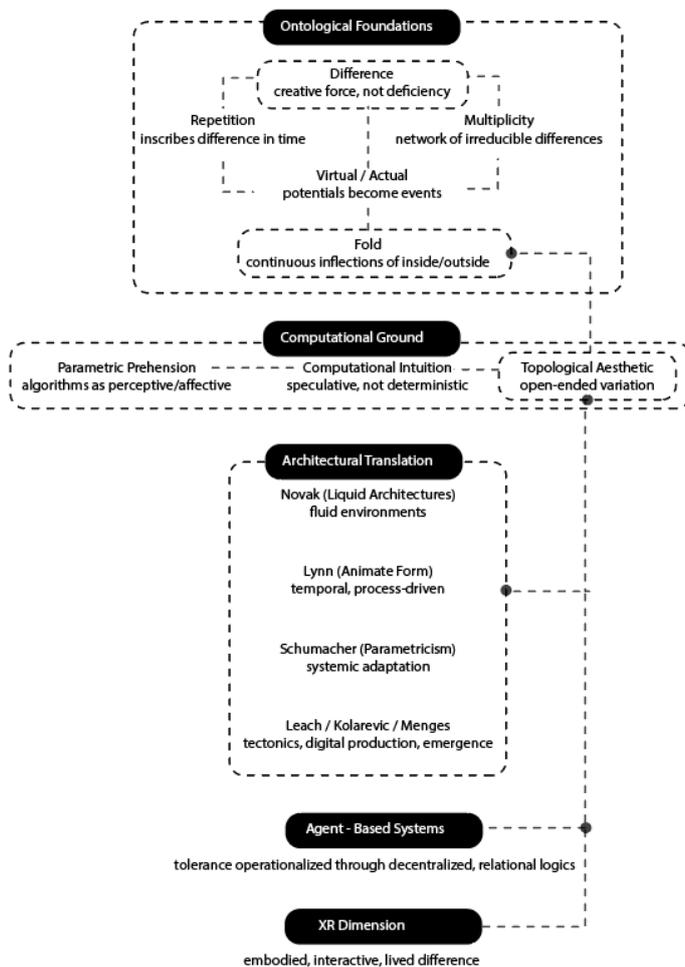


Figure 2: Conceptual Trajectory of Tolerance in XR-Mediated Digital Space.

3. TOLERANCE IN AGENT-BASED SYSTEMS: ALGORITHMIC FLEXIBILITY AND DISTRIBUTED GENERATION

In XR-mediated digital space production, the design is shaped not through predetermined forms but through interactive and plural processes; this causes design thinking to shift from static representation toward relational interaction, from precision toward openness, and from control toward emergence. This transformation is embodied through agent-based systems (Agent-Based Systems, ABS), which have emerged as an important methodological approach in the field of computational design. In such systems, tolerance is not a fixed margin of error but a range that enables the behavioral flexibility and evolutionary capacity of the system. More importantly, tolerance becomes the creative principle that allows unpredictable agent behaviors to produce novel spatial events in XR environments. In this section, the concept of tolerance will be analyzed through the basic features of agent-based models; the productive role of tolerance in distributed, local, and interaction-based space production will be discussed.

Agent-based systems are defined as decentralized structures that work on the behaviors of subcomponents and derive the whole from these local interactions. As defined by Macal and North, each agent is a unit that can perceive its environment, make decisions, and change its behavior according to the situation (Macal & North, 2010) . In these systems, integrity emerges not as a form imposed from above but through the micro-level relationships that agents establish with each other and their environments. Therefore, XR-based digital space is not an object produced by the designer; it is a process of formation resulting from the interactions of agents. In this process, tolerance comes into play as an openness that allows the system to differentiate and restructure rather than disintegrate when these interactions involve deviation, error, or unpredictability. From a methodological perspective, this means that system parameters (such as threshold values, behavioral rules, or probabilistic triggers) need to be explicitly defined and tested. In the following experimental section, these parameters will be detailed and visualized through step-by-step demonstrations to clarify how tolerance operates within the system.

In this context, tolerance becomes visible both in the way behavioral rules are defined and in the uncertainty of the agents' reactions to the environment. For example, an agent's not taking action when it passes a certain threshold value but showing different behaviors when it approaches the threshold value increases the tolerance capacity of the system. This enables the establishment of probabilistic systems based on openness instead of deterministic structures based on fixed rules. Thus, tolerance becomes a productive area that triggers behavioral diversity and differentiation, not a flexibility that only allows for error.

As Eric Bonabeau points out, agent-based modeling allows the system to operate in a way that is based on heterogeneity and local decisions (Bonabeau, 2002). This situation offers a radical alternative to the long-standing top-down modeling practices common in digital modeling traditions. In traditional modeling approaches, all components of the system are defined centrally, and each unit is obliged to comply with this definition. However, in agent-based approaches, the components (agents) are independent; they shape their behaviors according to the micro-scale interactions they enter with the environment. Here, tolerance becomes indispensable for the system to maintain its decentralized structure: even when the behavior of each agent is not completely predictable, the system has the capacity to develop new patterns instead of collapsing.

In agent-based systems, space is not just a background; it is an interaction surface for agents. Agents are both affected by this environment and change it by affecting it. This two-way relationship transcends classical understandings of space and transforms digital space into a "behavior area". Within this behavior area, tolerance shapes the dynamics of space depending on how agents read environmental data, how they react, and what deviations these reactions may contain. Here, the designer constructs the agent's area of action, decision mechanism, and interaction protocol, not the form. Tolerance operates in space between these decisions. In creative terms, this means that the designer shifts from authoring forms to co-authoring conditions for emergence. Tolerance provides the necessary openness for this co-authorship between designer, agent, and user.

4. EXPERIMENTAL APPLICATIONS: VISIBILITY AND PRODUCTIVE EFFECTS OF DIGITAL TOLERANCE

Tolerance in XR-mediated digital space production is not only a technical margin of flexibility but a principle that enables behavioral diversity and formal differentiation. To explore this, initial experiments employed a simple metaball algorithm. Although often treated as a basic modeling tool, metaballs can be read as an agent-based system, since each metaball acts as an agent generating a field and interacting locally with others. The focus here was not the final form but the dynamics of the system.

By varying parameters such as population count, seed, and threshold, it became clear that tolerance functions as a systemic condition: small shifts in thresholds produced radically different densities and connections, revealing that space emerges as a relational field rather than a predetermined geometry. These experiments established tolerance as the bandwidth through which uncertainty becomes generative.

The system used in experimental productions is based on a simulation in which interactive agents create a certain gravitational field, and these fields approach each other to form a superficial space. In this context, the basic inputs of the system were controlled with three parameters:

- Population Count: Number of agents
- Seed: Random value that determines the initial distribution
- Threshold: Interaction distance between agents, that is, tolerance range that determines whether the form will merge or not

To move beyond abstract simulation, the system was extended through visual analyses and embodied experiments in which the designer entered the network via sensor data. In this setting, tolerance became directly perceptible: deviations from bodily movement were absorbed by the algorithm and transformed into new spatial formations. The diagrams and video stills thus demonstrate that tolerance operates not

only technically but also formally and experientially, sustaining novelty as the core condition of XR-mediated design.

4.1. Visual Analysis: Formal Expansion of Tolerance

As represented visually in the diagram in **Figure 3**, the presence of a single agent and a high threshold value caused the system to remain unsolved without creating any surfaces. This shows that the system loses its productivity in the absence of tolerance. When the number of agents is zero or the interaction thresholds are reduced to zero, no connection can be established between the parts, and the system remains in the void without producing forms.

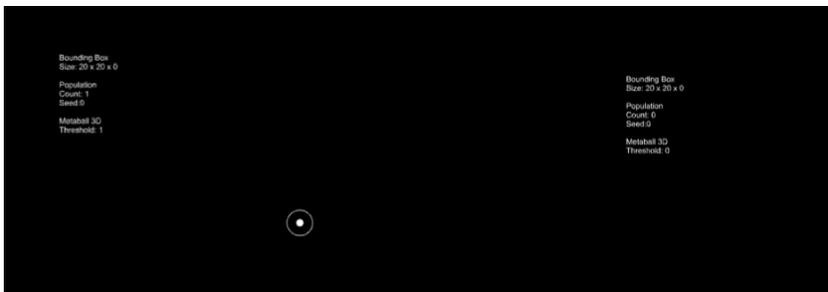


Figure 3: Left Image: Population Count: 1, Seed: 0, Threshold: 1 & Right Image: Population Count: 0, Seed: 0, Threshold: 0.

As represented visually in the diagram in **Figure 4** and **Figure 5**, it was observed that with the increase in the population number, the points surfaced, connected, and formed more holistic structures depending on the threshold value. The fact that the same number of agents produced completely different results only when the threshold value was different confirms that tolerance is a dynamic determinant in the production of digital space. This variability demonstrates tolerance as a mechanism of creative differentiation, where the system explores multiple possible outcomes instead of converging on a single solution.

Figure 4: Left Image: Population Count: 20, Seed: 0, Threshold: 0.5. & Right Image: Population Count: 20, Seed: 0, Threshold: 0.

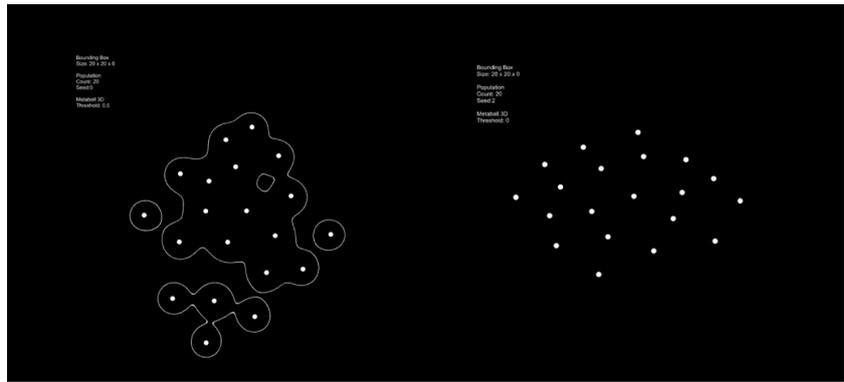
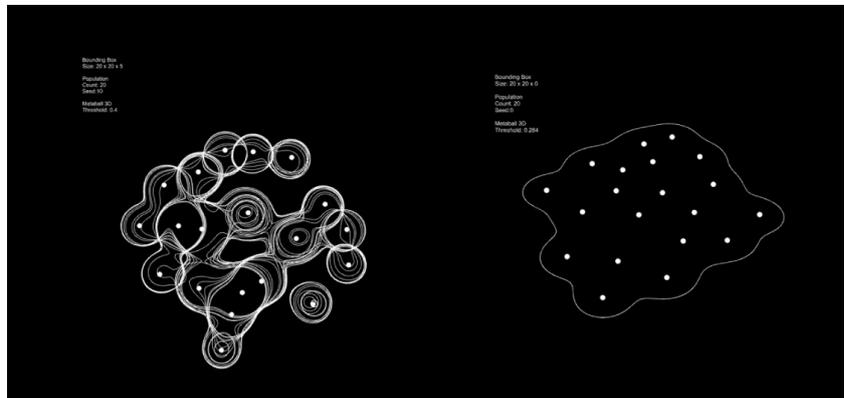


Figure 5: Left Image: Population Count: 20, Seed: 10, Threshold: 0.4. & Right Image: Population Count: 20, Seed: 20, Threshold: 0.284.



As represented visually in the diagram in **Figure 6** and **Figure 7**, it is seen that the system started to produce both denser and more complex surfaces; the form is no longer only connected but also layered, curved, and multi-centered. This situation shows that tolerance has the potential to create not only connection but also topological complexity. Especially when the threshold value is kept within certain ranges, the transitions between surfaces become softer and more discontinuous, while when this value is increased, the boundaries of the space become sharper, denser, and more organic.

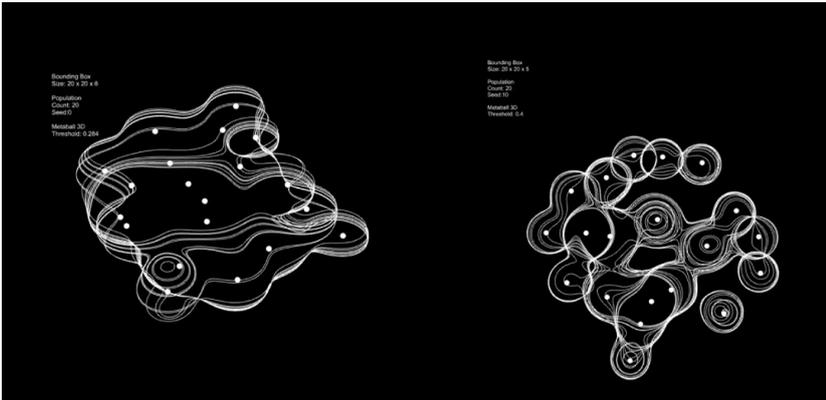


Figure 6: Left Image: Population Count: 20, Seed: 10, Threshold: 0.284. & Right Image: Population Count: 20, Seed: 10, Threshold: 0.4.

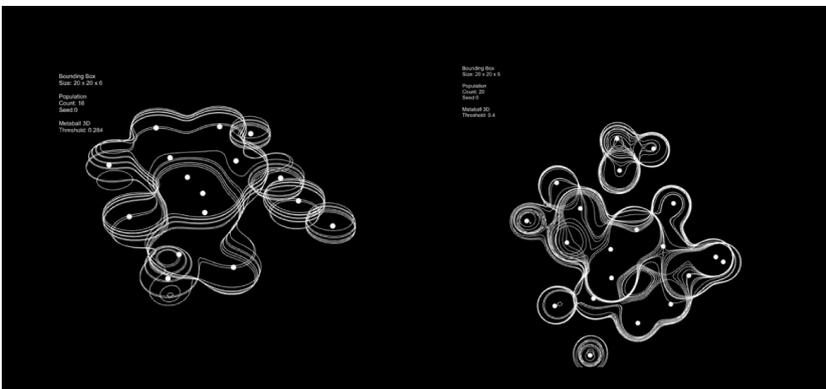


Figure 7: Left Image: Population Count: 16, Seed: 10, Threshold: 0.284. & Right Image: Population Count: 20, Seed: 20, Threshold: 0.4.

The diagrams above outline the algorithmic logic of the system, illustrating how agents interact through thresholds, densities, and probabilistic rules. Variations in parameters such as population, seed, and threshold determine whether surfaces merge, remain disconnected, or evolve into layered and multi-centered topologies. These visualizations confirm that tolerance is not simply a static parameter but the condition that governs how differences become spatially perceptible. Minor shifts in threshold values generate qualitatively different structures, demonstrating that tolerance operates as a dynamic determinant in the production of digital space. In Deleuzian terms, what emerges is not the suppression of error but the affirmation of difference as a productive force of becoming (Deleuze, 1994).

Yet the system becomes fully legible only when embodied interaction is introduced. In the second set of experiments, the designer entered the system through sensors, effectively becoming one of the agents. Using the Fologram app, smartphone sensor data (orientation, movement, and rhythm) was streamed into Grasshopper 3D, where it

directly modulated agent parameters. Each gesture, shift in orientation, or variation in cadence altered the interaction thresholds, producing outcomes that could not be predicted in advance. In this configuration, tolerance expands beyond technical flexibility into an embodied principle: it is the bandwidth within which the system absorbs the unpredictability of human action and transforms it into generative spatial variation.

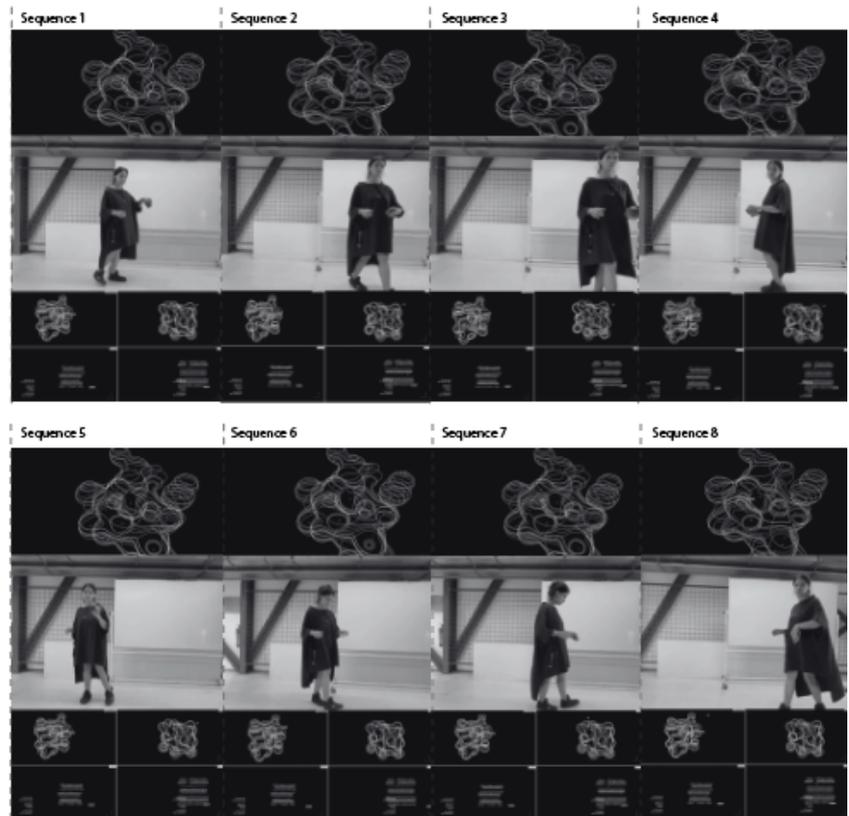


Figure 8: Sequential visualization of embodied interaction within the agent-based system.

Figure 8 demonstrates this embodied dimension through a sequence of stills (1–8). As the participant’s body enters the system as an agent, movement data perturbs the interaction rules, producing visible shifts in density, curvature, and connectivity. Each sequence reveals how tolerance mediates between bodily unpredictability and computational logic: rather than filtering out deviations, the system incorporates them, transforming gestures into new spatial configurations. These sequential frames make perceptible how difference itself is repeated—not identity—so that novelty is sustained across events.

This transformation resonates with accounts of computation as speculative rather than deterministic (Parisi, 2013). Code does not merely execute fixed instructions but folds external contingencies into its ongoing operations, opening new potentials. In the XR setting, the human body's entrance as an agent exemplifies this logic: tolerance mediates between the indeterminacy of movement and the responsiveness of algorithms, converting deviations into new spatial organizations. The notion of the fold is equally operative here (Deleuze, 1993): each embodied action inflects the system, folding external gestures into internal variations so that space is constantly rewritten.

As the diagrams and video sequences together illustrate, the system is not a closed machine but a relational field in which human and computational agents co-produce outcomes. The density, curvature, and connectedness of forms shift in real time with embodied input, making tolerance directly experiential. It is not hidden in the code but becomes perceptible as the very quality that sustains novelty across successive events. In this sense, tolerance mediates between algorithmic rules and lived immersion, ensuring that uncertainty is not eliminated but harnessed as the driver of creative difference in XR environments.

4.2. Visual Consideration of Tolerance:

As observed in the images, low threshold values generated sparse and discontinuous configurations, while high threshold values produced denser and more cohesive surfaces. This variation demonstrates that tolerance is operative not only as a functional parameter but also as a formal determinant in the digital production process. The behavioral logic of the system directly shapes its spatial articulation: tolerance does not prescribe how space should appear, but conditions how it comes into being. Deviations that might conventionally be dismissed as "errors" instead operate as productive variations, enabling the system to evolve into new spatial modalities.

The metaball experiment confirms that even the simplest agent-based simulations disclose the creative potential of tolerance. Spatial novelty here does not emerge from pre-determined formal intentions but from the relational protocols of interaction and from the tolerance ranges inscribed within them. In this sense, tolerance resonates with the affirmation of difference (Deleuze, 1994) and with the account of

speculative computation (Parisi, 2013): it is the operative openness that allows systems to absorb contingency and transform it into generative spatial complexity.

The results of these experiments thus support an understanding of XR-based digital environments not as representational projections but as emergent formations. Tolerance proves to be intrinsic not only to physical fabrication but also to the very logic of algorithmic production. Systems that suppress tolerance lapse into determinism, producing fixed and predictable outcomes; systems that embrace tolerance remain adaptive, enabling differentiation, transformation, and deviation. These differences should not be understood merely as technical artifacts but as aesthetic and ontological potentials that expand the horizon of what digital space can become.

5. CONCLUSION

This study has repositioned tolerance in XR-mediated digital space production from a narrow technical margin of error to a multi-layered principle of openness, uncertainty, and generative difference. Tolerance was reframed as the condition that affirms discontinuities and transforms them into productive variations, drawing on concepts of becoming and difference (Deleuze, 1994) and on the notion of speculative computation (Parisi, 2013). While architectural discourses have advanced the field toward dynamism and adaptation (Novak, 1991; Lynn, 1999; Schumacher, 2009; Leach, 2004; Kolarevic, 2003; Menges, 2007), this study makes explicit that tolerance is the missing conceptual link that sustains creativity in immersive systems.

Experiments with agent-based modeling demonstrated how small deviations in thresholds or initial conditions generate qualitatively distinct spatial outcomes, while embodied interaction experiments Figure 8 showed how sensor-driven movements directly perturb and co-shape computational dynamics. Together, these results revealed tolerance as a principle that mediates between algorithmic rules and lived immersion, turning unpredictability into creative potential.

In conclusion, tolerance enables XR-mediated digital environments to move beyond representation and control, establishing them as adaptive, relational, and processual spaces. Rather than suppressing

deviation, tolerant systems embrace difference as the driver of novelty. In doing so, tolerance emerges not only as a systemic bandwidth but as the creative principle that enables co-authorship, experimentation, and continuous invention in XR-based design.

Conflict of Interest Statement

The manuscript is entitled "From Control to Contingency: Tolerance as a Generator of Digital Space" has not been published elsewhere and that it has not been submitted simultaneously for publication elsewhere.

Author Contribution

All authors contributed equally to this article.

AI Use Disclosure

The authors declare that generative AI and AI-assisted tools were used for language editing and grammar correction in the preparation of this manuscript. The authors carefully reviewed and approved all AI-assisted suggestions and take full responsibility for the accuracy, integrity, and originality of the final manuscript.

References

- Bonabeau, E. (2002). Agent-based modeling: Methods and techniques for simulating human systems. *Proceedings of the National Academy of Sciences*, 99 (Suppl. 3), 7280–7287. <https://doi.org/10.1073/pnas.082080899>
- Colebrook, C. (2001). *Gilles Deleuze*. Routledge.
- Deleuze, G. (1993). *The fold: Leibniz and the Baroque* (T. Conley, Trans.). University of Minnesota Press.
- Deleuze, G. (1994). *Difference and repetition* (P. Patton, Trans.). Columbia University Press.
- Deleuze, G., & Guattari, F. (1987). *A thousand plateaus: Capitalism and schizophrenia* (B. Massumi, Trans.). University of Minnesota Press.
- Macal, C. M., & North, M. J. (2010). Tutorial on agent-based modelling and simulation. *Journal of Simulation*, 4(3), 151–162. <https://doi.org/10.1057/jos.2010.3>
- Parisi, L. (2013). *Contagious architecture: Computation, aesthetics, and space*. MIT Press.

Co-Creative Agency: An Insider Perspective on Generative Design through Differential Growth

Fikriye Aslı Yalçın¹

ORCID NO: 0000-0002-5949-7352¹

¹ Istanbul Technical University, Graduate School, Department of Architectural Design, Istanbul, Türkiye

This article examines how creative agency is constituted within a generative architectural design process through an insider investigation of a single installation developed for the International Architecture Biennial 2025. Positioned as a research-through-design study, it approaches the design process not merely as a means of producing form, but as a site of knowledge production through which the shifting relations between architect, algorithm, material, and fabrication technology can be critically examined. Rather than treating digital systems as neutral instruments, the study focuses on how design decisions emerged through ongoing interactions among the architect, a differential growth algorithm, representational media, and multi-scale 3D printing technologies. The theoretical framework is informed by three interconnected discussions. First, it draws on Margaret Boden's account of creativity, which defines creative work through novelty, surprise, and value, and distinguishes between combinational, exploratory, and transformational modes of creativity. Second, it engages literature on human-computer co-creativity, which challenges singular and human-centered models of authorship by emphasizing collaborative, symbiotic, and distributed forms of creative production. Third, it refers to 4E cognition theories, which understand cognition as embedded, embodied, extended, and enactive, and therefore as distributed across body, tools, environment, and action rather than confined to the mind of an individual designer. The study argues that after the second digital turn, creative agency in architectural design has shifted from a singular human-centered activity toward a hybrid co-creative agent emerging from architect-digital environment interaction. In this sense, generative architectural design should be understood not as a linear application of digital tools, but as an interactive process through which creative agency is distributed and constituted across human, digital, and material actors. By documenting this distribution from within the design process, the article contributes to ongoing discussions on co-creativity, research-through-design, and the changing role of the architect in computational practice.

Received: 10.01.2026

Accepted: 23.03.2026

Corresponding Author:

ayalcin@itu.edu.tr

Yalçın, F. A. (2026). Co-creative agency: An insider perspective on generative design through differential growth. *JCoDe: Journal of Computational Design*, 7(1), 72–93. <https://doi.org/10.53710/jcode.1860642>

ROR ID: 059636586

Keywords: Co-creativity, Research Through Design, Installation, Generative Design, Human-Computer Interaction.

71

JCoDe | Vol 7 No 1 | March 2026 | Generative Design Across Scales | Yalçın, F.A.

This work is licensed under a Creative Commons Attribution 4.0 International License.



Birlikte Yaratıcı Faillik: Diferansiyel Büyüme Üzerinden Üretken Tasarıma İçeriden Bakış

Fikriye Aslı Yalçın¹

ORCID NO: 0000-0002-5949-7352¹

¹ İstanbul Teknik Üniversitesi, Lisansüstü Eğitim Enstitüsü, Mimarlık Fakültesi, Mimari Tasarım, İstanbul, Türkiye

Bu makale, üretken bir mimari tasarım sürecinde yaratıcı failliğin nasıl kurulduğunu, 2025 Uluslararası Mimarlık Bienali için geliştirilen tekil bir enstalasyonun içeriden incelenmesi üzerinden araştırmaktadır. Çalışma, sayısal sistemleri nötr araçlar olarak ele almak yerine, tasarım kararlarının mimar, diferansiyel büyüme algoritması ve çok ölçekli üç boyutlu baskı teknolojileri arasındaki süregelen etkileşimler içinde nasıl ortaya çıktığına odaklanmaktadır. Araştırma, tasarım sürecinin kendisini bir bilgi üretim alanı olarak ele alan tasarım yoluyla araştırma yaklaşımına dayanmaktadır. Veri seti, süreç boyunca tutulan tasarım günlükleri, dijital süreç kayıtları, görsel dokümantasyon ve teknik notlardan oluşmaktadır. Bu veriler, düşünsel nitel yorumlama, zaman çizelgesi haritalama ve tematik analiz yoluyla çözümlenmiştir. Bulgular, yaratıcı kararların tekil bir öznenen doğmadığını; kavramsal niyet, algoritmik davranış, temsil araçları, malzeme kısıtları ve üretim süreçleri arasındaki geri bildirim döngüleri içinde aşamalı olarak biçimlendiğini göstermektedir. Geleneksel bereket motifinin diferansiyel büyüme üzerinden yeniden yorumlanması, beklenmedik ancak değerlendirilebilir biçimsel alternatiflerin üretilmesini mümkün kılmıştır. Çalışma, üretken mimari tasarımın sayısal araçların doğrusal bir uygulaması olarak değil, yaratıcı failliğin insan, sayısal ve maddi aktörler arasında dağılarak ortaya çıktığı etkileşimsel bir süreç olarak anlaşılması gerektiğini ileri sürmektedir. Bu dağılımı tasarım süreci içinden belgelemesi bakımından makale, birlikte yaratıcılık, tasarım yoluyla araştırma ve hesaplamalı pratikte mimarın değişen rolüne ilişkin tartışmalara katkı sunmaktadır.

Teslim Tarihi: 10.01.2026

Kabul Tarihi: 23.03.2026

Sorumlu Yazar:

ayalcin@itu.edu.tr

Yalçın, F. A. (2026). Birlikte yaratıcı faillik: Diferansiyel büyüme üzerinden üretken tasarıma içeriden bakış. *JCoDe: Journal of Computational Design*, 7(1), 72–93.
<https://doi.org/10.53710/jcode.1860642>

ROR ID: 059636586

Anahtar Kelimeler: Birlikte Yaratıcılık, Tasarım Yoluyla Araştırma, Enstalasyon, Üretken Tasarım, İnsan-Bilgisayar Etkileşimi.



1. GİRİŞ (INTRODUCTION)

Sayısal ortamın tasarım sürecine giderek daha etkin biçimde dahil olması, yaratıcı faile ilişkin tartışmaları yeniden gündeme taşımıştır. Sibernetik düşünce içinde gelişen erken yaklaşımlar, insan ve makinenin geri bildirim döngüleri aracılığıyla birbirine bağlanan bileşenler olarak ele alınabileceğini göstermiş; insan–bilgisayar simbiyozu, bilgisayarın bilişsel bir yükseltici olarak kavranması ve konuşma temelli etkileşim modelleri, bilgisayarı pasif bir araçtan çok yaratıcı sürece katılan bir ortak olarak düşünmenin kuramsal zeminini hazırlamıştır (Licklider, 1960; Engelbart, 1962; Pask, 1976; Negroponte, 1970, 1975). Bununla birlikte, dönemin teknolojik sınırlılıkları nedeniyle bu tartışmalar uzun süre büyük ölçüde kuramsal düzeyde kalmış; bilgisayarın yaratıcı süreçteki konumuna ilişkin eleştirel gerilimler de erken dönemde görünür olmuştur (Alexander, 1964).

Özellikle 2020’lerde, algoritmik modelleme, veri işleme, görselleştirme, yapay zekâ destekli sistemler ve sayısal üretim teknolojilerinin mimarlık alanında yaygınlaşması, bu erken tartışmaları güncel bağlamda yeniden düşünmeyi gerekli kılmıştır. Carpo’nun “ikinci sayısal dönüş” olarak tanımladığı bu bağlamda, mimar ile sayısal ortam arasındaki ilişki artık yalnızca komut veren kullanıcı ile araç arasındaki doğrusal ilişki olarak değil; geri bildirim, seçim, yorumlama ve yeniden yönlendirme süreçleri üzerinden kurulan çok katmanlı bir etkileşim alanı olarak görünür hâle gelmektedir (Carpo, 2023). Bu dönüşüm, yaratıcı faillğin tekil ve insan merkezli bir kapasite olarak değil, insan, sayısal ortam ve üretim süreçleri arasında dağılarak kurulan etkileşimsel bir oluşum olarak yeniden değerlendirilmesini gerekli kılmaktadır. Nitekim güncel literatür, sayısal sistemleri bir yandan “yaratıcı provokatör” olarak tanımlarken, diğer yandan mimarı “küratör” olarak yeniden konumlandırmakta; insan ve makine arasındaki bu ortak üretim alanını “hibrit zekâ” ve “bileşik özne” gibi kavramlarla açıklamaktadır (Yang et al., 2020; Özel & Ennemoser, 2019; Yuan, 2023; Chai & Yuan, 2023; Picon, 2011, 2020).

Bu geniş kuramsal tartışma hattı, yaratıcı failin artık yalnız başına yaratıcı deha olarak düşünülmemeyeceğini güçlü biçimde ortaya koysa da, pratik, süreçsel ve bilişsel düzeyde önemli boşluklar barındırmaktadır. Mimar–sayısal ortam etkileşiminin hangi bileşenlerinin hangi yaratıcı kararlara nasıl etki ettiği, bu etkileşimin

tasarım süreci boyunca nasıl haritalanabileceği ve mimarların bu dönüşümü nasıl deneyimlediğine ilişkin içeriden üretilmiş nitel veriler sınırlıdır. Bu makale, söz konusu boşluğu tasarım yoluyla araştırma yaklaşımıyla incelemekte ve yaratıcı failliğin hibrit bir oluşum olarak tasarım sürecinde nasıl ortaya çıktığını, yaratıcı kararların mimar ile sayısal ortam arasında nasıl paylaşıldığını araştırmacı-mimarın içeriden deneyimi üzerinden sorgulamaktadır (Frayling, 1993). Bu amaçla çalışma, 2025 Uluslararası Mimarlık Bienali için geliştirilen bir enstalasyonun tasarım ve üretim sürecine odaklanmakta; yaratıcı failliğin diferansiyel büyüme algoritması, sayısal modelleme ortamı ve çok ölçekli üç boyutlu baskı teknolojileriyle kurulan etkileşimler içinde nasıl biçimlendiğini somut bir vaka üzerinden ele almaktadır.

Bu doğrultuda çalışma, üretken mimari tasarım sürecinde yaratıcı failliğin nasıl kurulduğunu iki soru etrafında tartışmaktadır:

- Bir enstalasyonun tasarım ve üretim süreci boyunca mimar ile sayısal ortam arasındaki etkileşim nasıl kurulmaktadır?
- Bu etkileşim, yaratıcı failliği ve yaratıcı sürecin doğasını nasıl biçimlendirmekte ve dönüştürmektedir?

Bu sorular, Bir[Arada] enstalasyonu üzerinden ele alınmaktadır. Geleneksel halı metaforunun parametrik ortamda yeniden modellenmesi, diferansiyel büyüme algoritmaları aracılığıyla varyasyonların üretilmesi, bu varyasyonların düşünömsel diyaloglar yoluyla seçilmesi ve sayısal model ile fiziksel üretim arasındaki uyumlanmaların belgelenmesi, yaratıcı failliğin mimar ile sayısal ortam arasında nasıl dağılarak kurulduğunu görünür kılmaktadır. Bu yönüyle makale, üretken mimari tasarımda yaratıcı kararların oluşumunu süreç içinden okuyarak özel sayının hesaplamalı tasarım odağına katkı sunmaktadır.

2. KURAMSAL ÇERÇEVE (THEORETICAL FRAME)

Margaret Boden'in (2010) hesaplamalı yaratıcılık modeli, insan-bilgisayar birlikte yaratıcılığı literatürü ve 4E biliş kuramları birlikte düşünüldüğünde, yaratıcı failliğin tekil bir öznenin içsel yetisine indirgenemeyeceği; insan-sayısal ortam etkileşiminde ilişkisel olarak kurulduğu görülür. Bu üç yaklaşım, yaratıcı eylemi üreticinin kimliğinden bağımsızlaştırarak bilişi beden, araç, çevre ve eylem boyunca dağıtmakta; bilgisayarı pasif bir araç olmaktan çıkarıp yaratıcı sürecin

etkin bir bileşeni olarak yeniden konumlandırmaktadır. Bu çalışma, söz konusu üç hattı geniş bir kuramsal sentez üretmek amacıyla değil, üretken tasarım sürecinde yaratıcı kararların nasıl oluştuğunu yorumlamak için analitik bir çerçeve olarak bir araya getirmektedir.

Bu bağlamda birlikte yaratıcı fail kavramı, yeni materyalist düşünce ve aktör-ağ teorisiyle de sınırlı bir paralellik taşımaktadır. Haraway'ın (1991) melez öznellik, Barad'ın (2007) ilişkisel faillik, Latour'un (2005) insan ve insan dışı aktörleri birlikte ele alan yaklaşımı ve Braidotti'nin (2013) dağıtık özne kavrayışı, yaratıcı failliğin mimar-sayısal ortam etkileşimlerinin dinamik kesişiminde belirdiğini görünür kılar. Bununla birlikte bu çalışma, bu çerçeveleri geniş etik ya da politik açılımlarıyla değil, yalnızca dağıtık fail anlayışlarını hesaplamalı tasarım pratiğinin fenomenolojisini açıklamak üzere sınırlı biçimde kullanmaktadır. Dolayısıyla burada birlikte yaratıcı fail, post hümanist bir kopuş iddiasından çok, üretken tasarım süreçlerinde insan ve insan dışı aktörlerin karşılıklı dönüşüm ilişkileri içinde beliren melez bir yaratıcı özne olarak ele alınmaktadır.

2.1. Hesaplamalı yaratıcılık (Computational creativity)

İkinci sayısal dönemde üretken tasarım ortamlarının gelişmesi, yaratıcılığın yalnızca insana ait bir yeti olduğu yönündeki klasik yaklaşımı sorgulanabilir hâle getirmiş ve yaratıcı failliğin yeniden düşünülmesini gerekli kılmıştır. Bu bağlamda Boden'in (2010) hesaplamalı yaratıcılık modeli önemli bir referans sunar. Boden, yaratıcılığı üreticiden bağımsız biçimde yenilik, şaşırtıcılık ve değer ölçütleri üzerinden tanımlar. Yenilik, daha önce görülmemiş fikirlerin ortaya çıkmasını; şaşırtıcılık, yaratıcı fikrin beklenmedik bir sıçrama yaratmasını; değer ise bu fikrin bağlamsal anlam ve işlevsellik taşımasını ifade eder (Boden, 2010). Bu tanım, yaratıcı sonucu yalnızca öznenin niyetiyle değil, ortaya çıkan ürünün niteliğiyle değerlendirmesi bakımından özellikle önemlidir.

Boden (2010), yaratıcı düşüncenin ortaya çıkışını ayrıca kombinasyonel, keşifsel ve dönüşümsel yaratıcılık kipleriyle açıklar. Kombinasyonel yaratıcılık, bilindik öğelerin alışılmadık biçimlerde birleştirilmesine; keşifsel yaratıcılık, belirli kuralların tanımladığı kavramsal alan içinde yeni olanakların araştırılmasına; dönüşümsel yaratıcılık ise bu kuralların değiştirilerek önceden mümkün olmayan fikirlerin üretilebilir hâle gelmesine işaret eder. Bu üçlü ayırım, üretken tasarım süreçlerinde algoritmik varyasyon, seçim ve yeniden kural kurma pratiklerini okumak

açısından işlevsel bir analitik araç sunmaktadır. Bu nedenle çalışma, Boden'in modelini genel bir yaratıcılık kuramı olarak yeniden tartışmaktan çok, vaka analizinde ortaya çıkan yaratıcı hamlelerin niteliğini yorumlamak için kullanılmaktadır.

2.2. İnsan-Bilgisayar/Makine Birlikte yaratıcılığı (Human-Computer/Machine Co-creativity)

Birlikte yaratıcılık, yaratıcı sürecin tek bir öznenin içsel yetisine indirgenemeyeceğini; insan ve insan dışı aktörlerin etkileşimleri yoluyla ilişkisel olarak üretildiğini savunan bir yaklaşımdır (Candy & Edmonds, 2002; Hoffmann, 2016; Kantosalo, 2019). Bu yaklaşımda bilgisayar, mimarı destekleyen pasif bir araç değil, yaratıcı çıktının oluşumuna katkı sunan etkin bir ortaktır. Böylece birlikte yaratıcılık, yaratıcı destek araçlarının insanın bilişsel kapasitesini yalnızca genişlettiği yardımcı modelden ayrılarak, sayısal sistemi yaratıcı sürecin katılımcı bir bileşeni olarak kavramsallaştırır.

Hoffmann'a (2016) göre insan-bilgisayar birlikte yaratıcılığı, en az bir insan ve bir bilgisayar aktörünün yaratıcı sonucun üretimine birlikte müdahil olduğu durumları ifade eder. Kantosalo (2019) ise bu ortaklıkta her iki aktörün de belirli sorumluluklar üstlendiğini vurgular. Bu çerçevede yaratıcı süreç, karşılıklı etkileşim ve paylaşılan katkılar üzerinden ilerleyen yinelemeli bir ortaklık hâline gelir: bilgisayar çoğunlukla çözüm uzayını genişleten ıraksak aramalar üretirken, insan bu seçenekleri değerlendirip bağlamla ilişkilendirerek yakınsak kararlar alır. Davis'in (2013) yaklaşımı, bu iş birliğini önceden belirlenmiş görevlerin paylaşımı olarak değil, insan ve bilgisayarın birbirinin hamlelerine geri bildirim verdiği doğaçlamacı bir süreç olarak yorumlar. Davis vd. (2015) ise bu yapıyı "katılımcı anlamlandırma" kavramıyla ilişkilendirerek yaratıcı fikrin tekil bir zihinde değil, ortaklaşa inşa edilen anlam katmanlarında ortaya çıktığını gösterir.

Bu çalışma açısından birlikte yaratıcılık, üretken tasarım sürecinde mimar ile sayısal ortam arasındaki ilişkinin yalnızca araç kullanımı değil, karşılıklı yönlendirme, seçim, değerlendirme ve yeniden üretim süreçlerinden oluşan etkileşimsel bir ortaklık olduğunu göstermesi bakımından önemlidir. Ancak bu ortaklığın mimarlık bağlamında nasıl mümkün olduğunu daha açık biçimde anlamak için, bilişi beden, araç, malzeme ve çevre boyunca dağıtılmış bir süreç olarak tanımlayan 4E biliş yaklaşımına ihtiyaç vardır.

2.3. Birlikte yaratıcı fail (Co-creative agent)

Bu çalışma, birlikte yaratıcı faili 4E biliş kuramlarının sunduğu dağıtık biliş perspektifiyle kavramsallaştırmaktadır. 4E yaklaşımı—bütünleşmiş (embedded), bedenleşmiş (*embodied*), genişletilmiş (*extended*) ve enaktif (*enacted*) biliş—zihni yalnızca beynin içsel süreçlerine indirgemek yerine, bilişin beden, araçlar, çevre ve eylem boyunca kurulduğunu savunur (Varela vd., 1991; Thompson, 2007). Bütünleşmiş biliş, düşünme ve problem çözmenin çevresel bağlamla sürekli etkileşim içinde gerçekleştiğini ve ortamın bilişsel etkinliğin pasif zemini değil, kurucu bir parçası olduğunu gösterir (Hutchins, 1995; Clark & Chalmers, 1998). Bedenleşmiş biliş, bilişsel süreçlerin duyuşsal-motor yetilerle ayrılmaz biçimde örülü olduğunu ve bedenin çevreyle kurduğu eylemsel ilişkinin düşünceyi doğrudan şekillendirdiğini vurgular (Varela et al., 1991). Genişletilmiş biliş, dışsal araçların—örneğin not defteri, bilgisayar veya parametrik modelleme arayüzü gibi—bilişsel sürecin işlevsel bileşenleri hâline gelerek zihnin sınırlarını dışarıya doğru genişlettiğini ileri sürer (Clark & Chalmers, 1998). Enaktif biliş ise bilişi temsil üretimi değil, organizma ile çevre arasındaki sürekli algı-eylem döngülerinde ortaya çıkan aktif bir dünyayı kurma süreci olarak tanımlar (Varela vd., 1991; Noë, 2004).

Bu dört yaklaşım birlikte ele alındığında, yaratıcı failiğin ne yalnızca mimarın zihninde ne de yalnızca sayısal ortamda bulunduğu; insan, beden, araç, malzeme ve çevre etkileşimlerinden oluşan ilişkisel bir ağ içinde kurulduğu görülür. İkinci sayısal dönemin üretken tasarım ortamlarında yaratıcı eylem, bu çoklu bileşenlerin karşılıklı belirleyiciliği içinde ortaya çıkan etkileşimsel bir süreçtir. Bu nedenle 4E biliş yaklaşımı, mimar-sayısal ortam etkileşiminde beliren melez birlikte yaratıcı failin bilişsel temelini açıklamak için işlevsel bir zemin sunmaktadır. Bu çerçevede yaratıcı olan, yalnızca tekil özne değil, etkileşimin kendisidir.

3. METODOLOJİ (METHODOLOGY)

Bu bölümde çalışmanın metodolojik çerçevesi, araştırma yaklaşımı, veri toplama ve analiz süreçleriyle birlikte açıklanmaktadır.

3.1. Tasarım yoluyla araştırma yaklaşımı (Research through design approach)

Bu çalışma, mimari tasarımı yalnızca bir üretim pratiği değil, araştırmacı-mimar ile sayısal ortamlar arasındaki etkileşimlerde ortaya çıkan bir bilgi üretim biçimi olarak ele almaktadır. Yöntem, tasarım yoluyla araştırma yaklaşımına dayanmaktadır (Frayling, 1993). Bu çerçevede tasarım süreci, hem araştırmacının alanı hem de bilgi üretiminin aracı olarak konumlandırılmıştır. Araştırmacı, enstalasyonun tasarımcısı ve uygulayıcısı olarak sürece içeriden katılmış; süreç boyunca tutulan notlar, ara çıktılar ve görsel kayıtlar öz-düşünsel bir veri seti oluşturmuştur. Bu veri seti, tasarım süreci tamamlandıktan sonra geriye dönük ve analitik bir mesafeye yeniden değerlendirilmiştir. Böylece araştırmacı hem sürecin faili hem de yorumlayıcısı olarak konumlanmıştır. Bu bağlamda öznellik, bir metodolojik zafiyet olarak değil, mimar ile sayısal ortam arasındaki yaratıcı etkileşimi süreç içinden görünür kılan bir araştırma aracı olarak ele alınmıştır.

3.2. Bir[Arada] enstalasyonu

Bu araştırma, bienalin “Arada – Yeni Dünya Düzeninde Mimarlık ve Kent” teması kapsamında üretilen enstalasyon üzerinden gerçekleştirilmiştir. Çalışma, pandemi sonrası dönüşen mekânsal ve teknolojik koşulların yarattığı eşiksel durumlardan hareketle, mimar ile sayısal ortamın birlikte oluşturduğu hibrit yaratıcı faili mekânsal olarak görünür kılmayı amaçlamaktadır. 220×150×30 cm boyutlarındaki enstalasyon, Döşemealtı halı tarlaları metaforunun diferansiyel büyüme algoritmalarıyla yeniden yorumlanmasıyla tasarlanmıştır. Süreç boyunca konsept geliştirmede üç boyutlu modelleme ve parametrik tasarım ortamları ile algoritmik eklentiler, görselleştirmede yapay zekâ destekli görselleştirme araçları, üretimde ise farklı ölçeklerde çalışan üç boyutlu baskı teknolojileri kullanılmıştır. Bu çok aşamalı yapı nedeniyle enstalasyon, tasarım ve üretim boyunca farklı sayısal ortamlarla kurulan etkileşimleri izlemek için uygun bir araştırma vakası sunmaktadır.

3.3. Veri toplama (Data collection)

Veri toplama süreci, tasarım ve üretim sürecinin çok katmanlı biçimde belgelenmesine dayanmaktadır. Dört tür veri kullanılmıştır: tasarım günlükleri ve refleksif notlar; master modeller, iterasyonlar ve ekran görüntülerini içeren sayısal süreç kayıtları; baskı, montaj ve kurulum sürecine ait fotoğraf ve video kayıtlarından oluşan görsel

dokümantasyon; teknik üretim notları. Bu veriler, yaratıcı failliğin biçimsel, sayısal ve malzeme temelli kararlar arasında nasıl dağıldığını incelemeye imkân vermiştir.

3.4. Veri analizi (Data analysis)

Veri analizi nitel ve refleksif bir çerçevede yürütülmüş olup üç aşamadan oluşmuştur. İlk olarak tasarımın konsept, algoritmik üretim, seçim ve üretim/kurulum aşamalarını içeren kronolojik bir zaman çizelgesi oluşturulmuştur. Ardından süreç notları ve sayısal kayıtlar üzerinden tematik analiz yapılmıştır. Birlikte yaratıcılık, kontrol ve öngörülemezlik ve sayısal–fiziksel geçişler gibi temalar etrafında kodlama gerçekleştirilmiştir. Son olarak araştırmacı, birinci kişi tasarım analiziyle, mimar–sayısal ortam etkileşimlerinin hangi kararları nasıl şekillendirdiğini irdelemiştir. Bu yaklaşım, tasarım sürecini hem dışarıdan hem içeriden okunabilir çok katmanlı bir analize dönüştürmüştür.

3.5. Etik değerlendirme (Ethical review)

Enstalasyonun sergilendiği bienal kamusal bir ortamdır; ancak izleyicilerden herhangi bir veri toplanmadığından kişisel verilerin işlenmesi veya mahremiyet ihlali söz konusu değildir. Kullanılan yazılım ve üretim teknolojilerine ilişkin bilgiler, yöntemsel açıklık amacıyla verilmiş olup, ticari tanıtım niteliği taşımamaktadır.

3.6. Sınırlılıklar (Limitations)

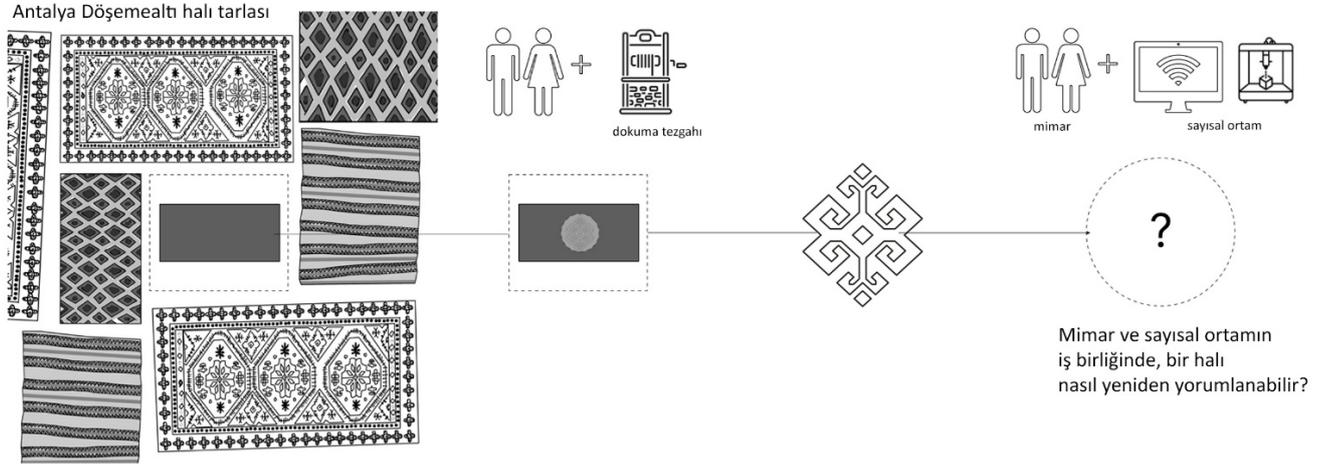
Araştırmanın temel sınırlılığı, tek bir vaka çalışmasına ve tek bir araştırmacı-mimarın öznel deneyimine dayanmasıdır. Bu nedenle bulgular genellenebilir sonuçlar üretmek yerine belirli bir bağlamda sayısal tasarım ortamlarıyla kurulan yaratıcı ortaklığa dair derinlikli bir içgörü sunar. Araştırmacının tasarımcı ve yorumlayıcı rollerinin örtüşmesi kaçınılmaz bir öznelik doğurur; bu öznelik metodolojinin parçası olmakla birlikte bulguların araştırmacı konumundan bağımsız olmadığı dikkate alınmalıdır. Ayrıca çalışma, belirli yazılım ve üretim teknolojileriyle sınırlıdır; farklı ortamlar kullanıldığında mimar–sayısal ortam etkileşimi farklı biçimlerde ortaya çıkabilir. Bununla birlikte bu sınırlılıklar, tasarım yoluyla araştırmanın bağlama özgü ve derinlemesine analiz üretme amacına uygun bir çerçevede bilinçli olarak kabul edilmiştir.

4. ALAN ÇALIŞMASI (FIELDWORK)

4.1. Enstalasyonun kavramsal çerçevesi (Conceptual framework of the installation)

Bienalin “Arada” teması, alışıldık olandan öngörülemezliğe uzanan eşik durumlarına odaklanmaktadır. Bu enstalasyon, **Şekil 1**’de gösterildiği üzere, bu temaya mimar ile sayısal ortamın bir aradalığı üzerinden yanıt aramaktadır. Endüstri 4.0’la birlikte belirginleşen ikinci sayısal paradigma kırılması, sayısal ortamı yalnızca bir araç değil, mimarın yaratıcı sürecine aktif biçimde katılan bir ortak hâline getirmiştir. Antalya Döşemealtı’ndaki halı tarlaları da bu birlikteliğe metaforik bir zemin sunmaktadır. Türkiye’nin farklı bölgelerinden gelen geleneksel halıların yaz aylarında renklerinin oturması ve temizlenmesi amacıyla rastlantısal biçimde tarlalara serilmesi, öngörülemez ama güçlü bir mekânsal örüntü yaratmaktadır. Alışıldık bir topografyada beliren bu plansız birliktelik, çalışma için ilham verici bir analogiye dönüşmektedir. Mimar, bu örüntüden yola çıkarak şu soruyu sormaktadır: mimar ile sayısal ortamın iş birliğinde bir halı nasıl yeniden yorumlanabilir?

Şekil 1: Enstalasyonun kavramsal çerçevesi (Conceptual framework of the installation) (Yalçın,2025).



4.2. Konsept aşamasında mimar ve sayısal ortamın etkileşimi (Interaction between the architect and the digital environment during the conceptual phase)

Bu bölümde, konsept geliştirme aşamasında mimar ile sayısal ortam arasında kurulan etkileşimin tasarım kararlarını nasıl biçimlendirdiği ele alınmaktadır.

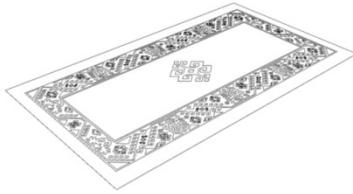
4.2.1. Geleneksel halının soyutlanması

Konsept aşamasında ilk adım, geleneksel Türk halısına göndermede bulunan 220x150 cm'lik bir halı yüzeyinin üç boyutlu modelleme ortamında iki boyutlu olarak çizilmesidir. Rhino'da oluşturulan bu yüzey, halıyı düz bir zemin olmaktan çıkarıp parametrik manipülasyonlara açık bir hale getirir.

Ardından, Döşemealtı halı tarlalarındaki topoğrafik dalgalanmalara referansla bu yüzey, Grasshopper ortamında eğrisel bir yüzeye dönüştürülür. Böylece mimarın zihnindeki halı imgesi, ekran, koordinat sistemi, eğri ve yüzeylerden oluşan sayısal ortamla bütünleşerek tek başına zihinsel bir temsil olmaktan çıkar ve insan-bilgisayar etkileşiminde kurulan bileşik bir bilişsel sürecin parçası hâline gelir.

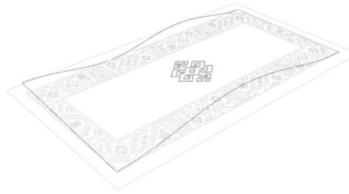
Şekil 2'de görüldüğü üzere bu süreçte mimar, ölçü, oran ve yüzey eğriliklerini yinelemeli olarak test ederken sayısal ortam bu kararların sonuçlarını anlık biçimde görselleştirmektedir. Konsept aşaması böylece mimarın niyetleri ile sayısal ortamın geri bildirimleri arasında kurulan yinelemeli bir müzakere süreci olarak işlemektedir.

Şekil 2: Geleneksel halı motifinin sayısal ortama aktarılması (Digital translation of the traditional carpet motif). (Yalçın,2025).



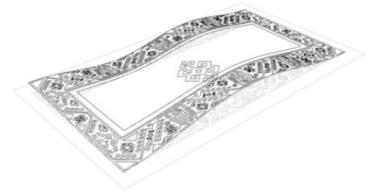
1

Geleneksel Türk halısına göndermede bulunan 220x150cm'lik bir halı yüzeyinin 3B modelleme ortamında iki boyutlu olarak çizilmesi



2

Döşemealtı halı tarlalarındaki topoğrafik dalgalanmalara referansla yüzeyin, eğrisel bir yüzeye dönüştürülmesi



3

Halının, salt bir temsil yüzeyi değil, diferansiyel büyüme algoritmasının üzerinde işleyeceği kesintisiz bir "büyüme alanı"na evrilmesi

4.2.2. Bereket motifini diferansiyel büyüme algoritması ile büyütme

Halı tarlalarındaki halıların rastlantısal biçimde doğaya serilmesi mantığı, diferansiyel büyüme algoritmasının işleyiş biçimiyle kavramsal bir akrabalık taşır. Tarlaya serilen halılar nasıl kontrol edilmemiş yerleşimlerle öngörülemez mekânsal örüntüler üretiyorsa, diferansiyel büyüme de basit kurallar üzerinden karmaşık ve öngörülemez biçimler üretir. Doğadaki organizmaların farklı büyüme

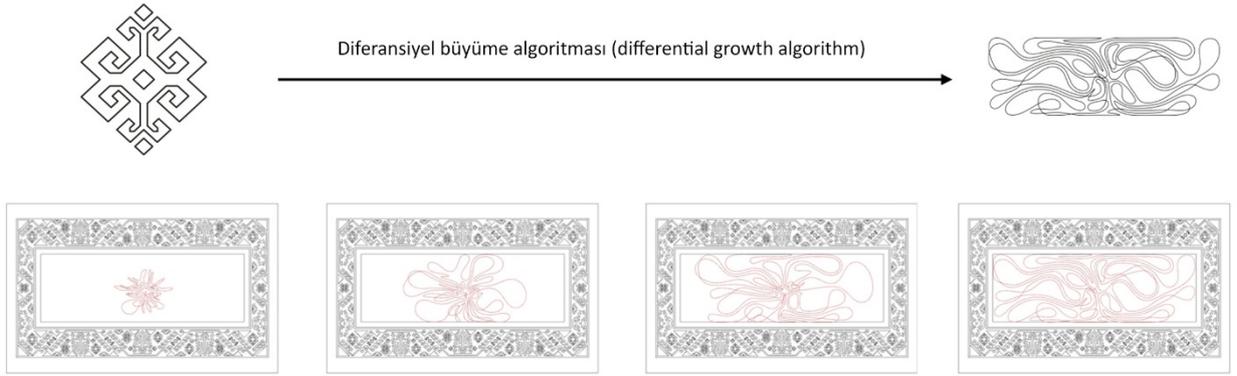
hızlarını taklit eden bu algoritma, kural temelli ama öngörülemeyen bir üretim mantığı sunar ve bu nedenle enstalasyonun hem kavramsal hem biçimsel merkezine yerleştirilmiştir. Yerleştirmenin çıkış noktası olarak geleneksel Türk halısının bereket motifi seçilmiştir. Kültürel hafızada süreklilik, yaşam döngüsü ve çoğalma ile ilişkilenen bu motif, sistemin salt biçimsel bir arayış olmadığını; geleneksel anlam katmanlarının sayısal bir büyüme mantığıyla yeniden ele alındığını göstermektedir. Motif, Grasshopper ortamında yeniden modellenmiş; çizgisel iskeleti bir dizi düğüm noktası ve bu noktaları birbirine bağlayan segmentler olarak tanımlanmıştır.

Diferansiyel büyüme sürecinde, bu düğüm ağı her iterasyonda belirli kurallara göre güncellenmiştir. İlk olarak, komşu noktalar arasında tanımlanan yay kuvveti, sistemin çizgisel sürekliliğini koruyarak segmentlerin tamamen kopmasını ya da aşırı gerilmesini engellemiştir. İkinci olarak, birbirine fazla yaklaşan noktalar arasında tanımlanan itici kuvvet, çizgilerin üst üste binmesini azaltmış ve örgünün kendi içinde nefes almasını sağlamıştır. Üçüncü olarak, belirli eşik değerlerini aşan segmentlerde yeni noktalar eklenerek büyümenin tüm yüzeye dağılması sağlanmıştır. Böylece sayısal ortam, mevcut motif çizgilerini yalnızca dönüştürmekle kalmamış, onları zaman içinde çoğalan ve yeniden örgütlenen bir yapıya çevirmiştir.

Mimar tarafından kontrol edilen başlıca parametreler; büyüme hızı, düğüm yoğunluğu, yay kuvveti katsayısı, itici kuvvet katsayısı, komşuluk/etki yarıçapı ve iterasyon sayısı olmuştur. Bu parametrelerin sistematik olarak değiştirilmesi, algoritmanın üretebileceği biçimsel uzayın sınırlarını görünür kılmıştır. Örneğin düşük itici kuvvet ve yüksek düğüm yoğunluğu daha sıkışık ve yoğun örüntüler üretirken; daha yüksek itici kuvvet ve geniş etki yarıçapı daha seyrek, daha akışkan ve boşluklu varyasyonlara yol açmıştır. Bu nedenle beklenmedik sonuçlar, rastlantısal bir teknik sapmadan çok, mimarın tanımladığı parametre aralıkları içinde sistemin ilişkisel davranışından doğan biçimsel belirmeler olarak değerlendirilmiştir.

Şekil 3: Bereket motifini diferansiyel büyüme algoritması ile büyütmek (Growing the abundance motif using a differential growth algorithm) (Yalçın,2025).

Bu süreçte bereket motifinin mevcut geometrisi ile diferansiyel büyümenin organik çizgisel örgütlenmesi bir araya getirilerek alışılmadık kombinasyonlar üretilmiş; motifi tanımlayan simetri, tekrar ve hiyerarşi gibi kuralların bir bölümü korunurken bir bölümü esnetilmiş ya da yeniden yazılmıştır. **Şekil 3**'te görüldüğü üzere, tek bir motiften çok sayıda varyasyon elde edilmiş; her varyasyon, sistemin davranışını gözlemlemeye yarayan bir tasarım deneyi olarak değerlendirilmiştir. Bu bağlamda diferansiyel büyüme algoritması, biçimi tek başına belirleyen otonom bir failden ziyade, mimarın kavramsal niyetleriyle etkileşime girerek öngörülmeleyen ama değerlendirilebilir alternatifler üreten üretken bir ortak olarak işlev görmüştür.



4.2.3. Tasarımı seçmek (Selecting the design)

Diferansiyel büyüme algoritmasıyla üretilen çok sayıdaki varyasyon, mimar ve sayısal ortamın ortak üretimi olarak okunabilecek Şekil 4'teki tasarım matrisini oluşturur. Bu aşamada amaç, algoritmanın ürettiği seçenekler arasından yalnızca görsel olarak etkileyici olanı seçmek değil; biçimsel tutarlılığı, üretim açısından uygulanabilirliği ve kavramsal karşılığı güçlü olan alternatifleri ayırt etmektir. Bu nedenle her varyasyon, biçimsel, üretimsel ve kavramsal ölçütler birlikte değerlendirilerek karşılaştırılmıştır.



Biçimsel değerlendirmede temel ölçüt yoğunluk olmuştur. Yoğunluk, çizgisel örgünün yüzey üzerinde ne kadar sıkı ya da gevşek dağıldığını ve buna bağlı olarak oluşan boşluk–doluluk dengesini ifade etmektedir. Çok yoğun varyasyonlar motifin okunabilirliğini azaltmış, geçirgenliği düşürmüştü ve yüzeyin aşırı kapanmasına yol açmıştır; buna karşılık aşırı seyrek varyasyonlar enstalasyonun mekânsal etkisini ve yüzey derinliğini zayıflatmıştır. Bu nedenle seçimde, ne tamamen tıkalı ne de aşırı boş kalan; çizgisel akış ile açıklıklar arasında dengeli bir ilişki kuran varyasyonlar öne çıkarılmıştır. Bu denge aynı zamanda ışıkla kurulan ilişki açısından da değerlendirilmiştir; çizgi yoğunluklarının ve boşlukların ritmi, gün ışığında katmanlı ve değişken gölge etkileri üretme potansiyeli üzerinden yorumlanmıştır.

Üretimsel değerlendirmede belirleyici ölçütlerden biri süreklilik olmuştur. Diferansiyel büyüme algoritması sürekli eğriler ürettiğinden, burada mesele kopuklukların oluşması değil; çizgisel sistemin özellikle Z ekseninde aşırı dolaşık, üst üste binen ve üç boyutlu üretimi zorlaştıran bir karmaşıklık seviyesine ulaşip ulaşmadığıdır. Bu nedenle seçim

Şekil 4: Tasarım matrisinden tasarımı seçmek (Selecting the design from the design matrix) (Yalçın,2025).

sürecinde, eğrisel yüzey üzerinde hem akış hissini koruyan hem de çizgisel örgüyü 3B baskı açısından üretilebilir kılan varyasyonlar tercih edilmiştir. Üretilebilirlik açısından belirleyici olan bir diğer ölçüt ise eleman çapı olmuştur. Üretken algoritma tarafından üretilen tasarımın fiziksel üretime aktarılabilmesi için farklı çap aralıkları denenmiş; bu denemeler sonucunda hem geometrik okunabilirliği koruyan hem de rasyonel ve fizibl üretim koşullarına uygun olan 5 mm çap değeri üzerinde karar kılınmıştır. Daha ince çaplar üretim ve montaj sırasında kırılma riski taşıırken, daha kalın çaplar diferansiyel büyümenin ürettiği çizgisel incelikleri ve geçirgenlik etkisini zayıflatmıştır.

Kavramsal değerlendirmede ilk olarak bereket motifinin okunabilirliği dikkate alınmıştır. Diferansiyel büyüme süreci motifin dönüşmesine izin verse de, seçilen varyasyonlarda başlangıçtaki kültürel referansın tümüyle kaybolmaması önemsenmiştir. Ayrıca varyasyonlar, çalışmanın ana teması olan “Arada” ile ilişkileri açısından değerlendirilmiştir. Bu bağlamda tercih edilen alternatifler, ne tamamen geleneksel motifin sabit geometrisine ne de bütünüyle amorf bir sayısal forma indirgenen; iki durum arasında geçiş, gerilim ve eşik hissi kurabilen örüntüler olmuştur. Son olarak halı tarlaları analogisiyle uyum, varyasyonların tekdüze tekrarlar yerine aynı aileye ait fakat birbirinin tam kopyası olmayan küçük kaymalar ve farklılaşmalar üretilip üretilmediğine bakılarak değerlendirilmiştir.

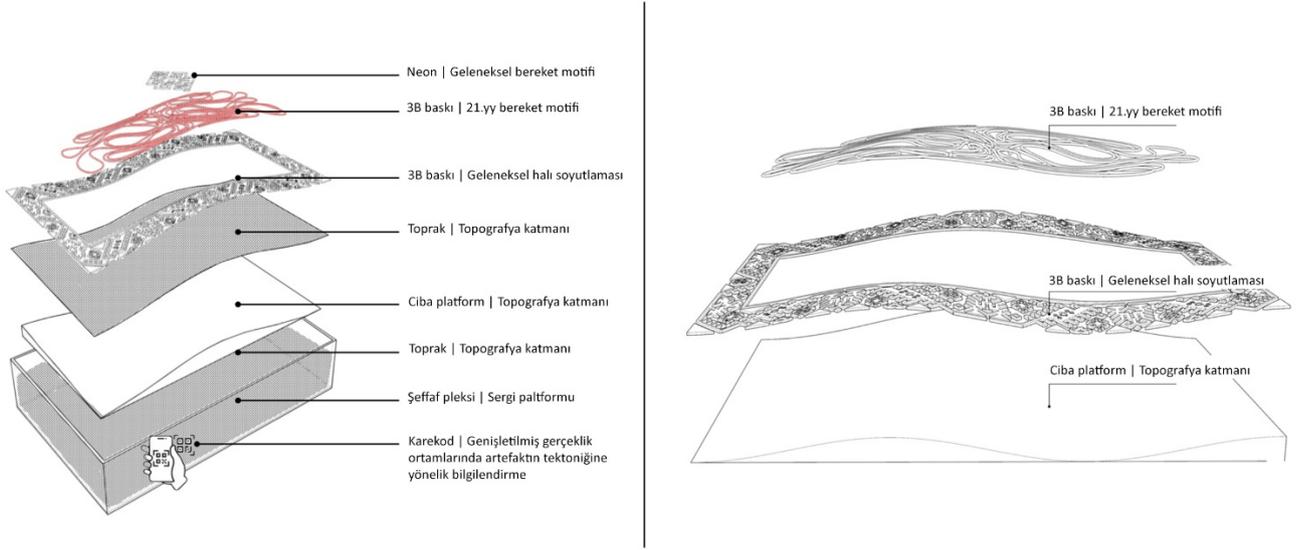
Bu aşama, birlikte yaratıcılık modellerinde tanımlanan yakınsak arama süreciyle örtüşmektedir. Algoritmanın ürettiği iraksak seçenekler arasından belirli ölçütlere göre seçim yapılması, yaratıcı süreci karar verme yönünde daraltmaktadır. Ancak bu daralma yalnızca sonucun belirlenmesi değil, aynı zamanda hangi biçimsel belirmelerin üretimsel ve kavramsal olarak anlamlı bulunduğu ortaya konması açısından da önemlidir. Sonuçta seçilen tasarım, ne yalnızca algoritmanın otomatik çıktısı ne de mimarın baştan tam olarak öngördüğü bir formdur. Aksine, mimarın değerlendirme ölçütleri ile algoritmik üretimin açtığı olasılıkların yinelenmeli etkileşimi içinde belirlenmiş bir tasarım çıktısıdır.

4.3. Üretim aşamasında mimar ve sayısal ortamın etkileşimi (Interaction between the architect and the digital environment during the production phase)

Enstalasyonun üretim aşaması, mimar ile sayısal ortam arasındaki ortaklığı fiziksel düzlemde görünür kılar. Şekil 5'te gösterildiği üzere

üretim süreci, üç farklı eklemeli üretim platformunun eşzamanlı kullanımına dayanır: geniş hacimli elemanlar ve eğrisel yüzeyler için Caracol AM, hızlı prototipleme için Bambu Lab, yüksek hassasiyetli detaylar için HP Multi Jet Fusion. Böylece serbest biçimli elemanlar az sayıda parça ile üretilirken, tolerans duyarlı bileşenlerde endüstriyel hassasiyet sağlanmıştır. Yerleştirmenin topografyası ise rijitlik ve hafiflik dengesi için 30 yoğunluk strafor üzerine biçimlendirilmiştir.

Şekil 5: Üretim senaryosu
(Production scenario) (Yalçın,2025).



Enstalasyon modüler parçalara ayrıştırılmış ve sayısal üretim ortamlarının sınırları ve kolay taşınabilirlik esas alınarak tasarlanmıştır. Kurulum süreci, Şekil 6'da ifade edildiği üzere, mimarın dahil olmasını gerektirmektedir. Yine Şekil 6'da görüldüğü üzere, sayısal ortamda mükemmel simetri ve toleranssız hassasiyetle modellenen biçimler, üretim sırasında malzemenin esnemesi, baskı hataları, sıcaklık–nem değişimleri ve montaj sürecindeki küçük sapmalar nedeniyle farklılaşır. Bu sapmalar, sistemin hatası olarak değil, mimar ile makine arasındaki ortak üretimin fiziksel izleri olarak okunmaktadır. Sonuç olarak enstalasyonun üretim aşaması, yaratıcı failiğin yalnızca tasarım kararlarında değil, üretim teknolojilerinin seçimi, malzeme davranışları, montaj stratejileri ve kurulum performansında da dağıldığını; yaratıcı sürecin sayısal ve fiziksel düzlemlerde birlikte yazıldığını göstermektedir.

Şekil 6: Kurulum süreci ve malzemenin davranışı (Installation process and material behaviour) (Yalçın,2025).



5. TARTIŞMA (DISCUSSION)

Bu bölüm, alan çalışmasından elde edilen bulguları kuramsal çerçeve bağlamında yorumlanmaktadır.

5.1. Yaratıcı düşüncenin yaratıcılık ölçütleri açısından değerlendirilmesi (Evaluation of creative thinking in terms of creativity criteria)

Enstalasyonun tasarım yoluyla araştırma süreci, mimar ile sayısal ortam etkileşiminde ortaya çıkan düşüncenin yeni, şaşırtıcı ve değerli nitelikler taşıdığını göstermektedir. Geleneksel bereket motifinin diferansiyel büyüme algoritmasıyla yeniden üretimi, hem biçimsel düzeyde beklenmedik sonuçlar üretmiş hem de kavramsal düzeyde “Arada” temasıyla uyumlu güçlü bir düşünsel çerçeve sunmuştur. Bu yönüyle enstalasyonun tasarım ve üretim süreci, Boden’in yaratıcılık ölçütleriyle büyük ölçüde örtüşmektedir. Enstalasyonun biçimsel çıktıları yenilik üretirken, bu çalışmada “sürpriz” rastlantısal ya da kuralsız bir sapma olarak değil; mimarın tanımladığı motif, kuvvet ilişkileri, düğüm yoğunluğu, etki yarıçapı, iterasyon sayısı ve üretim eşikleri gibi değişkenlerin etkileşiminden doğan görece bir öngörülemezlik olarak ele alınmaktadır. Başka bir deyişle, ortaya çıkan biçimsel sonuçlar bütünüyle tasarımcı tarafından önceden çizilmiş değildir; ancak tamamen kontrolsüz de değildir. Sürpriz, bu çalışmada, mimarın kurduğu parametre uzayı içinde sistemin ilişkisel davranışı sonucunda beliren ve süreç içinde tanınıp değerlendirilebilen varyasyonları ifade etmektedir. Geleneksel motifin kültürel belleği ile hesaplamalı süreçlerin çağdaş dili arasında kurulan ilişki ise değeri tanımlayan tematik tutarlılığı sağlamaktadır. Dolayısıyla çalışma, tasarım yoluyla

araştırma bağlamında, mimar–sayısal ortam etkileşiminin yaratıcı düşüncenin oluşumuna nasıl katkıda bulunabileceğini somut bir örnek üzerinden ortaya koymaktadır.

5.2. Yaratıcı sürecin üç yaratıcılık kipiyle değerlendirilmesi **(Evaluation of the creative process through the three modes of creativity)**

Enstalasyonun ortaya çıkışı, Boden'in üç yaratıcılık kipinin bir aradalığıyla açıklanabilir:

1. Kombinasyonel yaratıcılık: Geleneksel bereket motifinin simetrik geometrisi, diferansiyel büyümenin organik çizgisel örgütlenmesiyle birleşerek alışılmadık kombinasyonlar üretmiştir.
2. Keşifsel yaratıcılık: Parametrelerin sistematik biçimde değiştirilmesiyle algoritmanın üretebileceği biçimsel uzay araştırılmıştır. Bu süreç, motifin kavramsal alanını geleneksel yüzeysel örgütlenmeden diferansiyel büyümenin oluşturduğu topoğrafik çeşitliliğe doğru genişletmiştir.
3. Dönüşümsel yaratıcılık: Motifi tanımlayan simetri, tekrar ve merkez-çevre hiyerarşisi gibi kurallar yeniden yazılarak geleneksel kompozisyonla üretilmeyecek formlar görünür hâle gelmiştir.

Bu üç kipi eşzamanlı etkileşimi, enstalasyonun geleneksel motif ile hesaplamalı sistemler arasında kurulan hibrit ve etkileşimsel bir yaratıcı süreç içinde şekillendiğini göstermektedir.

5.3. Yaratıcılık kiplerinin 4E biliş yaklaşımlarıyla ilişkisi **(Relationship between the modes of creativity and 4E cognition approaches)**

Boden'in yaratıcılık kiplerinin bu çalışmada somut olarak açığa çıkması, bilişin yalnızca insan zihninin içsel etkinlikleriyle sınırlı olmadığını; mimar, sayısal ortam, arayüz geri bildirimleri ve üretim kısıtları arasında dağıtık biçimde gerçekleştiğini göstermektedir. Bu bağlamda algoritmanın rolü, bağımsız niyet sahibi bir özne olmak değil; mimarın kurduğu sistem içinde biçimsel olasılıkları çoğaltan üretken bir bileşen olmaktır. Mimar başlangıç koşullarını, parametre aralıklarını ve seçim ölçütlerini tanımlarken, algoritma bu çerçevede önceden çizilmemiş varyasyonlar üretir. Böylece yaratıcı faillik, mimarın kararları ile algoritmanın hesaplamalı davranışı arasında dağılan etkileşimsel bir süreç olarak anlaşılmalıdır. Bu durum, tasarım sürecini 4E biliş yaklaşımlarıyla uyumlu biçimde bağlama gömülü, beden–araç

etkileşimleriyle şekillenen, sayısal ortamlarla genişleyen ve mimar–algoritma döngülerinde kurulan dağıtık bir bilişsel performans olarak görünür kılar.

- Bütünleşmiş biliş: Tasarım probleminin tanımlanması ve gelişimi, mimarın yalnızca zihinsel süreçlerine değil, algoritmanın davranışlarına, arayüzün geri bildirimlerine ve üretim süreçlerinin gerekliliklerine bağlı olarak bağlamsal biçimde şekillenmiştir.
- Bedenleşmiş biliş: Mimarın üç boyutlu modellerle kurduğu etkileşimler bilişsel sürecin ayrılmaz parçaları hâline gelmiştir. Malzeme, yalnızca pasif bir taşıyıcı değil, tasarımın algısal ve duysal boyutunu belirleyen etkin bir bileşen olarak konumlanır. Straforun esnekliği, baskı izlerinin dokusu, parçaların elle taşınabilirliği, tasarımın deneyimini doğrudan şekillendirir. Buna bağlı olarak düşünme, yalnızca zihinsel değil, beden–araç etkileşimleri içinde ortaya çıkmıştır.
- Genişletilmiş biliş: Parametrik modeller ve iterasyon log’ları mimarın bilişinin dışsal uzantıları gibi davranmış; tasarım sürecinin belleği ve hesaplama kapasitesi mimarın biyolojik sınırlarının ötesine taşınmıştır.
- Enaktif biliş: Bilgi edilgen biçimde alınmamış, mimar–sayısal ortam etkileşiminin eylemsel döngülerinde kurulmuştur. Tasarım, bu sapmalar aracılığıyla her kurulumda yeniden kurulur; form, sabit ve değişmez bir nesne olmaktan çok, malzeme, mekân, üretim teknolojisi ve insan eylemleri arasındaki dinamik ilişkiler ağında her seferinde yeniden ortaya çıkan bir süreç hâline gelir.

5.4. Birlikte yaratıcı faile doğru dönüşüm (Transformation toward a co-creative agent)

Tüm bu nedenlerle, enstalasyonun üretildiği tasarım yoluyla araştırma süreci, mimarlıkta yaratıcı failliğin dönüşmekte olduğunu göstermektedir. Ancak bu dönüşüm, algoritmanın insanla eşdeğer bilinçli bir fail hâline geldiği anlamına gelmemektedir. Daha çok, yaratıcı sonucun mimarın kurduğu kurallar, sayısal ortamın hesaplamalı davranışı, arayüz geri bildirimleri ve üretim teknolojilerinin maddi kısıtları arasında oluşan döngüsel ilişkiler içinde şekillendiğini göstermektedir. Bu nedenle çalışmada savunulan hibrit yaratıcı faillik, insan öznenin ortadan kalkması değil; tasarım kararlarının kurulması,

varyasyonların ortaya çıkması ve bu varyasyonlara değer atanması süreçlerinin farklı aktörler arasında dağıldığı etkileşimsel bir modeli ifade etmektedir.

Bu bağlamda, sistemden kaynaklanan teknik sapmalar ile yaratıcı belirmeler birbirinden ayrıştırılarak değerlendirilmiştir. Teknik hata, algoritmik sistemin işleyişinden doğan ve tasarımcının yaratıcı niyetinden bağımsız olarak ortaya çıkan durumları ifade etmektedir. Buna karşılık yaratıcı belirme, tasarımcının doğrudan öngörmediği; ancak kendisi tarafından tanımlanan parametre aralıkları ve kurallar içinde sayısal ortamın açığa çıkardığı biçimsel olasılıkları tanımlamaktadır. Dolayısıyla araştırmada değerli kabul edilen sonuçlar, sistemin rastgele bozulmaları değil; kural temelli işleyiş içinde ortaya çıkan ve daha sonra biçimsel, kavramsal ve üretimsel ölçütler üzerinden seçilerek anlamlandırılan varyasyonlardır.

Böylece mimar, tasarımı tek başına belirleyen tanrısal yaratıcı güce sahip olan (*demiurgic*) figürden çok; parametre alanını kuran, süreci yönlendiren ve ortaya çıkan belirmeleri değerlendiren bir küratör-karar verici olarak yeniden konumlanmaktadır. Dolayısıyla çalışma, ikinci sayısal dönüş bağlamında mimarlıkta yaratıcı öznenin sabit ve tekil bir kaynak olarak değil, çoklu etkileşimler içinde kurulan dağıtık bir performans olarak yeniden düşünülmesi gerektiğine işaret etmektedir.

6. SONUÇ (CONCLUSION)

Bu çalışma, ikinci sayısal dönüş sonrasında mimari tasarımda yaratıcı failliğin artık tekil ve insan merkezli bir faaliyet olarak değil, mimar ile sayısal ortam arasındaki etkileşimde kurulan dağıtık bir bilişsel süreç olarak işlediğini göstermektedir. Bir[Arada] enstalasyonu, bu hibrit failliği hem tasarım ve üretim sürecinde hem de mekânsal çıktılarında görünür kılmıştır. Diferansiyel büyüme algoritması aracılığıyla geleneksel bir motifin yeniden yorumlanması, Boden'in yaratıcılık ölçütleri doğrultusunda yeni, şaşırtıcı ve değerli düşünsel ve biçimsel sonuçlar üretmiştir. Kombinasyonel, keşifsel ve dönüşümsel yaratıcılık kiplerinin eşzamanlı işleyişi ise geçmiş ile gelecek, sayısal ile fiziksel ve kural ile öngörülemezlik arasında konumlanan bir üretim mantığını açığa çıkarmıştır.

Bu bulgular, yaratıcı sürecin 4E biliş modelleriyle açıklanabileceğini göstermektedir. Tasarım bağlama gömülü biçimde gelişmiş, beden-araç etkileşimleriyle şekillenmiş, sayısal ortamlarla genişlemiş ve mimar-algoritma döngülerinde ortaya çıkmıştır. Bu çerçevede yaratıcı fail, ne yalnızca insan ne de yalnızca makinedir; yaratıcı faillik, insan, sayısal ortam ve maddi üretim süreçleri arasında dağılarak kurulan etkileşimsel bir oluşumdur.

Çalışmanın temel katkısı, üretken mimari tasarımda yaratıcı kararların nasıl ortaya çıktığını sonuç üründen çok süreç içinden okuyarak görünür kılmasıdır. Tasarım yoluyla araştırma yaklaşımı, bu dağılımı içeriden belgeleme ve yorumlama bakımından etkili bir yöntem sunmuştur. Bu doğrultuda çalışma, mimarın rolünün ortadan kalkmadığını; aksine parametre alanını kuran, süreci yönlendiren ve ortaya çıkan belirmeleri değerlendiren bir küratör-karar verici olarak yeniden tanımlandığını göstermektedir. Böylece makale, hesaplamalı tasarım bağlamında yaratıcı failliğin insan ile makine arasında basit bir görev paylaşımı olarak değil, karşılıklı geri bildirimler, seçimler ve maddi kısıtlar içinde kurulan ilişkiyel bir performans olarak yeniden düşünülmesine katkı sunmaktadır.

Çıkar Çatışması Beyanı (Conflict of interest)

" Diferansiyel Büyüme Üzerinden Üretken Tasarıma İçeriden Bakış" başlıklı yazı başka bir yerde yayınlanmamıştır ve başka bir yerde aynı anda yayınlanmak üzere gönderilmemiştir.

Yapay Zekâ Kullanım Beyanı (AI Use Disclosure)

Bu makalenin hazırlanması sürecinde yapay zekâ destekli araçları bilimsel fikir üretimi, veri analizi, yorumlama veya özgün araştırma içeriği oluşturma amacıyla kullanılmamıştır. Yazar, YZ tarafından sağlanan tüm önerileri gözden geçirmekle birlikte, Makalenin nihai hâlinin doğruluğu, bütünlüğü ve özgünlüğünden tamamen sorumludur.

Referanslar (References)

- Alberti, L. B. (1988). *On the art of building in ten books* (J. Rykwert, N. Leach, & R. Tavernor, Trans.). MIT Press.
- Alexander, C. (1964). *Notes on the synthesis of form*. Harvard University Press.
- Barad, K. (2007). *Meeting the universe halfway: Quantum physics and the entanglement of matter and meaning*. Duke University Press.

- Boden, M. A. (2010). *Creativity and art: Three roads to surprise*. Oxford University Press.
- Bono, G., & Guerrieri, P. M. (2021). Digital anonymity: Human-machine interaction in architectural design. *TECHNE – Journal of Technology for Architecture and Environment*, (2), 177–181. <https://doi.org/10.13128/techne-10705>
- Braidotti, R. (2013). *The posthuman*. Polity Press.
- Candy, L., & Edmonds, E. (2018). Practice-based research in the creative arts: Foundations and futures from the front line. *Leonardo*, 51(1), 63–69. https://doi.org/10.1162/LEON_a_01471
- Carpó, M. (2023). *Beyond digital design and automation at the end of modernity*. MIT Press.
- Chai, H., & Yuan, P.-F. (2023). Hybrid intelligence. *Architectural Intelligence*, 2, Article 11. <https://doi.org/10.1007/s44223-023-00029-w>
- Clark, A., & Chalmers, D. (1998). The extended mind. *Analysis*, 58(1), 7–19. <https://doi.org/10.1093/analys/58.1.7>
- Davis, N. (2013). Human–computer co-creativity: Blending human and computational creativity. *Proceedings of the AAAI Conference on Artificial Intelligence and Interactive Digital Entertainment*, 9(6), 9–12. <https://doi.org/10.1609/aiide.v9i6.12603>
- Davis, N., Hsiao, C.P., Popova, Y., & Magerko, B. (2015). An enactive model of creativity for computational collaboration and co-creation. In N. Zagalo & P. Branco (Eds.), *Creativity in the digital age*, (pp. 109–133). Springer. https://doi.org/10.1007/978-1-4471-6681-8_7
- Engelbart, D. C. (1962). *Augmenting human intellect: A conceptual framework*. Stanford Research Institute.
- Frayling, C. (1993). Research in art and design. *Royal College of Art Research Papers*, 1(1), 1–5. <https://antle.iat.sfu.ca/wp-content/uploads/2018/08/Frayling.pdf>
- Haraway, D. (1991). *Simians, cyborgs, and women: The reinvention of nature*. Routledge.
- Hoffmann, O. (2016). On modeling human–computer co-creativity. In T. Nishida (Ed.), *Knowledge, information and creativity support systems*, 37–48. Springer. https://doi.org/10.1007/978-3-319-27478-2_3
- Hutchins, E. (1995). *Cognition in the wild*. MIT Press.
- Kantosalo, A. (2019). *Human–computer co-creativity: Designing, evaluating and modelling computational collaborators for poetry writing* [Doctoral dissertation, University of Helsinki].

- Latour, B. (2005). *Reassembling the social: An introduction to actor-network theory*. Oxford University Press.
- Licklider, J. C. R. (1960). Man–computer symbiosis. *IRE Transactions on Human Factors in Electronics, HFE-1*(1), 4–11. <https://doi.org/10.1109/THFE2.1960.4503259>
- Negroponte, N. (1970). *The architecture machine: Toward a more human environment*. MIT Press.
- Negroponte, N. (1975). *Soft architecture machines*. MIT Press.
- Noë, A. (2004). *Action in perception*. MIT Press.
- Özel, G., & Ennemoser, B. (2019). Interdisciplinary AI. In *Proceedings of ACADIA 2019: Ubiquity and Autonomy*, 380–391. <https://doi.org/10.52842/conf.acadia.2019.380>
- Pask, G. (1976). *Conversation theory: Applications in education and epistemology*. Elsevier.
- Picon, A. (2011). *Digital culture in architecture: An introduction for design professions*. Birkhäuser Architecture.
- Picon, A. (2020). Beyond digital avant-gardes: The materiality of architecture and its impact. *Architectural Design, 90*(5), 118–125. <https://doi.org/10.1002/ad.2618>
- Thompson, E. (2007). *Mind in life: Biology, phenomenology, and the sciences of mind*. Harvard University Press.
- Varela, F. J., Thompson, E., & Rosch, E. (1991). *The embodied mind: Cognitive science and human experience*. MIT Press.
- Yang, Q., Steinfeld, A., Rosé, C. P., & Zimmerman, J. (2020). Re-examining whether, why, and how human–AI interaction is uniquely difficult to design. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, (pp. 1–13). <https://doi.org/10.1145/3313831.3376301>
- Yuan, P. F. (2023). Toward a generative AI-augmented design era. *Architectural Intelligence, 2*, Article 16. <https://doi.org/10.1007/s44223-023-00038-9>

How Well Can AI Contribute to Interior Architecture? A Comparative Analysis of Descriptive Accuracy

Yaren Şekerci¹, Müge Develier²

ORCID NO: 0000-0003-4509-6299¹, 0000-0001-7248-4065²

^{1,2} Antalya Bilim University, Faculty of Fine Arts and Architecture, Department of Interior Architecture and Environmental Design, Antalya, Turkey

This study presents a comparative evaluation of the descriptive and design output performance of three advanced artificial intelligence (AI) models—Claude 3.5 Sonnet, Gemini 1.5 Flash, and ChatGPT 4o—within the context of interior architecture. The assessment focuses on seven predefined design criteria: design style, colour, lighting, furniture and product selection, interior materials, architectural features, and spatial layout. Six eclectic reception area designs, combining classical and modern influences, were selected as the visual stimuli for the evaluation process. A total of 15 participants, all professional interior architects with a minimum of five years of experience, scored the AI-generated outputs for each criterion on a scale from 1 (very poor) to 5 (very successful). The evaluation followed a standardized prompt structure for each AI model to ensure consistency and fairness in the comparison. The findings indicate that Claude 3.5 Sonnet achieved the highest overall performance, maintaining stable and reliable results across most categories, with particular strengths in architectural features and spatial layout. Gemini 1.5 Flash closely followed, excelling in design style and colour while showing some variability in other areas. ChatGPT 4o demonstrated strong performance in furniture and lighting but was less consistent overall, especially in interior materials and spatial layout. Despite these differences, the performance gap between the models was relatively small, indicating a competitive landscape among the evaluated tools. Across all three models, spatial layout and interior materials emerged as the most challenging criteria, suggesting that these aspects require more advanced spatial reasoning, contextual awareness, and material recognition than current AI models can consistently provide. While the study highlights these limitations, it also underscores the potential of AI to enhance the creative and technical phases of interior architecture by enabling faster concept generation, detailed description, and alternative design exploration. Overall, the results suggest that when integrated into collaborative co-design processes, AI models can serve as valuable partners in both professional practice and design education, complementing human expertise with algorithmic precision. The study contributes to the growing discourse on AI's role in design by mapping out the strengths and weaknesses of each model and by identifying opportunities for further refinement to produce more context-aware, accurate, and consistent design outputs.

Received: 19.08.2025

Accepted: 13.12.2025

Corresponding Author:

muge.develier@antalya.edu.tr

Şekerci, Y. & Develier, M. (2026). How well can AI contribute to interior architecture? A comparative analysis of descriptive accuracy. *JCoDe: Journal of Computational Design*, 7(1), 95-132.
<https://doi.org/10.53710/jcode.1765357>

ROR ID: 059636586

Keywords: AI-Generated Interior Design, Interior Design, Describe, Design Technology.



Yapay Zeka İç Mimarlığa Ne Ölçüde Katkı Sağlayabilir? Betimsel Doğruluk Üzerine Karşılaştırmalı Bir Analiz

Yaren Şekerci¹, Müge Develier²

ORCID NO: 0000-0003-4509-6299¹, 0000-0001-7248-4065²

^{1,2} Antalya Bilim Üniversitesi, Güzel Sanatlar ve Mimarlık Fakültesi, İç Mimarlık ve Çevre Tasarımı Bölümü, Antalya, Türkiye

Bu çalışma, Claude 3.5 Sonnet, Gemini 1.5 Flash ve ChatGPT 4o olmak üzere üç yapay zeka modelinin, yedi temel tasarım kriterine dayalı olarak iç mekân tasarımı çıktıları üretme performansını değerlendirmektedir. Bu kriterler; tasarım stili, renk, aydınlatma, mobilya ve ürün seçimi, iç mekân malzemeleri, mimari özellikler ve mekânsal yerleşimden oluşmaktadır. Değerlendirme süreci, altı farklı mekân tasarımı üzerinden gerçekleştirilmiş ve 15 katılımcı, yapay zeka tarafından üretilen çıktıları 1 ile 5 arasında puanlamıştır. Sonuçlar, Claude 3.5 Sonnet'in birçok kriterde tutarlı puanlar elde etmesi sayesinde genel performans açısından en başarılı model olduğunu ortaya koymaktadır. Bunu, tasarım stili ve renk alanlarında öne çıkan ancak belirli ölçüde değişkenlik gösteren Gemini 1.5 Flash takip etmektedir. ChatGPT 4o ise mobilya ve aydınlatma kategorilerinde güçlü performans sergilemesine karşın, genel tutarsızlıklar nedeniyle daha düşük bir sıralamada yer almıştır. Modeller rekabetçi bir performans göstermelerine rağmen, özellikle mekânsal yerleşim ve iç mekân malzemeleri gibi alanlar tüm modeller için belirli zorluklar teşkil etmiş ve bu bağlamda gelişime açık noktalar ortaya koymuştur. Bu çalışma, yapay zekâ destekli sistemlerin tasarım süreçlerine katkı potansiyelini vurgularken, karmaşık mekânsal ve malzeme odaklı bağlamlarda mevcut sınırlamaların aşılabilmesi adına daha fazla geliştirme ve kapsam genişletme gerekliliğine dikkat çekmektedir.

Teslim Tarihi: 19.08.2025

Kabul Tarihi: 13.12.2025

Sorumlu Yazar:

muge.develier@antalya.edu.tr

Şekerci, Y. & Develier, M. (2026). Yapay zeka iç mimarlığa ne ölçüde katkı sağlayabilir? Betimsel doğruluk üzerine karşılaştırmalı bir analiz. *JCoDe: Journal of Computational Design*, 7(1), 95-132.

<https://doi.org/10.53710/jcode.1765357>

Anahtar Kelimeler: Yapay Zekâ Tarafından Üretilmiş İç Mekân Tasarımı, İç Mekân Tasarımı, Betimleme, Tasarım Teknolojisi

ROR ID: 059636586



1. INTRODUCTION

The impact of artificial intelligence (AI) on interior architecture is profound, comparable to other technological advancements, and this is only the beginning. AI tools continue to evolve, introducing enhanced capabilities with each iteration. Assessing how these new features affect the design process and determining their performance levels are essential for both practice and research. Among AI tools with conversational interfaces, OpenAI's ChatGPT, Google's Gemini, and Anthropic's Claude are prominent examples. These platforms, alongside others such as X platform's Grok, not only support text-based interaction but also offer the ability to generate visual content. Initially, these tools functioned similarly to text-to-image AI models like Midjourney and Leonardo.ai, where users could input prompts to create images. However, with the addition of image "describe" functions, these chatbots have acquired the ability to interpret and describe visual content comprehensively, marking a significant step forward in understanding visual data.

The recent introduction of image description features—such as Claude's implementation in September 2024—provides a novel opportunity to evaluate the extent to which AI models can accurately interpret and articulate the components of interior spaces. Existing research has extensively explored the generation of design concepts using text-to-image AI tools, yet there is limited focus on their ability to describe images accurately and how this influences visualization processes. In particular, the potential for improved mental visualization when a well-described space is provided in verbal form holds promise for advancing both AI applications and design education. This study addresses this research gap by evaluating how accurately ChatGPT, Gemini, and Claude describe eclectic interior reception areas for dermatology and aesthetic clinics based on predefined design elements and criteria.

In this study, six reception area designs, created as part of an interior architecture studio course, will be used as the primary visual stimuli. These designs, which combine classical and modern elements in an eclectic style, will be described by the AI models in terms of their key components, including design style, colour, lighting, furniture, interior materials, architectural features, and spatial layout. Participants with a

minimum of five years of experience in interior architecture will rate the accuracy of these descriptions on a scale from 1 (very poor) to 5 (very successful). The results will help identify which AI tool provides the most accurate and detailed descriptions of interior spaces, contributing valuable insights to the literature and professional practice in interior architecture. By fostering a collaborative codesign process, these AI tools enable designers to refine their concepts more efficiently, bridging the gap between automated analysis and human creativity. By determining the most effective tool for understanding and describing visual content, this research aims to support the development of more intuitive and impactful design tools that enhance both creativity and communication.

2. LITERATURE REVIEW

A fundamental goal of architecture is to create built environments that enhance psychological well-being, a responsibility that has grown as people now spend over seventy percent of their lives indoors (Akram, 2013). As a crucial component of the built environment, interior design significantly influences user experience, affecting spaces not only functionally but also aesthetically and psychologically. The representation of interior design is essential in interior architecture, as it enables effective visual communication of ideas and fosters collaboration among stakeholders (Chiu, 1995).

Design styles, which define the approach and methodology used in planning and decorating spaces, play a crucial role in their aesthetic, functional, and psychological qualities. These styles are influenced by user preferences and spatial functions, impacting colour schemes, materials, furniture, and accessories (Goldschmidt et al., 1998; Eckert et al., 2000). A structured interior design process thus enhances spatial functionality while contributing to occupants' overall experience and well-being.

2.1. Concept Development and the Integration of AI in Interior Design

A successful interior design process begins with concept development, where key spatial and functional relationships are identified through brainstorming. According to Ching and Binggeli (2018), this phase

requires synthesizing diverse ideas into a cohesive whole, ensuring coherence between human interaction and spatial organization. Designers refine their concepts by analysing how individual elements impact the overall structure. Once initial explorations are complete, a concise concept statement is formulated, guiding the schematic design phase, where spatial layouts, proportions, and circulation patterns are established to shape user experiences (Ching & Binggeli, 2018).

As technological advancements transform design methodologies, artificial intelligence (AI) has emerged as a powerful tool, enhancing both conceptual and schematic design. AI enables designers to analyse extensive datasets, recognize patterns, and generate optimized functional-aesthetic solutions (Almaz et al., 2024). AI integration in education and practice expands design possibilities, streamlines repetitive tasks, and improves overall efficiency (Graef & Ilche, 2021; Halpern, 2020). Additionally, AI enhances decision-making, predicts design challenges, and optimizes spatial arrangements for sustainability (Münch, 2022; Smith, 2018).

Artificial intelligence, rooted in cognitive science, emulates human cognition through computational simulations (Sucu & Ataman, 2020). AI models human thought and perception, generating data-driven solutions (Huynh-The et al., 2023). Its evolution parallels the shift from mechanization to digital automation, enabling intelligent design processes (Bayrak, 2020). By continuously refining itself through vast data analysis, AI systems improve precision and adaptability (Deveci, 2022).

In interior design, AI allows for realistic scenario simulations, enabling data-informed spatial arrangements and material optimizations (Münch, 2022; Smith, 2018). The iterative integration of AI fosters a balance between human creativity and algorithmic precision, ultimately enhancing design quality and user experience (Almaz et al., 2024).

2.2. The Role of AI in Creative Fields and Its Impact on Text-to-Image Generation

One significant application of artificial intelligence (AI) in creative fields is text-to-image generation, where textual descriptions are transformed into visual representations using deep neural networks and machine learning techniques (Reviriego & Merino-Gomez, 2022; He & Deng, 2017). These models autonomously generate images based on vast training datasets, enabling innovative solutions beyond traditional programming (Fernandez, 2022). In interior design, text-to-image AI has proven particularly valuable, improving visualization speed, client communication, and allowing non-experts to engage more effectively in the creative process (Yıldırım & Emiraraslan, 2021). Additionally, increased accessibility has fostered online creative communities, bridging the gap between amateur and professional designers while driving technological advancement (Vartiainen & Tedre, 2023).

However, generating realistic and accurate images from text remains a complex challenge, affecting applications such as digital art, image editing, video games, and computer-aided design. The introduction of generative adversarial networks (GANs) (Goodfellow et al., 2014; Denton et al., 2015) has significantly improved image generation quality (Reed et al., 2016; Xu et al., 2018). Conditional GANs (cGANs) have further refined this process by allowing models to generate visuals based on specific textual cues (Dong et al., 2017; Reed et al., 2016). However, fine control over outputs remains an issue—small changes in text, such as modifying a colour description, can cause unintended variations in object placement or form, posing challenges for precision-driven applications.

Since the mid-2010s, research in text-to-image AI has surged, driven by model improvements and large-scale datasets (Dhariwal & Nichol, 2021; Saharia et al., 2022). Exposure to millions of annotated images enables AI to learn patterns and generate contextually relevant outputs (Bommasani et al., 2021). This has democratized visual content creation, reducing reliance on technical expertise (Fiebrink, 2019; Oppenlaender, 2022).

Scholars argue that generative AI reshapes human-machine interactions, redefining co-creativity (Audry, 2021). The process increasingly relies on iterative refinement of textual prompts (Gwern, 2020; Rezwana & Maher, 2022), where users gradually guide AI toward their artistic vision through repeated adjustments (Vartiainen & Tedre, 2023). This evolving human-AI dialogue highlights the collaborative nature of generative design (Audry, 2021).

2.3. Understanding AI-Generated Designs

The advent of generative AI has significantly reshaped creative workflows and brought important epistemological distinctions into focus, particularly the difference between propositional knowledge ("knowing that") and procedural knowledge ("knowing how"), as well as the nuances among ability, knowledge, and understanding (Darwiche, 2018). Current generative models, despite their advanced capabilities, primarily operate by statistical pattern matching, generating outputs based on learned correlations without genuine comprehension or meaning (Smith, 2019; Saharia et al., 2022). Such models analyze pixel patterns corresponding to text descriptions to create coherent and contextually appropriate visual content. However, they inherently lack qualities like intuition, qualitative insight, agency, personal experience, and judgment (Smith, 2019). Additionally, they cannot reason consistently, plan strategically, understand their environment comprehensively, or retain information beyond limited contexts (Vartiainen et al., 2025).

Recent developments in computer vision and natural language processing have expanded potential applications for generative AI, particularly through text-guided image generation. Notably, models such as DALL-E 2 (Ramesh et al., 2022) and Stable Diffusion (Rombach et al., 2022) employ advanced techniques involving joint image-text embeddings and diffusion processes (Sohl-Dickstein et al., 2015). These approaches enable highly detailed and photo-realistic image creation from textual prompts. However, achieving optimal results requires precise and careful prompt engineering, defined as systematically designing input prompts to enhance generative outputs (Dang et al., 2022).

Prompt engineering typically involves adding specific phrases like “trending on art station” or “highly detailed” to enhance visual appeal (Liu and Chilton, 2022). Nevertheless, these practices often rely on intuition rather than established guidelines, resulting in phrases that can seem arbitrary. Additionally, robust evaluation tools to systematically assess prompt quality remain scarce, leaving users to rely on single-output judgments (Pavlichenko and Ustalov, 2023). Research highlights that prompt effectiveness significantly depends on word sequence and context length. For example, Lu et al. (2021) demonstrated the considerable impact of word arrangement, while Wu et al. (2021) observed that combining multiple instructions within extended prompts can introduce conflicting directives. Alternative strategies include leveraging the language model itself to refine prompts by elaborating on the problem, akin to human “think aloud” problem-solving methods (Betz et al., 2021).

3. METHODOLOGY

3.1. Materials

This study utilized six reception area designs, which were initially conceptualized and later developed into fully realized interior designs by students enrolled in the IAED 3002 Interior Design Studio VI course. The project required students to create eclectic interior designs by combining one classical and one modern design style. To ensure randomness and diversity, each student was instructed to draw one classical style and one modern style from separate bowls containing predefined style names. This process provided a unique starting point for each student, with a balanced combination of historical and contemporary aesthetics.

The project brief tasked students with designing an aesthetic dermatology clinic, allowing them to select any space within the clinic's spatial program for their initial focus. However, students were required to generate their initial design concept using an AI model. This conceptual output, referred to as the "Conceptual Image by AI" in Appendix 1, served as a foundation for the subsequent design critiques and iterations. The conceptual design's visual approach, colour palette, and overall aesthetic were then integrated into their final design outcomes.

Students were granted freedom in their choice of AI model (e.g., text-to-image or image-to-image) and platform, ensuring flexibility and creativity in their workflow. The only limitations imposed were adherence to the eclectic design styles assigned through the random draw and alignment with the spatial and functional requirements of the clinic project.

The final designs, referred to as “Interior Design of the Reception Area” in Appendix 1, represent the culmination of the students' efforts, incorporating both technical and aesthetic details. While one student (Student 1) chose to focus on the doctor's office for the conceptual image, the majority of students concentrated on the waiting area for their initial design exploration.

Appendix 1 thus illustrates the progression from AI-generated conceptual designs to the finalized 3D renderings of the reception areas, highlighting the integration of AI tools and student creativity in achieving functional and visually cohesive interior designs.

The prompt is “Describe the interior in these values: design style(s), colour, lighting, furniture, products, interior materials, architectural features (ceiling height, size of the space, windows, doors, etc.), spatial layout.”. According to the prompt, the descriptions of AI models for 6 interior designs as in Appendix 2-7.

Random assignment of one classical and one modern design style was intentionally employed to minimize stylistic bias and habitual design tendencies among students. This method was designed to encourage out-of-context spatial thinking and to stimulate genuine eclectic composition rather than preference-based stylistic consistency. By disrupting familiar design patterns, the study aimed to generate heterogeneous visual outputs that could challenge the descriptive capabilities of AI models under diverse aesthetic conditions.

3.2. Participants

The study involved 15 experienced interior architects and designers as expert evaluators. All participants had a minimum of five years of professional experience in interior design practice. The evaluators were recruited from different professional backgrounds, including

architectural offices, academia, and independent design studios. This diversity was intentionally sought to reduce single-discipline bias and to strengthen the reliability of expert judgment. The evaluators participated voluntarily and were not involved in the production of the design stimuli.

3.3. Data Collection

The six eclectic reception area designs served as visual stimuli for the study. Descriptions of these designs were generated using ChatGPT, Gemini, and Claude based on a standardized prompt, which included components such as:

- Design style(s)
- Colour
- Lighting
- Furniture and products
- Interior materials
- Architectural features (e.g., ceiling height, windows, doors)
- Spatial layout

Participants reviewed the descriptions and scored the accuracy and detail on a scale of 1 (very poor) to 5 (very successful). The collected scores and feedback were recorded for analysis.

3.4. Data Analysis

Although numerical scoring was employed, the evaluation process is fundamentally grounded in expert judgment and therefore constitutes a structured expert-based evaluative approach rather than a purely objective quantitative experiment. The 1–5 Likert scale was used to systematically organize and compare expert perceptions across the evaluated criteria.

The numerical scores provided by the 15 professional interior architects were analysed by summing the total points each AI model received for each criterion across all six reception area designs. The analysis focused on two comparative levels:

- Overall Performance

For each AI model, the total scores obtained across all design criteria (design style, colour, lighting, furniture and products, interior materials, architectural features, and spatial layout) were summed to determine its overall descriptive performance.

- Criterion-Based Performance

For each individual criterion, the total scores assigned to each AI model across the six designs were calculated. This enabled the identification of the relative strengths of the models in specific design aspects. For instance, by comparing the total scores obtained in the “lighting” category, the model demonstrating superior descriptive capability in lighting could be determined.

The results therefore represent comparative patterns of expert perception rather than statistically absolute measurements. This approach enables relative performance comparison among the AI models but does not claim predictive or generalizable statistical inference. The structured nature of this expert-based quantitative comparison provides a systematic framework for evaluating the descriptive capacities of the AI models in complex interior design contexts.

3.5. Procedure

The study followed a structured process:

- Stimulus Presentation: Participants were presented with six reception area designs and the AI-generated descriptions from ChatGPT, Gemini, and Claude.
- Scoring Phase: Participants rated each AI model's description for each design based on specific criteria (design style, colour, lighting, furniture and products, interior materials, architectural features, and spatial layout) using a 1 to 5 scale (1 = very poor, 5 = very successful).
- Data Collection: The scores provided by the 15 participants were recorded for each AI model across all criteria and designs.

This step-by-step process ensured consistency in the evaluation and enabled a comprehensive comparison of the descriptive performance of the AI models. The structured nature of the procedure also ensured that all participants used the same assessment framework.

3.6. Ethical Approval

The study was reviewed and approved by Antalya Bilim University, Natural and Applied Sciences Scientific Research and Publication Ethics Committee, in their decision dated February 18, 2025, and marked as 2025/03, ensuring that all procedures complied with ethical guidelines for research involving human participants. Participants were informed

about the purpose of the study, assured of their anonymity, and provided informed consent before participation.

4. FINDINGS

The average points given by the participants for each AI model across the six different spaces in seven different criteria and overall can be seen in **Table 1**.

DESIGN STYLE		COLOUR	
ChatGPT	3.5	ChatGPT	3.4
Claude	3.2	Claude	3.9
Gemini	3.7	Gemini	3.6
LIGHTING		FURNITURE & PRODUCT	
ChatGPT	3.5	ChatGPT	3.6
Claude	3.5	Claude	3.4
Gemini	3.5	Gemini	3.5
INTERIOR MATERIALS		ARCHITECTURAL FEATURES	
ChatGPT	3.2	ChatGPT	3.3
Claude	3.5	Claude	3.7
Gemini	3.5	Gemini	3.6
SPATIAL LAYOUT		OVERALL	
ChatGPT	3.4	ChatGPT	3.4
Claude	3.6	Claude	3.5
Gemini	3.0	Gemini	3.5

Table 1: Average Points of the Participants (Green indicates the best performance, yellow represents moderate performance, and red shows the worst performance for the specific criterion).

As summarized in **Table 1**, the performance of different AI models varies across design criteria, with Gemini achieving the highest ratings in Design Style and ChatGPT in Furniture & Product.

Table 2 presents the average performance of the AI models across seven criteria and six space designs, providing a comprehensive comparison of their effectiveness.

Design Style							
AI Model	1 st Design	2 nd Design	3 rd Design	4 th Design	5 th Design	6 th Design	Overall
ChatGPT	2.3	4.1	3.9	3.5	3.9	3.3	3.5
Claude	3.1	3.4	3.5	2.7	3.4	2.9	3.2
Gemini	3.3	4.1	4.0	3.6	3.7	3.8	3.7
Colour							
AI Model	1 st Design	2 nd Design	3 rd Design	4 th Design	5 th Design	6 th Design	Overall
ChatGPT	2.1	4.2	3.7	3.4	3.8	3.5	3.4
Claude	3.9	4.1	4.0	3.5	3.9	4.1	3.9

Table 2: Average Performance of AI Models Across Seven Criteria and Six Space Designs

Gemini	3.8	4.5	3.4	3.7	2.8	3.4	3.6
Lighting							
AI Model	1st Design	2nd Design	3rd Design	4th Design	5th Design	6th Design	Overall
ChatGPT	2.3	3.9	3.9	3.5	3.7	3.8	3.5
Claude	3.5	3.9	3.7	3.4	3.1	3.6	3.5
Gemini	2.8	4.0	3.3	3.5	3.9	3.7	3.5
Furniture & Product							
AI Model	1st Design	2nd Design	3rd Design	4th Design	5th Design	6th Design	Overall
ChatGPT	3.2	4.3	3.5	3.1	3.9	3.7	3.6
Claude	3.5	4.1	2.7	3.5	3.6	3.1	3.4
Gemini	3.6	3.7	2.7	3.6	3.1	4.3	3.5
Interior Materials							
AI Model	1st Design	2nd Design	3rd Design	4th Design	5th Design	6th Design	Overall
ChatGPT	2.2	3.7	2.9	3.5	3.7	3.4	3.2
Claude	3.9	3.5	3.1	3.3	3.5	3.5	3.5
Gemini	4.1	3.5	2.7	3.5	3.1	4.1	3.5
Architectural Features							
AI Model	1st Design	2nd Design	3rd Design	4th Design	5th Design	6th Design	Overall
ChatGPT	2.7	3.3	3.1	3.3	3.4	4.0	3.3
Claude	3.9	3.3	3.8	3.9	3.5	3.7	3.7
Gemini	3.3	3.7	3.3	3.6	3.7	3.9	3.6
Spatial Layout							
AI Model	1st Design	2nd Design	3rd Design	4th Design	5th Design	6th Design	Overall
ChatGPT	2.2	4.2	4.0	3.2	3.5	3.5	3.4
Claude	3.2	4.1	3.7	3.6	3.5	3.5	3.6
Gemini	3.3	2.9	2.9	2.7	2.6	3.3	3.0

4.1. Design Style

In the design style criterion, the overall performance of the three AI models reveals notable differences in their ability to accurately capture and describe the design style across six different spaces. Gemini 1.5 Flash stands out as the most successful model, achieving the highest overall average of 3.7. It consistently received high scores, particularly in the 2nd and 3rd designs, with scores of 4.1 and 4.0, demonstrating both accuracy and consistency.

ChatGPT 4o, with an overall average of 3.5, follows as the second-best performer. Although it received relatively high scores in some spaces (such as the 2nd and 5th designs with scores of 4.1 and 3.9), it struggled in the 1st design, where its score dropped to 2.3. This indicates moderate success but a lack of consistency across different designs.

Claude 3.5 Sonnet, with the lowest overall average of 3.2, exhibited high consistency in its scores but failed to achieve strong performance. Its scores remained within a narrow range, with a low point of 2.7 in the 4th design and a high point of 3.5 in the 3rd design. This suggests that while participants generally agreed on its performance, the model was unable to accurately or effectively describe the design style compared to the other models.

Overall, Gemini 1.5 Flash demonstrated both strong performance and consistency, making it the most effective model for this criterion, whereas Claude 3.5 Sonnet's consistent but low performance highlights its limitations in capturing the complexity of design styles.

4.2. Colour

In the colour criterion, the AI models demonstrated varied performance levels, with Claude 3.5 Sonnet achieving the highest overall average of 3.9. Claude consistently performed well across all six designs, receiving high scores particularly in the 1st and 6th designs (3.9 and 4.1). This suggests that Claude was effective in accurately interpreting and representing colour information, with minimal fluctuations across different designs.

Gemini 1.5 Flash, with an overall average of 3.6, followed closely behind Claude. It demonstrated strong performance in the 2nd design (4.5) but experienced a significant drop in the 5th design (2.8). This indicates that although Gemini generally handled colour well, its performance was less consistent compared to Claude.

ChatGPT 4o achieved the lowest overall average of 3.4, with notable fluctuations in its performance. It received its highest score in the 2nd design (4.2) but struggled in the 1st design (2.1). This inconsistency suggests that ChatGPT's ability to interpret colour varied significantly depending on the design context.

Overall, Claude 3.5 Sonnet demonstrated both accuracy and consistency in the colour criterion, outperforming the other models. Gemini 1.5 Flash showed strong potential but occasional inconsistencies, while ChatGPT 4o struggled with variability in performance across different designs.

4.3. Lighting

In the lighting criterion, the performance of the three AI models was remarkably close, with all models achieving an overall average of 3.5. However, slight differences emerge when examining the finer details of their performance, revealing a small but notable distinction in ranking. Gemini 1.5 Flash demonstrated the best performance among the models, with its highest score in the 2nd design (4.0) and generally stable performance across most designs. Although it experienced a slight drop in the 3rd design (3.3), its ability to perform consistently at a high level gave it a slight edge over the others.

Claude 3.5 Sonnet closely followed Gemini, maintaining steady scores between 3.1 and 3.9 across all designs. This consistency allowed it to achieve solid performance, though it slightly lagged behind Gemini due to its lack of higher peaks.

ChatGPT 4o ranked just behind Claude, with its scores ranging from 2.3 in the 1st design to 3.9 in the 2nd and 3rd designs. While it performed well in several designs, its lower score in the 1st design negatively affected its overall ranking in this category.

Overall, despite their similar average scores, Gemini 1.5 Flash emerged as the best-performing model due to its slightly higher peak scores and overall stability. Claude 3.5 Sonnet displayed strong consistency but lacked standout moments, while ChatGPT 4o showed moderate success, impacted by its weaker performance in certain designs.

4.4. Furniture & Product

In the furniture and product criterion, ChatGPT 4o achieved the highest overall average of 3.6, followed by Gemini 1.5 Flash with 3.5, and Claude 3.5 Sonnet with 3.4. Despite the relatively close overall averages, the models displayed distinct performance patterns.

ChatGPT 4o showed strong performance in the 2nd design (4.3) and maintained relatively stable scores across most designs. Its lowest score was in the 4th design (3.1), but overall, its performance was consistent and reliable, making it the most successful model for this criterion.

Gemini 1.5 Flash demonstrated variability, with its lowest score in the 3rd design (2.7) and its highest score in the 6th design (4.3). This

suggests that although Gemini had the potential for high performance, it experienced fluctuations across different designs, impacting its consistency.

Claude 3.5 Sonnet received moderate scores, ranging from 2.7 in the 3rd design to 4.1 in the 2nd design. Although it maintained a narrow score range compared to Gemini, its performance was generally lower and less effective in accurately identifying furniture and product-related aspects.

Overall, ChatGPT 4o demonstrated both strong performance and consistency, making it the most effective model for this criterion. Gemini 1.5 Flash had potential but was hindered by inconsistent performance, while Claude 3.5 Sonnet remained moderately consistent but less successful overall.

4.5. Interior Materials

In the interior materials criterion, Gemini 1.5 Flash and Claude 3.5 Sonnet both achieved an overall average of 3.5, but a closer examination reveals that Gemini slightly outperformed Claude due to its higher peaks and fewer fluctuations across designs. ChatGPT 4o followed with a lower average of 3.2.

Gemini 1.5 Flash demonstrated its best performance in the 1st (4.1) and 6th (4.1) designs, showing its ability to accurately capture material details. Although it experienced a slight drop in the 3rd design (2.7) and 5th design (3.1), its overall performance remained strong, making it the top model for this criterion.

Claude 3.5 Sonnet maintained steady performance, with scores ranging between 3.1 and 3.9 across all designs. While it lacked the high peaks seen in Gemini's performance, its consistent scores allowed it to remain competitive, closely trailing behind Gemini.

ChatGPT 4o struggled in this criterion, with its lowest score of 2.2 in the 1st design. Although it showed improvement in the 2nd and 5th designs (3.7), its overall performance was impacted by lower scores in other designs, leading to a final average of 3.2.

Overall, Gemini 1.5 Flash emerged as the top-performing model due to its combination of high peaks and relatively stable performance. Claude 3.5 Sonnet followed closely, benefiting from its consistency, while ChatGPT 4o lagged due to fluctuations and lower initial performance.

4.6. Architectural Features

In the architectural features criterion, Claude 3.5 Sonnet secured the highest overall average with 3.7, followed closely by Gemini 1.5 Flash with 3.6, and ChatGPT 4o with 3.3. Despite the relatively close averages, the models showed distinct patterns of performance across the six designs.

Claude 3.5 Sonnet consistently performed well, receiving its highest score of 3.9 in the 4th design and maintaining scores above 3.3 in all designs. Its strong and consistent performance highlights its ability to effectively capture architectural features with minimal fluctuations.

Gemini 1.5 Flash also demonstrated stable performance, with its scores ranging from 3.3 to 3.9. Its best performance was observed in the 6th design (3.9), reflecting its capability to interpret architectural features accurately. Although it closely followed Claude, its slightly lower peak scores kept it in second place.

ChatGPT 4o showed the most variability, with its lowest score in the 1st design (2.7) and its highest score in the 6th design (4.0). While it managed to achieve success in some designs, its inconsistent performance limited its overall effectiveness in this criterion.

Overall, Claude 3.5 Sonnet stood out as the most effective model due to its consistent and strong performance. Gemini 1.5 Flash closely followed, demonstrating stable results, while ChatGPT 4o struggled with fluctuations, making it the least effective in capturing architectural features.

4.7. Spatial Layout

In the spatial layout criterion, Claude 3.5 Sonnet achieved the highest overall average of 3.6, followed by ChatGPT 4o with 3.4, while Gemini 1.5 Flash lagged behind with an overall average of 3.0.

Claude 3.5 Sonnet demonstrated consistent performance, with scores ranging from 3.2 in the 1st design to 3.7 in the 3rd design. Its ability to maintain steady scores across all designs highlights its effectiveness in capturing spatial layout accurately without major fluctuations.

ChatGPT 4o showed moderate success, with its lowest score in the 1st design (2.2) and its highest score in the 3rd design (4.0). Although it displayed improvement in later designs, its performance variability across designs limited its overall success in this category.

Gemini 1.5 Flash struggled the most, with its scores ranging from 2.6 in the 5th design to 3.3 in the 6th design. The lack of strong or consistent performance suggests that Gemini had difficulty accurately capturing and representing the spatial layout.

Overall, Claude 3.5 Sonnet emerged as the most successful and consistent model in this criterion. ChatGPT 4o followed with moderate success but some variability, while Gemini 1.5 Flash experienced the most challenges, making it the least effective in this category.

4.8. Overall Performance

The overall performance of the AI models across all seven criteria shows that the differences between them are relatively small, indicating that all models performed closely. Claude 3.5 Sonnet ranked 1st with an overall average of 3.5, followed by Gemini 1.5 Flash in 2nd place with an average of 3.5, and ChatGPT 4o in 3rd place with 3.4.

When examining the total points across all designs and criteria, Claude scored the highest with 2228 points, followed by Gemini with 2199 points, and ChatGPT with 2161 points. These results further highlight how close the models are in terms of overall performance, with only small differences observed.

- Claude 3.5 Sonnet (3.5 average, 2228 points): Claude's performance was characterized by consistency, with strong scores across key criteria such as architectural features (3.7) and spatial layout (3.6). Its ability to maintain steady results in various designs gave it an advantage over the other models.
- Gemini 1.5 Flash (3.5 average, 2199 points): Gemini demonstrated strength in areas such as design style (3.7) and colour (3.6) but experienced slight variability in criteria like spatial layout (3.0).

Despite these fluctuations, its high peaks in certain designs allowed it to compete closely with Claude.

- ChatGPT 4o (3.4 average, 2161 points): ChatGPT showed potential in specific areas like furniture & product (3.6) and lighting (3.5) but suffered from greater variability across designs. Its inconsistent performance in criteria like spatial layout (3.4) and interior materials (3.2) kept it behind the other models.

In conclusion, while Claude 3.5 Sonnet slightly outperformed the others in terms of overall stability and effectiveness, the small differences in average scores and total points indicate that Gemini 1.5 Flash and ChatGPT 4o were not far behind, highlighting the competitive nature of their performance.

Beyond numerical comparison, the findings indicate that current AI models demonstrate stronger performance in categories associated with visually explicit attributes such as colour, lighting, and furniture. In contrast, spatial layout and interior materials—both of which require deeper three-dimensional reasoning and contextual interpretation—remain comparatively weaker. This reveals a fundamental limitation in image-to-text AI systems, where surface-level features are more reliably interpreted than complex spatial and material relationships. These findings align with previous research emphasizing the challenges of spatial cognition and material recognition in generative AI systems.

5. CONCLUSION

This study compared the performance of three AI models—Claude 3.5 Sonnet, Gemini 1.5 Flash, and ChatGPT 4o—across seven design-related criteria, including design style, colour, lighting, furniture and product, interior materials, architectural features, and spatial layout. The results revealed Claude 3.5 Sonnet as the top-performing model due to its consistency and reliability, with Gemini 1.5 Flash closely following, while ChatGPT 4o ranked third.

Despite their differences, the small variations in total points and overall averages indicate a highly competitive outcome. Claude's consistent performance in categories like architectural features (3.7) and spatial layout (3.6) contributed to its success, while Gemini excelled in design style (3.7) and colour (3.6) but experienced minor fluctuations.

ChatGPT's variable performance, with notable strengths in furniture and product (3.6) and lighting (3.5), limited its overall effectiveness.

The findings demonstrate that AI tools hold great potential for enhancing design processes, but the models' fluctuating performance in spatial layout and interior materials highlights opportunities for further improvements, as evidenced by varying scores and limited overall success in these criteria. in accuracy. By refining these models and integrating them more effectively into design workflows, AI can serve as a valuable creative and technical support system for designers.

Limitations & Further Studies

This study has several limitations that should be acknowledged. Firstly, the evaluation relies on expert-based subjective assessment rather than automated or fully objective computational metrics. Although numerical scales were applied, the findings ultimately reflect patterns of professional perception. Additionally, the experimental setup did not include inter-rater reliability analysis, which could be addressed in future studies to strengthen the statistical robustness and methodological rigor of the results.

The evaluation was limited to only three AI models—Claude 3.5 Sonnet, Gemini 1.5 Flash, and ChatGPT 4o. Including additional AI models with varying capabilities could provide a more comprehensive comparison of AI-generated interior designs and reveal performance differences across a wider range of systems.

Additionally, the study focused on a limited set of design criteria within six spatial contexts. Expanding the study to include more design elements, such as ambiance, emotional response, or different functional aspects of the spaces, could provide a more comprehensive understanding of AI performance in interior design.

Another limitation is the static nature of the evaluations. The AI models were assessed based on outputs generated from standardized prompts, without iterative refinement or feedback loops. Future studies could explore how real-time interactions between designers and AI models, or adaptive AI systems that learn from feedback, affect design quality and outcomes.

Finally, the scope of this study was limited to text-to-image AI models. Exploring how other AI modalities, such as generative models for material suggestions, space optimization, or multisensory design, could further enrich the design process is a promising area for future research.

Conflict of Interest

The manuscript titled “How Well Can AI Contribute to Interior Architecture? A Comparative Analysis of Descriptive Accuracy” has not been published elsewhere and has not been submitted simultaneously for publication in any other journal.

Author Contributions

In this study, the contributions of the authors are as follows: The first author contributed to the identification of the main idea of the study, data collection, data analysis and interpretation, manuscript writing, and critical revision. The second author contributed to data collection, data analysis and interpretation, and manuscript writing. These contributions clearly reflect the extent of each author's involvement in the study.

AI Use Disclosure

During specific stages of the manuscript preparation process, AI-assisted tools such as Grammarly and ChatGPT were utilized. These tools supported the organization and summarization of selected literature and datasets, as well as improvements in linguistic accuracy, coherence, formatting, and overall readability. Additionally, AI tools were used to ensure compliance with the journal's structural and formatting requirements. All content generated or suggested with the assistance of AI was carefully reviewed, revised, and validated by the authors. The conceptual design of the study, methodological and analytical decisions, interpretation of the findings, and final conclusions were developed independently by the authors.

References

- Akram, J. A. A. (2013). Toward a psychological design process for interior architecture. *Journal of King Saud University - Architecture & Planning*, 25, 21–38.
- Almaz, A. F., El-Agouz, E. A. E. A., Abdelfatah, M. T., & Mohamed, I. R. (2024). The future role of artificial intelligence (AI) design's integration into

architectural and interior design education is to improve efficiency, sustainability, and creativity. *Sustainability and Creativity*, 3(12), 1749–1772. DOI: 10.13189/cea.2024.120336

- Audry, S. (2021). *Art in the age of machine learning*. Cambridge, MA: The MIT Press.
- Bayrak, E. (2020). *Yapay Zekâ ve Mekân Tasarımı Etkileşiminin Günümüz Tasarım Eğitiminde Değerlendirilmesi* [Master's thesis, Hacettepe Üniversitesi, Güzel Sanatlar Enstitüsü].
- Beltagy, I., Peters, M. E., & Cohan, A. (2020). Longformer: The long-document transformer. arXiv preprint arXiv:2004.05150.
- Betz, G., Richardson, K., & Voigt, C. (2021). Thinking aloud: Dynamic context generation improves zero-shot reasoning performance of GPT-2. arXiv preprint arXiv:2103.13033.
- Bommasani, R., Hudson, D. A., Adeli, E., Altman, R., Arora, S., von Arx, S., Bernstein, M. S., et al. (2021). On the opportunities and risks of foundation models. arXiv:2108.07258.
- Ching, F. D., & Binggeli, C. (2018). *Interior design illustrated*. John Wiley & Sons.
- Chiu, M. L. (1995). Collaborative design in CAAD studios: Shared ideas, resources, and representations. In *Proceedings of the International Conference on CAAD Futures* (Vol. 95, pp. 749–759).
- Dang, H., Mecke, L., Lehmann, F., Goller, S., & Buschek, D. (2022). How to prompt? Opportunities and challenges of zero- and few-shot learning for human-AI interaction in creative applications of generative models. arXiv preprint arXiv:2209.01390.
- Darwiche, A. (2018). Human-level intelligence or animal-like abilities? *Communications of the ACM*, 61(10), 56–67. <https://doi.org/10.1145/3271625>
- Denton, E. L., Chintala, S., Szlam, A., & Fergus, R. (2015). Deep generative image models using a Laplacian pyramid of adversarial networks. In *Advances in Neural Information Processing Systems* (pp. 1486–1494).
- Deveci, M. (2022). Yapay Zekâ Uygulamalarının Sanat ve Tasarım Alanlarına Yansımaları. *Vankulu Sosyal Araştırmalar Dergisi*, 9, 119–140.
- Eckert, C., & Stacey, M. (2000). Sources of inspiration: A language of design. *Design Studies*, 21, 523–538. [https://doi.org/10.1016/s0142-694x\(00\)00022-3](https://doi.org/10.1016/s0142-694x(00)00022-3)
- Goldschmidt, G. (1998). Creative architectural design: Reference versus precedence. *Journal of Architectural and Planning Research*, 15, 258–270.

- Graef, S., & Georgievski, I. (2021). Software architecture for next-generation AI planning systems. arXiv (Cornell University). <https://doi.org/10.48550/arXiv.2102.10985>
- Halpern, O. (2020). Architectural intelligence: How designers and architects created the digital landscape by Molly Wright Steenson. *Technology and Culture*, 61(4), 1265–1267. <https://doi.org/10.1353/tech.2020.0151>
- Fernandez, P. (2022). Technology behind text to image generators. *Library Hi Tech News*, 39(10), 1–4. <https://doi.org/10.1108/lhtn-10-2022-0116>
- Fiebrink, R. (2019). Machine learning education for artists, musicians, and other creative practitioners. *ACM Transactions on Computing Education (TOCE)*, 19(4), 1–32. <https://doi.org/10.1145/3294008>
- Goodfellow, I., Pouget-Abadie, J., Mirza, M., Xu, B., Warde-Farley, D., Ozair, S., Courville, A., & Bengio, Y. (2014). Generative adversarial nets. In *Advances in Neural Information Processing Systems* (pp. 2672–2680).
- Gwern. (2020). GPT-3 creative fiction. Retrieved from <https://www.Gwern.Net/GPT-3>
- He, X., & Deng, L. (2017). Deep learning for image-to-text generation: A technical overview. *IEEE Signal Processing Magazine*, 34(6), 109–116. <https://doi.org/10.1109/MSP.2017.2741510>
- Huynh-The, T., Pham, Q. V., Pham, X. Q., Nguyen, T. T., Han, Z., & Kim, D. S. (2023). Artificial intelligence for the metaverse: A survey. *Engineering Applications of Artificial Intelligence*, 117, 105581. <https://doi.org/10.1016/j.engappai.2022.105581>
- Hhandelwal, U., He, H., Qi, P., & Jurafsky, D. (2018). Sharp nearby, fuzzy far away: How neural language models use context. In *Proceedings of the 56th Annual Meeting of the Association for Computational Linguistics (Vol. 1, Long Papers)*.
- Liu, V., & Chilton, L. B. (2022). Design guidelines for prompt engineering text-to-image generative models. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems (CHI '22)*, New Orleans, LA, USA. Association for Computing Machinery. <https://doi.org/10.1145/3491102.3501825>
- Lu, Y., Bartolo, M., Moore, A., Riedel, S., & Stenetorp, P. (2021). Fantastically ordered prompts and where to find them: Overcoming few-shot prompt order sensitivity. arXiv preprint arXiv:2104.08786.
- Münch, T. (2022). *System architecture design and platform development strategies: An introduction to electronic systems development in the age of AI, agile development, and organizational change*. Springer.

- O'Connor, J., & Andreas, J. (2021). What context features can transformer language models use? arXiv preprint arXiv:2106.08367.
- Oppenlaender, J. (2022). The creativity of text-based generative art. arXiv:2206.02904.
- Pavlichenko, N., & Ustalov, D. (2023, July). Best prompts for text-to-image models and how to find them. In Proceedings of the 46th International ACM SIGIR Conference on Research and Development in Information Retrieval (pp. 2067–2071). <https://doi.org/10.1145/3539618.3592000>
- Radford, A., Metz, L., & Chintala, S. (2015). Unsupervised representation learning with deep convolutional generative adversarial networks. arXiv preprint arXiv:1511.06434.
- Reed, S., Akata, Z., Yan, X., Logeswaran, L., Schiele, B., & Lee, H. (2016). Generative adversarial text to image synthesis. arXiv preprint arXiv:1605.05396. <https://doi.org/10.48550/arXiv.1605.05396>
- Reed, S. E., Akata, Z., Mohan, S., Tenka, S., Schiele, B., & Lee, H. (2016). Learning what and where to draw. In Advances in Neural Information Processing Systems (pp. 217–225).
- Reviriego, P., & Merino-Gómez, E. (2022). Text to image generation: Leaving no language behind. arXiv preprint arXiv:2208.09333.
- Ramesh, A., Dhariwal, P., Nichol, A., Chu, C., & Chen, M. (2022). Hierarchical text-conditional image generation with CLIP latents. arXiv:2204.06125.
- Rombach, R., Blattmann, A., Lorenz, D., Esser, P., & Ommer, B. (2022). High-resolution image synthesis with latent diffusion models. In Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR) (pp. 10684–10695). IEEE. <https://doi.org/10.1109/cvpr52688.2022.01042>
- Sohl-Dickstein, J., Weiss, E., Maheswaranathan, N., & Ganguli, S. (2015). Deep unsupervised learning using nonequilibrium thermodynamics. In Proceedings of the 32nd International Conference on Machine Learning (ICML 2015) (pp. 2256–2265). PMLR.
- Smith, P. D. (2018). Hands-on artificial intelligence for beginners: An introduction to AI concepts, algorithms, and their implementation. Packt Publishing Ltd.
- Smith, B. C. (2019). The promise of artificial intelligence: Reckoning and judgment. The MIT Press.
- Sucu, İ., & Ataman, E. (2020). Dijital evrenin yeni dünyası olarak yapay zeka ve Her Filmi üzerine bir çalışma. Yeni Medya Elektronik Dergisi, 4(1), 40–52.

- Vartiainen, H., & Tedre, M. (2023). Using artificial intelligence in craft education: Crafting with text-to-image generative models. *Digital Creativity*, 34(1), 1–21. <https://doi.org/10.1080/14626268.2023.2174557>
- Vartiainen, H., Liukkonen, P., & Tedre, M. (2025). Emerging human-technology relationships in a co-design process with generative AI. *Thinking Skills and Creativity*, 56, 101742. <https://doi.org/10.1016/j.tsc.2024.101742>
- Xu, T., Zhang, P., Huang, Q., Zhang, H., Gan, Z., Huang, X., & He, X. (2018). AttnGAN: Fine-grained text to image generation with attentional generative adversarial networks. In *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition* (pp. 1316–1324). <https://doi.org/10.1109/cvpr.2018.00143>
- Yıldırım, B., & Emirarslan, S. (2021). İç mimarlıkta yapay zekâ: İnsana öykünen makineler çağında yapay zekânın mesleki paydaşlığı. *Yapay Zekâ ve Dijital Teknoloji*, İksad Publishing House, Ankara, 101.
- Zhang, H., Xu, T., Li, H., Zhang, S., Wang, X., Huang, X., & Metaxas, D. N. (2017). StackGAN: Text to photorealistic image synthesis with stacked generative adversarial networks. In *Proceedings of the IEEE International Conference on Computer Vision* (pp. 59). <https://doi.org/10.1109/iccv.2017.629>

Appendix 1. The reception area designs used in the research, along with their conceptual images and design styles.

Number	Design Styles	Conceptual Image by AI	Interior Design of the Reception Area
1	Gothic & Mackintosh		
	AI Tool: Midjourney	<p>(Phase 1) Blend: Images taken from Dezeen and Behance were blended at Midjourney.</p> <p>(Phase 2) Upscale: Image was upscaled with Midjourney</p> <p>(Phase 3) Blend: Image taken from the Mackintosh design page and Upscaled image were blended at Midjourney.</p>	
2	Art Deco & Op Art		
	AI Tool: Midjourney	<p>(Phase 1) Prompt: art deco interior space, op art interior space, interior architecture, 8k, ultra realistic renderings, realistic office photo.</p> <p>(Phase 2) Prompt: art deco interior architecture, op art interior architecture, interior architecture, 8k, ultra realistic renderings, art deco interior space, op art interior space , realistic office photo, led light, art deco office design, op art office design, Decor elements and accessories for an Art deco interior, Decor elements and accessories for an op art interior.</p> <p>(Phase 3) Blend: Two images generated from prompts were blended.</p>	
3	Baroque & Bauhaus		

	<p>AI Tool: Midjourney</p>	<p>(Phase 1) Prompt: a waiting area with bauhaus furniture positioned in front of a baroque-style background, with column.</p> <p>(Phase 2) Upscale: Image was upscaled with Midjourney.</p> <p>(Phase 3) Prompt: baroque columns and baroque wall reliefs, simple single armchairs with bauhaus metal legs, waiting area.</p> <p>(Phase 4) Upscale: Image was upscaled with Midjourney.</p> <p>(Phase 5) Blend: Two images generated from prompts were blended.</p>	
4	<p>Ancient Greece & Deconstructivism</p>		
	<p>AI Tool: Midjourney</p>	<p>(Phase 1) Prompt: A mixture of ancient greek and deconstructivism architecture clinical waiting area interior design, wide-angle vision, postmodern, modern, sharpness, turmoil, uncertainty, geo-metric imbalance, futuristic, ancient greek, colon, regularity, energetic, mobile, dynamic, deconstruction, non vertical, trapezoid, oblique, folded, balanced and stationary, curved, marble surfaces, bright spaces.</p> <p>(Phase 2) Upscale: Image was upscaled with Midjourney.</p> <p>(Phase 3) Blend: Image taken from Upscaled image, Pinterest, Harpersbazaar, Dezeen and Archdaily were blended at Midjourney.</p> <p>(Phase 4) Upscale: Image was upscaled with Midjourney.</p> <p>(Phase 5) Variation: Image was varied with Midjourney.</p>	
5	<p>Romanesque & Minimalism</p>		

	AI Tool: Midjourney	(Phase 1) Blend: Image taken from Pinterest and Dezeen were blended at Midjourney. (Phase 2) Blend: Image taken from Pinterest, Dezeen and Blended image were blended at Midjourney. (Phase 3) Blend: Blended 2 images were blended again at Midjourney.	
6	Ancient Greece & Pop Art		
	AI Tool: Midjourney	(Phase 1) Prompt: Living room design including ancient greek and pop art design styles, pastel green and yellow details, pastel colours, organic furniture, plant details, ancient greek poster, colourful furniture and ancient greek poster, pastel coloured living room, pop art furniture. (Phase 2) Prompt: colourful living room design interior design, colourful columns, column details, pop art furniture pop art poster in the prayer room, glass coffee table blue, arched walls colourful design. (Phase 3) Blend: Two images generated from prompts were blended.	

Appendix 2. The descriptions for the 1st design

	ChatGPT 4o	Claude 3.5 Sonnet	Gemini 1.5 Flash
Design Style(s)	-The design combines neoclassical elements (evident in the Corinthian-style columns and decorative wall panels) with modern minimalism (clean lines of the furniture and reception desk).	-Minimalist modern -Contemporary luxury -Clinical sophistication	- Modern Minimalist: The overall aesthetic leans towards a modern minimalist style, with clean lines, neutral colours, and a focus on functionality. -Contemporary: The design incorporates contemporary elements like the sleek furniture and the use of natural light.
Colour	-The interior features a monochromatic blue-gray palette, creating a serene and professional atmosphere.	Predominantly neutral with: -Warm white walls -Light grey concrete textures -Light wood tones -Black accents -White marble with gold/beige veining	- Neutral Tones: The primary colours used are neutral tones, such as white, beige, and light brown. This creates a calming and sophisticated atmosphere. -Black Accents: Black accents are used strategically to add contrast and definition, such as the black lines on the wall and the black frames around the mirrors.

Lighting	<ul style="list-style-type: none"> -The space uses recessed lighting embedded into the coffered ceiling, providing uniform illumination. -Hanging linear pendant lights over the reception desk add a modern touch. 	<ul style="list-style-type: none"> -Recessed ceiling lights -Hidden LED strip lighting behind wooden panels creating ambient glow -Modern linear black track lighting visible in background -Well-lit space with even illumination 	<ul style="list-style-type: none"> - Recessed Lighting: Recessed lighting is used to provide general illumination throughout the space, creating a clean and modern look. -Spotlights: Spotlights are used to highlight specific areas, such as the reception desk and the wall with the clinic's name. -Natural Light: The large windows likely allow for ample natural light to enter the space, further enhancing the bright and airy feel.
Furniture	<ul style="list-style-type: none"> -The reception desk is a geometric, minimalist design, blending seamlessly into the monochromatic theme. -Waiting area seating is modern and understated, with metal or upholstered finishes. 	<ul style="list-style-type: none"> -Large reception desk in white marble-look material with veining -Two black chairs/stools against the feature wall -Built-in shelving visible in background 	<ul style="list-style-type: none"> - Reception Desk: The reception desk is a modern and minimalist design, with a white marble-like countertop and a black base. -Chairs: Two black chairs are placed in front of the reception desk, providing a comfortable seating area for visitors. -Shelves: Shelves are visible on the right side of the image, likely used to display products or decorative items.
Products	<ul style="list-style-type: none"> -Branding elements like the "Meta Clinic" signage are integrated into the reception desk, reflecting a sleek corporate identity. 		<ul style="list-style-type: none"> - Aesthetic Products: The shelves likely display products related to the clinic's services, such as skincare products, makeup, or other beauty items.
Interior Materials	<ul style="list-style-type: none"> -Painted paneling on the walls adds texture and elegance. -Plaster or gypsum detailing is present on the ceiling and columns. -Glass elements in the window sections, framed by metal grids, introduce natural light while maintaining privacy. -Green wall features with plants enhance the biophilic quality of the design. 	<ul style="list-style-type: none"> -Concrete-look wall panels -Wood veneer wall cladding -Marble-look surfaces (likely porcelain or engineered stone) -Smooth painted drywall -Black metal accents 	<ul style="list-style-type: none"> - Wood: Wood is used for the wall behind the reception desk, adding warmth and texture to the space. -Marble: The reception desk features a marble-like countertop, creating a luxurious and sophisticated look. -Painted Walls: The walls are likely painted in a neutral colour, such as white or beige.
Architectural Features	<ul style="list-style-type: none"> -Ceiling Height: High ceilings amplify the grandeur and openness of the space. -Size of the Space: The room appears expansive, likely a large clinic reception area. -Windows: Large, rectangular windows with grid patterns allow for natural light while maintaining symmetry. -Doors: Doorways blend with the wall panels and may include arched elements, maintaining the classical aesthetic. 	<ul style="list-style-type: none"> -High ceilings (appears to be approximately 9-10 feet) -Clean-lined geometric ceiling detail in black/grey -No visible windows in reception area -Appears to be a moderately sized reception space (roughly 15-20 feet wide) -Linear wall detailing creating vertical panels -Integrated wall signage reading "Derma Aesthetic" 	<ul style="list-style-type: none"> - Ceiling Height: The ceiling height appears to be relatively high, contributing to the spacious feel of the interior. -Space Size: The space seems to be of moderate size, with a well-defined reception area and additional space to the right. -Windows: Large windows are present, allowing natural light to enter the space and providing views of the exterior. -Doors: The doors appear to be modern and minimalist in design, with clean lines and a neutral colour.

Spatial Layout	<ul style="list-style-type: none"> -The reception desk is centrally positioned as a focal point, framed by evenly spaced columns. -Symmetrically arranged seating areas flank the reception zone, creating balance. -Vertical greenery along the walls adds interest and warmth to the spatial organization. 	<ul style="list-style-type: none"> - Open plan reception area -Linear reception counter as focal point -Symmetrical design with balanced elements -Clear sight lines to back areas -Well-defined circulation space in front of counter -Storage/display areas visible in background 	<ul style="list-style-type: none"> - Reception Area: The reception area is clearly defined and centrally located, welcoming visitors upon entry. -Waiting Area: The chairs in front of the reception desk create a small waiting area for visitors. -Shelves: The shelves on the right side of the image provide additional storage and display space.
-----------------------	---	---	---

Appendix 3. The descriptions for the 2nd design

	ChatGPT 4o	Claude 3.5 Sonnet	Gemini 1.5 Flash
Design Style(s)	<ul style="list-style-type: none"> -The interior embraces an Art Deco design style, characterized by geometric patterns, bold contrasts, and metallic accents. 	<ul style="list-style-type: none"> -Art Deco revival -Modern geometric -Glamorous contemporary 	<ul style="list-style-type: none"> - Art Deco: The overall aesthetic strongly reflects the Art Deco style, characterized by geometric patterns, bold colours, and luxurious materials. -Modern: The design incorporates modern elements like the sleek furniture and the use of digital displays.
Colour	<ul style="list-style-type: none"> -The space features a warm colour palette with shades of beige, peach, black, and gold, adding a luxurious and inviting ambiance 	<ul style="list-style-type: none"> -Black and white as base colours -Peach/salmon pink accents -Gold/brass metallic details -Navy blue accent in the logo backdrop 	<ul style="list-style-type: none"> - Warm Tones: The primary colours used are warm tones, such as beige, peach, and gold. These colours create a welcoming and sophisticated atmosphere. -Black Accents: Black accents are used strategically to add contrast and definition, such as the black stripes on the floor and the black trim around the doors. -White Accents: White accents are used to create a sense of balance and contrast with the warm tones, such as the white walls and the white countertop of the reception desk.
Lighting	<ul style="list-style-type: none"> -Wall-mounted sconce lighting with gold finishes enhances the vertical design elements. -The overall lighting is soft, accentuating the reflective materials and the geometric patterns. 	<ul style="list-style-type: none"> -Modern vertical wall sconces with warm lighting -Appears to have ambient overhead lighting -Strategic lighting highlighting the brand name and logo 	<ul style="list-style-type: none"> - Wall Sconces: Wall sconces with gold accents provide ambient lighting, adding to the luxurious feel of the space. -Recessed Lighting: Recessed lighting is likely used to provide general illumination throughout the space.
Furniture	<ul style="list-style-type: none"> -The reception desk has a rounded and streamlined design, emphasizing symmetry and geometric patterns in gold and black. -Accessories such as metallic planters complement the Art Deco theme. 	<ul style="list-style-type: none"> -Reception desk with curved edges and two-tone striped design -Two Apple computers on stands at the reception Decorative potted plant in a metallic planter -Custom "Onirique" signage with Art Deco- 	<ul style="list-style-type: none"> - Reception Desk: The reception desk is a modern and sleek design, with a white marble-like countertop and a black base. The geometric patterns on the front of the desk are a nod to the Art Deco style. -Chairs: Two black chairs are placed in front of the reception desk, providing a comfortable seating area for visitors. -Coffee Table: A small coffee table with a gold base and a black top is visible in the foreground, adding a touch of luxury.

Products	-Branding, such as the "ONIRIQUE" signage, is integrated elegantly into the wall design, reflecting a sophisticated identity. -Dual computers on the desk highlight the functional purpose of the reception area.	inspired cloud/arch motif	- Digital Displays: Two computer monitors are placed on the reception desk, likely used for customer service or administrative tasks.
Interior Materials	-Gold accents on the wall and furniture emphasize elegance. -High-gloss finishes on the floor and decorative wall panels contribute to a polished, luxurious look. -Glass and metal details add a modern touch to the Art Deco style.	-Mixed panel wall system with geometric patterns -High-gloss or lacquered surfaces -Metallic trim details -Appears to be vinyl or tile flooring	- Marble: The reception desk features a marble-like countertop, creating a luxurious and sophisticated look. -Wood: Wood is likely used for the base of the reception desk and the coffee table, adding warmth and texture to the space. -Painted Walls: The walls are likely painted in a neutral colour, such as white or beige.
Architectural Features	-Ceiling Height: Standard ceiling height with layered detailing and recessed areas. -Size of the Space: Medium-sized area designed for functionality while maintaining style. -Windows and Doors: Doors are seamlessly integrated into the paneling, maintaining a consistent design language.	-Standard height ceiling with crown molding -Air conditioning unit visible -Geometric wall paneling creating visual interest -No visible windows in this view -Bold geometric floor pattern with black and white stripes	- Ceiling Height: The ceiling height appears to be relatively high, contributing to the spacious feel of the interior. -Space Size: The space seems to be of moderate size, with a well-defined reception area and additional space to the right. -Doors: The doors appear to be modern and minimalist in design, with clean lines and a black trim.
Spatial Layout	-The reception desk is centrally placed, serving as the primary focal point. -The geometric flooring pattern directs attention to the reception area and creates a sense of depth. -Surrounding spaces are clean and open, with decorative wall panels reinforcing the cohesive design.	-Symmetrical design centered on reception desk -Balanced wall sconces flanking the logo -Dynamic diagonal floor pattern leading to desk -Wall panels creating rhythm and movement -Well-defined reception area	- Reception Area: The reception area is clearly defined and centrally located, welcoming visitors upon entry. -Waiting Area: The chairs in front of the reception desk create a small waiting area for visitors.

Appendix 4. The descriptions for the 3rd design

	ChatGPT 4o	Claude 3.5 Sonnet	Gemini 1.5 Flash
Design Style(s)	-The interior predominantly reflects neoclassical architecture, evident from the Corinthian-style columns, symmetrical layout, and detailed wall paneling.	-Modern Neoclassical -Contemporary interpretation of Greek Revival -Luxury medical/spa aesthetic	- Neoclassical: The overall aesthetic strongly reflects the Neoclassical style, characterized by symmetry, proportion, and the use of classical motifs like columns and arches. -Modern: The design incorporates modern elements like the sleek furniture and the use of muted colours.

Colour	-The colour scheme is monochromatic blue-gray, creating a cool, calm, and formal ambiance suitable for a clinic.	- Soft powder blue/gray walls -Crisp white trim and columns -Green from vertical plant walls -Monochromatic grey reception desk	- Muted Tones: The primary colours used are muted tones, such as light gray, white, and a hint of green from the vertical garden. This creates a calming and sophisticated atmosphere. -Black Accents: Black accents are used strategically to add contrast and definition, such as the black countertop of the reception desk and the black trim around the windows.
Lighting	-The space is lit by recessed ceiling lights arranged within a coffered ceiling, providing uniform illumination. -Additional hanging linear pendant lights above the reception desk add modern functionality.	- Elaborate coffered ceiling with integrated square lighting panels -Modern linear pendant light over reception -Bright, even illumination throughout -Natural light suggestion from plant wall areas	- Recessed Lighting: Recessed lighting is used to provide general illumination throughout the space. -Pendant Lights: Pendant lights are used to create a focal point over the reception desk. -Natural Light: The large windows likely allow for ample natural light to enter the space, further enhancing the bright and airy feel.
Furniture	-The reception desk is minimalistic with clean lines, blending seamlessly into the overall colour scheme. -Waiting area furniture is understated and consistent with the formal environment, likely made of metal or upholstered materials.	-Modern geometric reception desk in grey -Built-in seating areas visible on sides -Living green walls in arched niches -"YTTA CLINIC" signage on desk	- Reception Desk: The reception desk is a modern and minimalist design, with a black countertop and a white base. -Chairs: Two black chairs are placed in front of the reception desk, providing a comfortable seating area for visitors. -Vertical Garden: A vertical garden is incorporated into the design, adding a touch of greenery and a sense of nature.
Products	-The "META Clinic" signage is integrated into the design of the reception desk, showcasing branding as a part of the decor.		-
Interior Materials	-Plaster or gypsum is used for the decorative wall and ceiling moldings. -Glass panels with a grid-like structure in the windows enhance natural light intake and symmetry. -Living green walls add texture and biophilic design elements to the otherwise formal space.	-Plaster or gypsum decorative elements -Smooth painted walls -What appears to be marble or light stone flooring -Preserved moss/plant wall sections -High-gloss or matte surfaces on desk	- Marble: The floor and columns are likely made of marble or a marble-like material, creating a luxurious and sophisticated look. -Wood: Wood is likely used for the base of the reception desk and the trim around the windows, adding warmth and texture to the space. -Painted Walls: The walls are likely painted in a neutral colour, such as light gray.
Architectural Features	- Ceiling Height: High ceilings enhance the grand, airy feeling of the space. -Size of the Space: The layout suggests a spacious reception or lobby area designed to accommodate multiple visitors. -Windows and Doors: Large grid-framed windows allow	-Classical fluted columns with Corinthian capitals -High coffered ceiling with detailed grid pattern -Decorative wall panels with arched detailing -Symmetrical fan/shell motif on feature wall	-Ceiling Height: The ceiling height appears to be relatively high, contributing to the spacious feel of the interior. -Space Size: The space seems to be of moderate size, with a well-defined reception area and additional space to the right. -Columns: The use of columns creates a sense of grandeur and formality.

	natural light to enter, while arched wall niches align with the neoclassical aesthetic.	-Wainscoting along lower walls -Arched wall niches with vertical gardens -Substantial room height (appears 12-14 feet)	-Windows: Large windows are present, allowing natural light to enter the space and providing views of the exterior. -Arches: Arches are used to frame the windows and create a sense of depth.
Spatial Layout	-The space is designed symmetrically, with the reception desk centrally located as the focal point. -Columns frame the reception area, creating distinct zones while maintaining an open-plan layout. -Vertical greenery and evenly spaced seating areas offer functional and aesthetic balance.	-Grand symmetrical entrance space -Central reception desk as focal point -Colonnade creating defined walkways -Clear sight lines through space -Balanced architectural elements -Spacious open plan design	-Reception Area: The reception area is clearly defined and centrally located, welcoming visitors upon entry. -Waiting Area: The chairs in front of the reception desk create a small waiting area for visitors.

Appendix 5. The descriptions for the 4th design

	ChatGPT 4o	Claude 3.5 Sonnet	Gemini 1.5 Flash
Design Style(s)	-A blend of classical and contemporary styles, with Corinthian columns and a modern angular reception desk emphasizing a juxtaposition of old and new.	- Contemporary Greco-Roman fusion -Geometric modernism -Luxe industrial	-Modern Classic: The overall aesthetic blends modern elements with classic architectural features, creating a contemporary and sophisticated look. -Art Deco: There are some Art Deco influences visible in the geometric shapes and the use of rich colours.
Colour	- The colour palette includes soft greens, muted grays, and warm yellows, creating a fresh yet sophisticated atmosphere. -Subtle pink accents on the walls enhance warmth and visual interest.	- Muted mauve/dusty rose -Warm gold/yellow accents -Sage green ceiling trim -Grey concrete textures -Off-white walls	-Neutral Tones: The primary colours used are neutral tones, such as light gray, beige, and brown. This creates a calming and sophisticated atmosphere. -Bold Accents: Bold accents are used strategically to add contrast and interest, such as the dark green trim on the ceiling and the deep red/purple on the reception desk.
Lighting	-The ceiling features a backlit translucent panel, providing even, diffused lighting. -Additional ambient light comes from modern architectural lighting integrated into the space.	- Large skylight with diffused panels -Integrated screen/digital display -Ambient natural lighting -Architectural lighting highlighting brand signage	-Skylight: A large skylight provides ample natural light, creating a bright and airy feel. -Recessed Lighting: Recessed lighting is used to provide general illumination throughout the space.
Furniture	- The reception desk has a bold, angular design, using wood textures in warm yellow and brown tones, contrasting with the softer colours of the space. -Minimalist seating and decorative elements focus	-Angular geometric reception desk with faceted design -Large digital display/screen embedded in wall	-Reception Desk: The reception desk is a modern and geometric design, with a wooden top and a bold red/purple base. -Columns: The columns add a classic architectural touch, creating a sense of grandeur and formality.

	attention on the reception area.	-"Atlantis Beauty Clinic" signage with classical column motif	
Products	- The Aphrodite Beauty Clinic logo is prominently displayed on the wall, reinforcing the brand identity. -A large, modern art piece on the left wall adds a contemporary touch.	-Geometric, origami-like desk design in contrasting colours	-
Interior Materials	-Stone or concrete finishes dominate the walls, adding texture and durability. -Wood panels on the desk contrast with the classical materials, introducing warmth. -Marble detailing on the ceiling edges and columns enhances the luxurious feel.	-Brushed or textured metal panels on desk -Concrete or concrete-look surfaces -Metallic signage -What appears to be metal or composite panels in mauve and gold -Glass/acrylic skylight panels	-Marble: The floor and walls are likely made of marble or a marble-like material, creating a luxurious and sophisticated look. -Wood: Wood is used for the top of the reception desk, adding warmth and texture to the space. -Painted Walls: The walls are likely painted in a neutral colour, such as light gray.
Architectural Features	-Ceiling Height: Standard height, with attention drawn upward by the decorative and illuminated ceiling panel. -Size of the Space: A moderately sized reception area designed to feel open yet defined. -Windows and Doors: Large glass openings allow natural light to brighten the space and provide views to the outside.	- Classical Ionic columns Sculptural ceiling with angular planes -Skylight with green metal framing -Wall niches/recesses -Textured concrete-look wall surfaces -Modern interpretation of classical moldings -High ceilings with geometric details	-Ceiling Height: The ceiling height appears to be relatively high, contributing to the spacious feel of the interior. -Skylight: The skylight provides natural light and adds a sense of openness to the space. -Columns: The use of columns creates a sense of grandeur and formality. -Arches: Arches are used to frame the windows and create a sense of depth.
Spatial Layout	- The angular reception desk is centrally located, commanding attention and creating a focal point. -Classical columns frame the desk and wall, creating zones that guide the visitor's attention. -Artwork and decorative details are placed asymmetrically, contrasting with the symmetry of the classical features.	- Asymmetrical yet balanced design -Angular forms creating dynamic movement -Open reception area -Clear sight lines to branded elements -Integration of classical and modern elements	-Reception Area: The reception desk is centrally located, welcoming visitors upon entry.

Appendix 6. The descriptions for the 5th design

	ChatGPT 4o	Claude 3.5 Sonnet	Gemini 1.5 Flash
Design Style(s)	-The interior showcases a modern Mediterranean style, emphasizing clean lines, neutral colours, and	- Modern Mediterranean -Contemporary minimalist -Organic modern	-Modern Minimalist: The overall aesthetic leans towards a modern minimalist style, with clean lines, neutral colours, and a focus on functionality.

	an airy ambiance. Classical elements like columns and arches subtly enhance the aesthetic.		-Contemporary: The design incorporates contemporary elements like the sleek furniture and the use of natural light.
Colour	- The colour palette is dominated by white and accented with gold for text and branding. Hints of green are introduced through indoor plants and furniture.	-Crisp white walls and surfaces -Gold lettering accents -Deep burgundy artwork -Forest green upholstery -Light grey office chairs	-Neutral Tones: The primary colours used are neutral tones, such as white, beige, and light brown. This creates a calming and sophisticated atmosphere. -Black Accents: Black accents are used strategically to add contrast and definition, such as the black lines on the wall and the black frames around the mirrors.
Lighting	-Recessed spotlights in the ceiling provide soft, even illumination. -A linear pendant light hangs above the reception desk, adding functional task lighting while maintaining simplicity.	- Recessed square ceiling lights -Hidden cove lighting in arches -Natural-looking ambient light -Clean, bright overall illumination	-Recessed Lighting: Recessed lighting is used to provide general illumination throughout the space, creating a clean and modern look. -Spotlights: Spotlights are used to highlight specific areas, such as the reception desk and the wall with the clinic's name. -Natural Light: The large windows likely allow for ample natural light to enter the space, further enhancing the bright and airy feel.
Furniture	-The curved reception desk has a smooth, minimalist design with gold branding for elegance. -Additional furniture includes minimalist seating in green tones, aligning with the natural elements of the design.	- Curved white reception desk with gold lettering -Grey ergonomic office chairs -Built-in seating area with green upholstery -Large-scale burgundy artwork panel -Indoor plants (appears to be Bird of Paradise or similar)	-Reception Desk: The reception desk is a modern and minimalist design, with a white marble-like countertop and a black base. -Chairs: Two black chairs are placed in front of the reception desk, providing a comfortable seating area for visitors. -Shelves: Shelves are visible on the right side of the image, likely used to display products or decorative items.
Products	-Branding is prominently displayed as gold lettering on the desk and back wall ("EA Clinic"). -A framed modern artwork on the wall behind the desk adds a subtle decorative element.	-Gold "ERA CLINIC" signage	-Aesthetic Products: The shelves likely display products related to the clinic's services, such as skincare products, makeup, or other beauty items.
Interior Materials	-Smooth white plaster covers walls and the ceiling, contributing to a cohesive, clean look. -Gold finishes enhance luxury and contrast the minimalism. -Natural elements such as potted plants and a green wall provide warmth and vibrancy.	- Smooth white painted walls -What appears to be seamless flooring -Metallic gold signage -Textile upholstery -Possible corian or solid surface reception desk	-Wood: Wood is used for the wall behind the reception desk, adding warmth and texture to the space. -Marble: The reception desk features a marble-like countertop, creating a luxurious and sophisticated look. -Painted Walls: The walls are likely painted in a neutral colour, such as white or beige.
Architectural Features	-Ceiling Height: Standard ceiling height with simple detailing. -Arches and Columns: Classical arches and a single column add architectural	- Series of elegant arched walkways/openings -Classical column with decorative capital -Clean-lined ceiling details	-Ceiling Height: The ceiling height appears to be relatively high, contributing to the spacious feel of the interior. -Space Size: The space seems to be of moderate size, with a well-defined reception area and additional space to the right.

	<p>interest and reflect Mediterranean influences.</p> <p>-Size of the Space: The layout appears spacious and well-organized, with wide circulation areas.</p> <p>-Doors and Openings: Arched doorways complement the overall style and create smooth visual transitions.</p>	<p>-High ceilings (appears 9-10 feet)</p> <p>-Minimalist wall treatments</p> <p>-Curved architectural elements</p> <p>-Built-in seating alcove</p>	<p>-Windows: Large windows are present, allowing natural light to enter the space and providing views of the exterior.</p> <p>-Doors: The doors appear to be modern and minimalist in design, with clean lines and a neutral colour.</p>
Spatial Layout	<p>-The reception desk is centrally positioned as the focal point of the space.</p> <p>-A seating area with green accents is placed to the side, creating a comfortable waiting zone.</p> <p>-Decorative plants and architectural details (arches and niches) are strategically placed to balance function and aesthetic.</p>	<p>- Open, flowing floor plan</p> <p>-Clear separation between reception and waiting areas</p> <p>-Curved forms creating organic movement</p> <p>-Symmetrical architectural elements</p> <p>-Well-defined circulation paths</p> <p>-Integration of nature through plants</p> <p>-Alcove seating area for waiting</p>	<p>-Reception Area: The reception area is clearly defined and centrally located, welcoming visitors upon entry.</p> <p>-Waiting Area: The chairs in front of the reception desk create a small waiting area for visitors.</p> <p>-Shelves: The shelves on the right side of the image provide additional storage and display space.</p>

Appendix 7. The descriptions for the 6th design.

	ChatGPT 4o	Claude 3.5 Sonnet	Gemini 1.5 Flash
Design Style(s)	<p>- The interior combines modern contemporary design with neoclassical influences, incorporating sleek, minimalist furniture and decorative columnar elements.</p>	<p>- Modern Greco</p> <p>-Contemporary Art Deco</p> <p>-Luxury minimalist</p>	<p>-Eclectic: The overall aesthetic is eclectic, blending elements of Art Deco, Mid-Century Modern, and contemporary design.</p> <p>-Modern: The design incorporates modern elements like the sleek furniture and the use of bold colours.</p>
Colour	<p>-The palette features soft blue-gray tones for the walls and columns, balanced by black framing and white surfaces.</p> <p>-Gold accents—notably the striking sculptural piece—add warmth and a sense of luxury.</p>	<p>- Dusty blue wall sections</p> <p>-White walls</p> <p>-Soft pink floor accents</p> <p>-Black metal frames</p> <p>-Gold/amber sculpture</p> <p>-Sage green wainscoting</p> <p>-Yellow accent chair</p>	<p>-Bold Colours: The primary colours used are bold and vibrant, such as blue, pink, yellow, and black. This creates a dynamic and energetic atmosphere.</p> <p>-Neutral Tones: Neutral tones like white are used to balance the bold colours and create a sense of calm.</p>
Lighting	<p>-Recessed spotlights in the ceiling provide focused and clean illumination.</p> <p>-The backlit wall panel behind the logo adds depth and emphasis to the branding.</p> <p>-Additional vertical light fixtures contribute a modern ambiance.</p>	<p>-Black track spotlights</p> <p>-Backlit brand signage</p> <p>-Large windows providing natural light</p> <p>-Linear wall sconce</p> <p>-Ambient lighting behind architectural elements</p>	<p>-Recessed Lighting: Recessed lighting is used to provide general illumination throughout the space.</p> <p>-Pendant Lights: Pendant lights are used to create focal points in different areas, such as the reception desk and the seating area.</p> <p>-Natural Light: The large windows likely allow for ample natural light to enter the space, further enhancing the bright and airy feel.</p>

Furniture	<ul style="list-style-type: none"> -The reception desk is understated, allowing attention to focus on the sculptural centerpiece. -Seating, such as the yellow accent chair, introduces bold colour and soft curves for contrast. 	<ul style="list-style-type: none"> -Statement gold organic sculpture in glass case -Modern yellow lounge chair -Black-framed glass display case/vitrine -Decorative arched metal screens -Grecian profile logo in coral/terracotta -Floor-to-ceiling windows 	<ul style="list-style-type: none"> -Reception Desk: The reception desk is a modern and minimalist design, with a glass display case and a black base. -Chairs: A yellow armchair is placed in the seating area, adding a pop of colour and a touch of Mid-Century Modern style. -Art: A large golden sculpture is displayed on the reception desk, adding a unique and artistic touch.
Products	<ul style="list-style-type: none"> - The golden sculptural object in the glass display case serves as an artistic focal point, highlighting the clinic's aesthetic emphasis. -The "Grecian Aesthetic Clinic" branding on the back wall is prominently featured with elegant typography. 		
Interior Materials	<ul style="list-style-type: none"> -Textured fabrics are used for the soft wall panels and curtains. -Glass partitions with black metal framing create defined zones while maintaining openness. -Polished surfaces on the floors reflect light, enhancing the sense of spaciousness. 	<ul style="list-style-type: none"> - Polished white flooring -Pink terrazzo or similar floor insets -Metal framework in black -Glass panels -Painted wall surfaces -Metallic sculptural element -Textile upholstery 	<ul style="list-style-type: none"> -Glass: Glass is used for the display case on the reception desk, creating a sense of transparency and lightness. -Metal: Metal is used for the black frames around the windows and the base of the reception desk, adding a modern and industrial feel. -Painted Walls: The walls are likely painted in bold colours, such as blue and pink.
Architectural Features	<ul style="list-style-type: none"> -Ceiling Height: Medium-high ceilings allow for the large column-like elements to feel proportional. -Windows: Large glass windows bring in natural light and provide a connection to the green outdoor environment. -Columns: Vertical columnar details on either side of the wall enhance the Grecian theme. 	<ul style="list-style-type: none"> -Fluted wall columns in blue -Arched decorative metalwork -Art Deco-inspired geometric patterns -Floor level changes with platform -Large windows with garden views -High ceilings (appears 10-12 feet) -Geometric wall paneling 	<ul style="list-style-type: none"> -Ceiling Height: The ceiling height appears to be relatively high, contributing to the spacious feel of the interior. -Space Size: The space seems to be of moderate size, with a well-defined reception area and a seating area. -Windows: Large windows are present, allowing natural light to enter the space and providing views of the exterior. -Arches: Arches are used to frame the windows and create a sense of depth.
Spatial Layout	<ul style="list-style-type: none"> - The sculptural piece is centrally positioned, framed by the branding wall and serving as the room's primary focal point. -The reception area and seating are separated by glass partitions, balancing openness and privacy. -The design emphasizes symmetry and linearity, with clear pathways and a clean, uncluttered arrangement. 	<ul style="list-style-type: none"> - Gallery-like display area -Defined seating zone -Clear circulation paths -Strong architectural framing -Integration of indoor-outdoor spaces -Symmetrical design elements -Open, flowing space 	<ul style="list-style-type: none"> -Reception Area: The reception desk is centrally located, welcoming visitors upon entry. -Seating Area: The yellow armchair creates a small seating area for visitors.

A Systematic Analysis of Artificial Intelligence Applications in Design Studio Pedagogy

İpek Yıldırım Coruk¹

ORCID NO: 0000-0001-8782-9943¹

¹ Fenerbahçe University, Faculty of Architecture and Design, Interior Architecture and Environmental Design, Istanbul, Türkiye

This study aims to identify the effects of integrating artificial intelligence (AI) into design studio pedagogy by conducting a systematic review of recent research on the subject, with a particular focus on its impact on design processes, learning outcomes, and instructor–student interaction. To ensure a structured and replicable analysis, a systematic review methodology was adopted. Accordingly, the study was designed based on qualitative research methods, and the data were collected through keyword searches in Google Scholar, Scopus, and Web of Science using the following combinations: “artificial intelligence” AND “design studio pedagogy,” “AI in architectural education,” “AI-assisted design education,” “AI AND design education,” “studio-based learning” AND “AI,” “human-AI collaboration” AND “design studio.” After applying the inclusion criteria, 21 articles were selected to form the data set. These studies were categorized along four analytical dimensions: the role AI assumes in the studio, the scope of its influence, the design stage at which it is utilized, and the methodological approach of each study. The findings indicate that AI contributes to design studio environments across three main areas: (1) its role as an idea-generation partner; (2) its influence on learning outcomes and performance indicators, including changes in the design process, enhancement of creativity, and improved conceptualization skills; and (3) its support of the early conceptual stages within the design workflow. However, several studies note that using AI as an idea-generation partner does not always correspond to improved design quality or enhanced creativity. Similarly, while AI tools may accelerate workflow and increase time efficiency, this does not necessarily translate into higher-quality design outputs. In addition to these contributions, some studies highlight disadvantages such as maintaining design logic, integrating AI-generated outputs into coherent and conceptually consistent design ideas, and addressing ethical concerns. Furthermore, the data remain insufficient regarding AI’s role in supporting instructors within studio environments and its potential effects on instructor–student relationships. The results also emphasize that despite the rapid adoption of AI tools, current research largely consists of small-scale case studies or experimental workshop implementations, leading to fragmented and limited collective pedagogical insights. Therefore, more systematic and comprehensive evaluations are needed to better understand how AI influences design workflows, cognitive processes, student performance, and instructor–student dynamics. It is additionally necessary to investigate the long-term integration of AI across all stages of the design process rather than focusing solely on specific phases. The study is significant in that it identifies the current state, potentials, and areas requiring further development regarding the research topic, and provides a reference framework for the structuring and evaluation of AI-supported design studios.

Keywords: Artificial intelligence, Generative AI in design, Design studio, Studio pedagogy, Learning performance.

Received: 06.12.2025

Accepted: 23.03.2026

Corresponding Author:

ipek.coruk@fbu.edu.tr

Yıldırım Coruk, İ. (2026). A systematic analysis of artificial intelligence applications in design studio pedagogy. *JCoDe: Journal of Computational Design*, 7(1), 133-152. <https://doi.org/10.53710/jcode.1837071>

ROR ID: 059636586



Tasarım Stüdyosu Pedagojisinde Yapay Zeka Uygulamalarının Sistemik Analizi

İpek Yıldırım Coruk¹

ORCID NO: 0000-0001-8782-9943¹

¹ Fenerbahçe Üniversitesi, Mimarlık ve Tasarım Fakültesi, İç Mimarlık ve Çevre Tasarımı Bölümü, İstanbul, Türkiye

Bu çalışma, yapay zekanın (YZ) tasarım stüdyo pedagojisine entegrasyonu üzerine yapılan araştırmaların sistemik bir incelemesini yürüterek tasarım süreçleri, öğrenme sonuçları ve eğitmen-öğrenci etkileşimi üzerindeki etkilerini belirlemeyi amaçlamaktadır. Nitel araştırma metoduna dayanan çalışmanın verileri, belirlenen anahtar kelimelerin Google Scholar, Scopus ve Web of Science (WOS) veri tabanlarında aranması ile elde edilmiştir. Ulaşılan çalışmalar, dahil etme kriterlerine göre elenerek çalışmanın veri setini oluşturan 21 makale üzerinden araştırma şekillenmiştir. Bulgular, yapay zekanın stüdyo ortamında fikir üretme partneri olarak rolü, öğrenme çıktıları ve performans göstergelerine etkileri ve erken kavramsal tasarım aşamasının desteklenmesi yönüyle üç temel alan üzerinde katkıda bulunduğunu göstermektedir. Bu etkilerin yanı sıra, yapay zekanın stüdyo ortamlarında eğitmenleri desteklemedeki rolü ve eğitmen-öğrenci ilişkisini ne şekilde etkileyebileceğine yönelik veriler yeterince tartışılmamıştır. Ancak, yapay zekanın stüdyoda üstlendiği roller nedeniyle, bu dinamik ilişkinin eğitmen-öğrenci etkileşim kalıplarını yeniden yapılandırma potansiyeline sahip olduğu düşünülmektedir. Sonuçlar ayrıca, yapay zeka araçlarının hızlı benimsenmesine rağmen, mevcut araştırmaların genel olarak küçük ölçekli vaka çalışması ya da deneysel atölye uygulamalarından oluşması sebebiyle kolektif pedagojik sonuçların parçalı ya da yetersiz kaldığını vurgulamaktadır. Bu nedenle, yapay zekanın tasarım iş akışlarını, bilişsel süreçleri, öğrenci performansını, eğitmen-öğrenci ilişkisini nasıl etkilediğine dair daha sistemik ve kapsamlı değerlendirmelere ihtiyaç vardır. Aynı zamanda, belirli tasarım aşamalarından ziyade uzun vadeli dahil etme ile tüm süreç aşamalarına olası katkılarının ve entegrasyonunun da sorgulanması gerekmektedir. Çalışma, araştırma konusuna yönelik mevcut durumu, potansiyelleri ve geliştirilmesi gereken yönleri ortaya koyarak YZ destekli tasarım stüdyolarının yapılandırılmasına ve değerlendirilmesine yönelik referans sunması yönüyle önem taşımaktadır.

Teslim Tarihi: 06.12.2025

Kabul Tarihi: 23.03.2026

Sorumlu Yazar:

ipek.coruk@fbu.edu.tr

Yıldırım Coruk, İ. (2026). Tasarım stüdyosu pedagojisinde yapay zeka uygulamalarının sistemik analizi. JCoDe: Journal of Computational Design, 7(1), 133-152. <https://doi.org/10.53710/jcode.1837071>

ROR ID: 059636586

Anahtar Kelimeler: Yapay zeka, Tasarımda üretken yapay zeka, Tasarım stüdyosu, Stüdyo pedagojisi, Öğrenme performansı.



1. GİRİŞ (INTRODUCTION)

Tasarım stüdyosu, açık uçlu problem çözme, deneme-yanılma yoluyla yinelemeli geliştirme ve sürekli geri bildirimle karakterize edilen yapıyla mimarlık ve tasarım eğitiminde merkezi bir pedagojik modeldir. YZ teknolojilerindeki son gelişmeler, bu merkezi ortamlar için yeni fırsatlar oluşturmaktadır. Söz konusu fırsatlara paralel olarak, YZ araçlarının tasarım eğitimi ortamlarına entegrasyonu yine bu stüdyolar üzerinden sorgulanmaktadır.

Literatürde, YZ araçlarının tasarım sürecinde çeşitli potansiyel kullanımlar sunduğu ortaya konulsa da bu araçların mimari tasarım eğitimi ve özellikle stüdyo ortamına nasıl entegre edileceği sorusu henüz netlik kazanmamıştır. Bu belirsizlik, yenilikçi tasarım araçlarının eğitimdeki rolünü tartışan güncel çalışmalarla da desteklenmiştir. Nitekim alan yazında, yapay zekâ destekli araçların stüdyo eğitimine entegrasyonuna yönelik araştırmaların artırılması gerektiği vurgulanarak, bu sürecin pedagojik boyutlarının daha kapsamlı biçimde ele alınmasının önemi dile getirilmektedir (Lekesiz ve Müezzinoğlu, 2025; Özorhon vd., 2025).

Bununla birlikte literatürde, yapay zekânın tasarım eğitime dâhil edilmeye başlanmasına rağmen stüdyo tabanlı pedagojideki uygulamalarının henüz erken aşamalarda olduğu; bu teknolojilerin stüdyo pedagojisindeki rolü ve etkilerinin yeterince sorgulanmadığı belirtilmektedir. Bu durum, yapay zekânın hem tasarım üretim sürecini hem de tasarımcıların yaratıcı ve bilişsel gelişimini destekleyecek biçimde stüdyo ortamlarında nasıl konumlandırılabilceği sorusunu gündeme getirmektedir (Salazar Rodriguez vd., 2025).

Bu tartışmalarla uyumlu olarak, YZ'nin mimari tasarım eğitimini nasıl dönüştürebileceği, yaratıcılık, sürdürülebilirlik ve uyum gibi kavramları nasıl teşvik edebileceğini sorgulayan yaklaşımlar (Agarwal, 2024) araştırmanın kritik önemini vurgulamakta ve bu çalışmanın kuramsal zeminini oluşturmaktadır.

Farklı araştırmacılar tarafından literatürde belirtildiği üzere, YZ'nin mimari tasarım stüdyosu ortamlarına nasıl dahil edilebileceği ve stüdyo pedagojisindeki etkilerine yönelik mevcut sorgulamalar yeterli değildir. Bu nedenle çalışma, YZ destekli tasarım stüdyosu araştırmalarının

yapılandırılmış bir incelemesi aracılığıyla ortak etkileri, sınırlamaları ve gelecekteki gelişim fırsatlarını belirleyerek bu boşluğu doldurmayı amaçlamaktadır.

Bu bağlamda araştırma soruları:

1.YZ araçları, tasarım stüdyosu süreçlerinin yapısını ve dinamiklerini nasıl etkiler?

2.YZ müdahalelerinin öğrenci performansı ve öğrenme sonuçları üzerinde ölçülebilir etkileri nelerdir?

3.YZ, stüdyo ortamlarında eğitmen-öğrenci etkileşim kalıplarını nasıl şekillendiriyor? Şeklinde belirlenmiştir.

Bu doğrultuda çalışmada, tasarım stüdyosuna yapay zekâ araçlarının entegrasyonunu bütüncül bir bakış açısıyla değerlendirebilmek amacıyla sistematik literatür incelemesi yöntemi benimsenmiştir. Sistematik yaklaşım, belirli ölçütler doğrultusunda ilgili çalışmaların kapsamlı, şeffaf ve tekrarlanabilir biçimde taranmasına olanak tanıyarak alandaki bilgi birikiminin tutarlı bir çerçevede sınıflandırılmasını ve karşılaştırmalı olarak analiz edilmesini mümkün kılmaktadır. Bu yönüyle kullanılan yöntem, parçalı bulguların bütünleştirilmesiyle araştırma sorularının yanıtlanması açısından tercih edilmiştir.

Araştırma bulguları doğrultusunda verilen yanıtlarla çalışma; mimari tasarım stüdyosu ortamlarında YZ'nin rolü, öğrenme üzerindeki etkileri ve yaygın olarak yer verildiği tasarım aşamaları gibi genel eğilimleri, verileri ve eksiklikleri ortaya koymaktadır. Bu doğrultuda elde edilen bulguların, yapay zekâ araçlarının tasarım stüdyosu pedagojisine entegrasyonuna ilişkin bir çerçeve oluşturması yönüyle alana katkı sağlaması öngörülmektedir.

2. YAPAY ZEKA VE TASARIM STÜDYOSU (ARTIFICIAL INTELLIGENCE AND DESIGN STUDIO)

YZ teknolojilerinin hızlı gelişimi, tasarım stüdyosunun işleyişini çok boyutlu biçimde dönüştürmektedir. Bir dizi eğitim örneğini inceleyip bunları oluşturan olasılık dağılımını öğrenerek tahmini olasılık dağılımından daha fazla örnek üretebilen üretken modeller (Goodfellow vd., 2020), dil modelleri ve YZ sistemlerinin iç yapıları ve davranışlarına odaklanarak karar alma süreçlerini görünür, yorumlanabilir ve açıklanabilir kılan açıklanabilir yapay zekâ yaklaşımları

(Lam, 2022), tasarım sürecine hem yaratıcı hem de analitik katkılar sağlamaktadır. Bu katkılarla birlikte, halen yeni ve gelişmeye devam eden bir alan olması nedeniyle YZ'nin potansiyel dezavantajları da tartışılmaktadır.

Literatür, YZ'nin mimari tasarım eğitimindeki konumunun spekülâtif bir tartışma alanından çıkarak stüdyo pratiğine taşındığını ifade etmektedir. YZ araçlarının farklı kurumsal yapılarda stüdyo ortamlarına dahil edilmesi, tasarım üretim süreçleri yanı sıra tasarımın öğretilme, öğrenilme ve eleştirilme biçimini yeniden şekillendirmeye başlamıştır. Bu değişimler, YZ'nin tasarımda fikir geliştirme ve kavramsal keşfin genişletilmesinde üretken bir partner olma potansiyelini ortaya koymaktadır. Buna karşın, eleştiri kültürü, hızlı okuryazarlık ve etik konular başlıklarıyla ortaya çıkan ikincil temalar, YZ'nin stüdyo pedagojisindeki rolüne yönelik yaklaşımların çeşitlenmesine ve farklılaşmasına neden olmaktadır (Karadağ, 2025).

Farklı seviyelerde tasarım stüdyosu ortamlarında YZ araçlarının denenmesine yönelik çalışmalar, bu araçların stüdyo pedagojisinde meydana getirdiği dönüşümler ve barındırdığı potansiyellerine yönelik önemli veriler sağlanmaktadır. Literatürün karşılaştırmalı okuması, YZ'nin stüdyo bağlamında öncelikle hız ve zaman kullanımı yönüyle süreç verimliliğini artıran ve erken tasarım aşamasında fikir geliştirmeyi hızlandıran üretken bir ortak olarak konumlandığını ortaya koymaktadır. Bununla birlikte, YZ sistemlerinin girdileri algılama potansiyelinin kısıtlı olması ve üyelik/erişim limitleri gibi kısıtlar stüdyo ortamlarında faydalanma yönünden temel sorun alanları olarak ortaya çıkmaktadır (Buldaç, 2024). Başka bir yönden, tasarım stüdyoları genelinde YZ'nin görsel üretiminin destekleyen bir araç olmanın yanı sıra, erken aşama fikir geliştirmede üretken ve eleştirel bir ortak olarak konumlandığı görülmektedir. Bu durum, yapay zekânın erken tasarım aşamalarında kavramsal düşünmeyi destekleyen, eleştiri ve yeniden yorumlama süreçlerine dâhil olan bir pedagojik aktör hâline gelmeye başladığını göstermektedir (Karadağ, 2025).

Söz konusu katkılara rağmen, tasarım stüdyosu ortamlarına YZ'nin dahil edilmesinde etik, akıl yürütme ve yazarlık farkındalığı konusunun ikinci planda kaldığı; bunun da öğrencilerin eleştirel yönlendirme olmaksızın üretken araçlarla yüzeysel etkileşimler kurmasına yol açabileceği yönünde tartışmalar bulunmaktadır (Karadağ, 2025). Bu eleştirilerle

paralel olarak, yapay zekânın yaratıcılık ve verimlilik açısından kayda değer kazanımlar sunduğu kabul edilmekle birlikte, tasarım sürecinin tüm iş akışını üstlenememesi nedeniyle parçalanmış süreçler ve üretilen çıktılar üzerindeki sınırlı denetim olasılığı da önemli bir endişe alanı olarak öne çıkmaktadır (Wang vd., 2025).

Öte yandan çalışmalar, yapay zekânın mimarlık eğitimindeki etkisinin, tasarım uygulamalarına ve öğrenci öğrenme ortamlarına bütünleşme düzeyiyle doğrudan ilişkili olduğunu ortaya koymaktadır. Yapay zekâ destekli sistemler, erken tasarım aşamalarında bireysel geri bildirim sunarak öğrencilerin yaratıcı potansiyellerini keşfetmelerine, öğrenme zayıflıklarını fark etmelerine ve tasarım kararlarında daha bilinçli ve özgüvenli olmalarına katkı sağlamaktadır (Elrefaie, 2025). Ancak bu potansiyelin sürdürülebilir hâle gelebilmesi için, mimari tasarım müfredatlarının yeniden yapılandırılması, stüdyo derslerinin yapay zekâ destekli öğrenme senaryolarına uygun biçimde kurgulanması ve öğrencilerin farklı yapay zekâ araçlarına yönelik eleştirel bir okuryazarlık kazanması gerektiği vurgulanmaktadır (İsmail Mahmoud vd., 2025).

Bu çerçevede literatür, YZ destekli tasarım stüdyosu eğitiminin yapılandırılmasının; müfredat geliştirme süreçlerine, öğretim üyelerinin YZ ile etkileşimdeki rolüne, etik sorumluluklara ve YZ'nin yaratıcılık ile öğrenme süreçleri üzerindeki gelişen etkilerinin değerlendirilmesine bağlı olduğunu ortaya koymaktadır (Karadağ, 2025).

Bu bağlamda literatür analizi, yapay zekânın tasarım stüdyosunda üstlendiği rollerin belirli yaklaşımlar etrafında şekillendiğini göstermektedir. İncelenen çalışmalarda yapay zekâ; erken tasarım aşamalarında fikir geliştirmeyi hızlandıran, kavramsal keşfi besleyen ve genişleten üretken bir tasarım partneri olarak konumlandırılmaktadır. Bunun yanı sıra, eleştiri ve yeniden yorumlama süreçlerine dâhil olan bir eleştirel aktör ve stüdyo pedagojisinde geri bildirim süreçlerini destekleyen bir asistan rolü de öne çıkmaktadır.

Öte yandan literatürde tanımlanan bu rollerin, yapay zekânın stüdyo ortamında meydana getirdiği etkileriyle birlikte ele alındığı görülmektedir. Bu etkiler ağırlıklı olarak; zaman verimliliği, bireysel geri bildirim yoluyla öğrencilerin yaratıcı potansiyellerini keşfetmeleri, öğrenme zayıflıklarını fark etmeleri ve tasarım kararlarında daha bilinçli ve özgüvenli olmaları gibi çıktılar üzerinden tartışılmaktadır. Buna

karşılık, etik sorumluluklar, akıl yürütme süreçleri ve yazarlık farkındalığı, yapay zekânın stüdyo pedagojisindeki kullanımına eşlik eden eleştirel tartışma alanları olarak ortaya çıkmaktadır.

Bu başlıkların yanı sıra yapay zekâ, öğrenme süreçleri ve müfredat geliştirme ile ilişkili çok katmanlı bir pedagojik aktör olarak tanımlanmaktadır. Bu yaklaşım, öğretim üyelerinin yapay zekâ ile etkileşimdeki rolünü ve stüdyo pedagojisinin yeniden yapılandırılmasına yönelik gereklilikleri de gündeme getirmektedir.

Özetle çalışma, mevcut tartışmalar üzerinden ilgili araçların tasarım stüdyosunda meydana getirdiği etkileri sorgulayarak, YZ'nin tasarım stüdyolarındaki rolü, öğrenme süreçlerindeki etkisi ve tasarım süreç aşamalarına dahil olma biçimleri yönüyle kapsamlı ve sistematik bir analiz sunmayı amaçlamaktadır.

3. YÖNTEM (METHOD)

Çalışmada, yapılandırılmış ve tekrarlanabilir bir analiz sağlamak için sistematik bir inceleme metodolojisi benimsenmiştir. Bu doğrultuda, nitel araştırma yöntemlerine dayalı olarak tasarlanan çalışmanın verileri, literatür araştırması ve doküman analizi yoluyla elde edilmiştir (Yıldırım & Şimşek, 2021).

3.1. Tarama ve Seçim kriterleri (Screening and Selection Criteria)

Veriler Google Scholar, Scopus ve Web of Science (WOS) veri tabanlarında **Tablo 1**'de yer verilen anahtar kelimelerin aranması ile elde edilmiştir. Veri tabanlarında aramalar gerçekleştirilirken konuyla doğrudan ilgili kaynaklara ulaşabilmek ve veri alanı daraltmak amacıyla Scopus'ta gelişmiş arama seçeneğiyle, arama alanı "article title-abstract-keywords" olarak sınırlandırılmıştır. WOS'ta da benzer şekilde title ve abstract sınırlandırması ile aramalar gerçekleştirilmiştir.

Literatür taramasında anahtar kelimeler başlangıç noktası olarak kullanılmış; tarama süreci, alanı temsil eden temel kavramların farklı kombinasyonlarıyla gerçekleştirilmiştir. Elde edilen kayıtlar, başlık, özet ve tam metin incelemesi aşamalarında, çalışmanın mimari tasarım eğitimi ve stüdyo pedagojisi bağlamıyla doğrudan ilişkisi olup olmama durumuna göre değerlendirilmiştir. Bu aşamalarda elemeler, önceden belirlenmiş dâhil etme ve dışlama ölçütleri doğrultusunda

sınırlandırılmış; yapay zekânın tasarım sürecindeki rolünü, pedagojik etkilerini veya tasarım aşamalarındaki kullanımını açık biçimde ele almayan çalışmalar kapsam dışı bırakılmıştır.

	Google Scholar	Scopus	WOS
"artificial intelligence" AND "design studio pedagogy"	288	2	1
"AI in architectural education"	209	7	4
"AI-assisted design education"	7	3	1
"AI" AND "design education"	37.500	1	1
"studio-based learning" AND "AI"	579	1	41
"human-AI collaboration" AND "design studio"	161	1	4

Anahtar kelime taraması sonucunda Google Scholar ile Scopus-WOS veri tabanları arasında nicel farklılıklar tespit edilmiştir. Scopus ve WOS'ta gelişmiş filtreleme ve sınırlandırma seçenekleri nedeniyle ulaşılan yayın sayısı görece sınırlı kalırken, Google Scholar'ın tez, kitap bölümü ve farklı belge türlerini de kapsamı ve ayrıntılı filtreleme imkânının kısıtlı olması nedeniyle sonuç sayısı oldukça yüksek çıkmıştır. Bu nedenle, Google Scholar'da "AI" AND "design education" anahtar kelimeleriyle yapılan tarama, analiz edilemeyecek ölçüde geniş bir sonuç üretmesi sebebiyle inceleme kapsamı dışında bırakılmıştır. Bununla birlikte, olası çalışmaların gözden kaçmaması için **Tablo 1**'de yer alan farklı anahtar kelime varyasyonlarıyla taramalar gerçekleştirilmiştir. Bu durum araştırmanın metodolojik sınırlılıklarından biri olarak değerlendirilmektedir.

Tablo 1: Literatür taraması sonucu ulaşılan kaynakların nicel olarak dağılımı (Quantitative distribution of the sources obtained through the literature review).

	Google Scholar	Scopus	WOS
"artificial intelligence"AND"design studio pedagogy"	47	4	1
"AI in architectural education"	66	3	2
"AI-assisted design education"	2	0	1
"AI"AND"design education"	İncelenmedi	1	1
"studio-based learning"AND"AI"	46	0	4
"human-AI collaboration"AND"design studio"	34	1	1

Literatür taraması sonucu ulaşılan ve **Tablo 1**'de dağılımlarına yer verilen çalışmalar, başlık ve özet düzeyinde incelenmiş, mimari tasarım eğitimi ve stüdyo pedagojisi ile doğrudan ilişkili olmayan yayınlar kapsam dışı bırakılmıştır. Bu bağlamda, **Tablo 2**'de yer verilen sayıda çalışmaya ulaşılmıştır.

Tablo 2: Başlık ve özet düzeyinde eleme sonucu ulaşılan çalışmaların nicel olarak dağılımı (The quantitative distribution of the studies identified after the title and abstract screening stage).

Bir sonraki aşamada tam metin incelemesi gerçekleştirilmiş; yapay zekânın tasarım stüdyosundaki rolünü iç mimarlık ve mimarlık disiplinleri kapsamında ele almayan, konuyu lisans eğitimi seviyesinde

tartışmayan ve YZ'nin pedagojik etkilerini veya tasarım sürecindeki konumlanışını doğrudan ele almayan, makale türünde olmayan çalışmalar elenmiş ve **Tablo 3**'te yer alan sayıda çalışmaya ulaşılmıştır. Tekrar eden çalışmalar ilk aşamada elenmemiş, tam metin aşamasında söz konusu eleme gerçekleştirilmiştir. Bu bağlamda 15 adet tekrar eden çalışma, araştırma dışında bırakılmıştır. Bu çok aşamalı eleme süreci sonucunda, çalışma kapsamında ayrıntılı olarak incelenen 21 çalışma nihai veri setini oluşturmuştur.

	Google Scholar	Scopus	WOS
"artificial intelligence"AND"design studio pedagogy"	5	1	1
"AI in architectural education"	14	0	0
"AI-assisted design education"	0	0	0
"AI"AND"design education"	İncelenmedi	0	0
"studio-based learning"AND"AI"	6	0	0
"human-AI collaboration"AND"design studio"	7	1	1

Tablo 3: Tam metin düzeyinde inceleme ve eleme sonucu ulaşılanlar çalışmaların niceliksel dağılımı (The quantitative distribution of the studies included after full-text review and eligibility assessment).

3.2. Kodlama Prosedürü ve Verilerin Analizi (Coding Procedure and Data Analysis)

Bu çalışmada kullanılan analiz parametreleri, literatürün karşılaştırmalı analizi sonucunda türetilmiştir. İncelenen çalışmalarda ele alınan kavramsal odaklarda, YZ'nin tasarım eğitiminde nasıl konumlandırıldığı, hangi boyutlarda etki yarattığı yönleriyle ve tasarım sürecinin hangi aşamalarında devreye girdiği sorularının öne çıktığı görülmüştür. Bu yaklaşımlar doğrultusunda analiz, yapay zekânın rolü, etki boyutu ve dahil edildiği tasarım aşaması başlıklarıyla ele alınmış, bu başlıkların yanı sıra, yaygın olarak tercih edilen araçlar ve araştırma yöntemlerine de yer verilmiştir. Bununla birlikte, analiz verilerinin ve bulguların sistematik bir biçimde ortaya konulabilmesi amacıyla, belirlenen her bir parametreye atanan kodlamalar üzerinden veriler çözümlenmiş ve yapılandırılmış biçimde sunulmuştur.

Çalışmada veri setini oluşturan araştırmalar dört analitik boyut çerçevesinde kategorize edilmiştir. Bu boyutlardan ilki, yapay zekânın tasarım stüdyosunda üstlendiği roller ve görevler temelinde yapılandırılmıştır. Bu kapsamda; Y1-Fikir üretme partneri, YZ'nin stüdyo ortamında alternatif geliştirme ve kavramsal keşfi destekleyen üretken bir ortak olarak konumlanmasını; Y2-Görselleştirme aracı, öğrencinin düşüncelerini dışsallaştırmasına ve kavramsal içeriği görsel temsile dönüştürmesine aracılık eden işlevini; Y3-Değerlendirme/geri bildirim aracı, tasarım kararlarına yönelik yönlendirici ya da analitik geri bildirim üretme kapasitesini; Y4-Süreci izleyen analitik araç, öğrencinin tasarım

sürecini veri temelli olarak takip eden ve analiz eden rolünü; Y5-Öğretim üyesi destek sistemi, eğitmenin stüdyo yönetimi ve değerlendirme süreçlerine katkı sunan işlevini; Y6-Eleştirel düşünmeyi tetikleyen araç, öğrencinin öz değerlendirme ve yeniden düşünme süreçlerini harekete geçiren yönünü; ve Y7-Süreç otomasyonu/ hızlandırma, belirli aşamaları otomatikleştirerek zaman ve üretkenlik avantajı sağlamasını ifade etmektedir.

Bir diğer analitik parametre olan etki boyutu, YZ araçlarının stüdyo ortamlarına dâhil edilmesiyle öğrencilerin öğrenme süreçleri ve stüdyo dinamiklerinde meydana gelen değişimleri incelemektedir. Bu kapsamda etki boyutu aşağıdaki alt kategoriler üzerinden yapılandırılmıştır: E1-Tasarım süreci değişiklikleri: Arama alanının genişlemesi, varyasyon üretimi ve yineleme döngülerinin artışı. E2-Tasarım problemini anlama: Öğrencinin verilen tasarım konusunu bağlam, kullanıcı ihtiyaçları, işlevsel gereklilikler, kısıtlar ve potansiyeller üzerinden analiz ederek anlamlandırma sürecinde yapay zekâdan yararlanması. E3-Zaman verimliliği: Sürecin hızlanması ve üretim kapasitesinin artması. E4-Eğitmen-öğrenci etkileşimi: Geri bildirim yapısındaki değişimler. E5-Yaratıcılık artışı: Alternatif çeşitliliği ve özgün fikir üretimindeki değişim. E6-Süreç farkındalığı: Öğrencinin tasarım adımlarını izleme, gerekçeleştirme ve değerlendirme kapasitesindeki gelişim. E7-Kavramsallaştırma becerisinde iyileşme: Soyut düşünme ve kavramsal çerçeve oluşturma yetisindeki dönüşüm. E8-Teknik üretim kapasitesinde artış: Çizim, modelleme ve performans temelli çıktılarda teknik yeterlilik artışı. E9-Öğrenci bağımlılığı/otonomi kaybı: Öğrencinin süreci büyük ölçüde yapay zekâ üzerinden yürütmesi sonucu özdenetim ve muhakeme becerilerinin zayıflama riski. E10-Etik kaygılar/doğruluk sorunları: Yazarlık, veri güvenilirliği ve akademik dürüstlükle ilgili tartışmalar. E11-Stüdyo kültüründe dönüşüm: Akran öğrenmesi, tartışma biçimleri ve kolektif üretim dinamiklerindeki değişimler.

Araştırma Metodolojisi parametresi, veri setini oluşturan çalışmaların benimsedikleri araştırma yaklaşımlarına göre sınıflandırılmasını amaçlamaktadır. Bu doğrultuda çalışmalar; M1-Deneysel karşılaştırma, M2-Vaka çalışması, M3-Ankete dayalı değerlendirme, M4-Nitel gözlem ve M5-Karma yöntemler olmak üzere beş alt başlık altında kategorize edilmiştir. Bu sınıflandırma, YZ müdahalelerinin hangi araştırma tasarımları aracılığıyla incelendiğini görünür kılmayı hedeflemektedir.

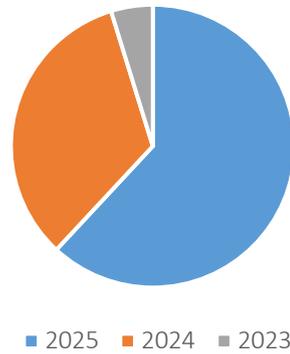
Tasarım Aşaması parametresi ise YZ araçlarının tasarım sürecinin hangi evrelerinde konumlandığını belirlemek amacıyla oluşturulmuştur. Bu kapsamda; T1-Erken kavramsal aşama, T2-Biçim arayışı, T3-Teknik geliştirme (yapay zekânın tasarımın teknik, analitik ve performans dayalı bileşenlerini geliştirmeye yönelik kullanımı), T4-Sunum / temsil ve T5-Tüm süreç (tasarım sürecinin tüm aşamalarında kullanımı) olmak üzere beş alt kategori tanımlanmıştır. Bu ayırım, yapay zekânın tasarım sürecindeki müdahale noktalarını sistematik biçimde karşılaştırmaya olanak sağlamaktadır.

Ek olarak, YZ araçlarının yaygın kullanım eğilimlerini belirlemek adına tercih edilen YZ araçları ve bu araçların stüdyoda kullanılma sürelerine de değinilmiştir. Bulgular, kodlamalar yoluyla değerlendirilmiş ve ardından genel eğilimler, tutarsızlıklar ve boşluklar tespit edilmiştir.

4. BULGULAR (RESULTS)

Bu araştırmada, çalışmaya dahil edilen örnekler üzerinden, YZ'nin tasarım stüdyo pedagojisine entegrasyonu üzerine sistematik bir inceleme gerçekleştirilmiş ve açıklamalı olarak sunulan bulgular arasından YZ'nin tasarım stüdyosundaki rolü ve etki boyutu özeti **Tablo 4**, diğer bulgular ise şekiller aracılığıyla ifade edilmiştir.

İncelemeler sonucu elde edilen verilere göre, çalışmaya dahil edilen örneklerden 13'ü 2025 yılına, 7'si 2024 yılına, 1'i ise 2023 yılına tarihlenmektedir (**Şekil 1**).



Şekil 1: Veri setini oluşturan çalışmaların yıl bazında dağılımı (Year-based distribution of the studies comprising the dataset).

	YZ Rolü							Etki Boyutu										
	Y1	Y2	Y3	Y4	Y5	Y6	Y7	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11
A.1.Çiçek&Özkar, 2025																		
A.2.Lee&Kang, 2025																		
A.3.Kee vd., 2024																		
A.4.Seyman Güray&Uyan, 2025																		
A.5.Salazar Rodriguez vd.,2025																		
A.6.Wang vd., 2025																		
A.7.Özorhon, vd., 2025																		
A.8.Elrefaie, 2025																		
A.9.Sadek&Abdel Gelil Mohamed, 2023																		
A.10.Montenegro, 2024																		
A.11.İşbilir&Bölükbaşı, 2025																		
A.12.İsmail mahmoud, vd., 2025																		
A.13.Wirawan Dharmatanna& Shanggrama Wijaya, 2025																		
A.14.Zeytin vd., 2024																		
A.15.Jin vd., 2024																		
A.16.Zahra vd., 2025																		
A.17.Fawzy Almaz&El-Azim El Agouz, 2024																		
A.18.Fawzy Aly Anber, 2025																		
A.19.Iranmanesh&Lotfabadi, 2024																		
A.20.Cao vd., 2024																		
A.21. Karadağ&Ozar, 2025																		

Çalışmalar incelendiğinde, YZ'nin fikir üretme partneri (makale 1,3,4,5,6,7,8,14,15,17,18,19,20,21), görselleştirme aracı (makale 2,4,9,10,12,19,20,21), değerlendirme-geri bildirim aracı (örnek 5,13,17), eleştirel düşünmeyi tetikleyici araç (makale 1,5,11), öğrenci sürecini takip eden analitik araç (makale 16) ve süreç otomasyonu rolleri (makale 12) ile stüdyo ortamlarında yer aldığı görülmektedir (**Şekil 2**). YZ'nin tasarım stüdyosunda üstlenebileceği roller arasında yer verilen öğretim üyesi destek sistemi (Y5) yönüyle ise herhangi bir çalışmada faydalanılmadığı görülmektedir. İncelenen çalışmalarda YZ'nin tasarım stüdyosundaki rolüne yönelik yaygın eğilimin ise fikir üretme partneri (Y1) ve görselleştirme aracı (Y2) rolleri olduğu söylenebilmektedir.

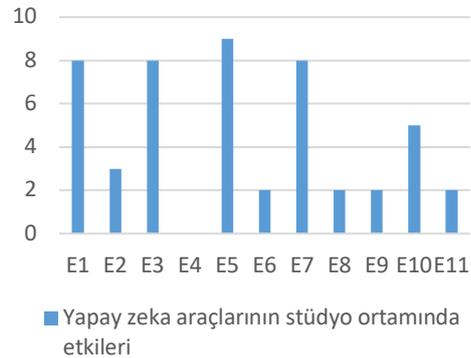
Tablo 4: Veri setini oluşturan çalışmaların, YZ rolü ve etki boyutunun analizini gösteren tablo (Table showing the AI roles and impact dimensions of the analyzed studies).

Şekil 2: İncelenen çalışmalarda yapay zeka rollerinin frekans dağılımı (Frequency distribution of AI roles in the analyzed studies).



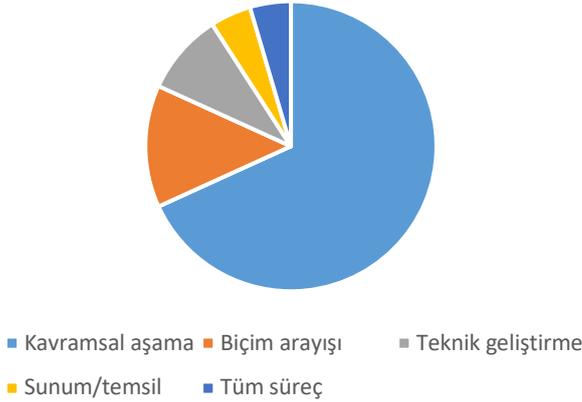
YZ araçlarının tasarım stüdyolarına dahil edilmesinin öğrenme üzerindeki etkileri **Şekil 3** üzerinden okunduğunda; tasarım süreci değişiklikleri-arama alanı, varyasyon, yineleme döngüleri- (araştırma 1,7,8,12,17,19,20 ve 21), tasarım problemini anlama (araştırma örnek 1,7,ve 14), zaman verimliliği (araştırma 5,8,10,12,15,16,17,19), yaratıcılık artışı (araştırma 2,3,4,7,8,9,10,11,16), süreç farkındalığı (araştırma 2,8), kavramsallaştırma becerisinde iyileşme (araştırma 2,3,4,5,10,15,18,21), teknik üretim kapasitesinde artış (araştırma 13,18), öğrenci bağımlılığı-otonomi kaybı (araştırma 14-19), etik kaygılar-doğruluk sorunları (araştırma 6,10,15,19,21), ve stüdyo kültüründe değişim (araştırma 6-8) yönüyle olduğu söylenebilmektedir. Bu kriter altında yer verilen eğitim-öğrenci etkileşimi (E4) yönüyle etkilerine ise herhangi bir çalışmada yer verilmediği görülmektedir. Öte yandan YZ'nin tasarım pedagojisinde yoğun olarak yaratıcılık (E5), tasarım sürecinde meydana gelen değişimler (E1) (arama alanı, varyasyon, yineleme döngülerinin avantajları), kavramsallaştırma becerisinin gelişmesi (E7) yönleriyle etkili olduğu söylenebilmektedir.

Şekil 3. İncelenen çalışmalarda YZ araçlarının stüdyo ortamında etkileri (The impact of AI tools on studio environments in the analyzed studies).



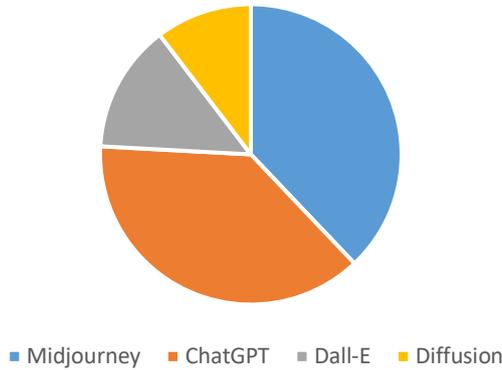
Şekil 4 üzerinden, YZ araçlarının tasarım aşamalarına dahil edilme eğilimi okunduğunda ise kavramsal tasarım aşamasında (araştırma

1,3,4,5,7,9,10,11,12,14,15,17,18,20,21), biçim arayışı süreçlerinde (araştırma 2,9,17), teknik geliştirme aşamasında (araştırma 13,15) , sunum-temsil aşamasında (araştırma 20) ve tüm süreç (araştırma 19) olmak üzere farklı aşamalarda faydalandığı görülmektedir. Ancak, bu faydalanma biçimlerinin kavramsal tasarım aşamasına (T1) yoğunlaştığı, diğer aşamaların ise ikinci planda kaldığı söylenebilmektedir.



Şekil 4. Yapay zeka araçlarının farklı tasarım aşamalarında kullanım dağılımı (Distribution of AI tool usage across different design phases).

Tasarım stüdyosunda kullanılan araçlar yönüyle araştırmalar değerlendirildiğinde (Şekil 5), yoğun olarak Midjourney (araştırma 3,7,8,9,10,15,17,18,19,20,21), takiben ChatGPT (araştırma 2,3,4,5,8,11,12,14,15,16,20), Dall-e (araştırma 8,9,10,19) ve diffusion (araştırma 1,10,15) araçlarından faydalandığı görülmektedir. Ek olarak DipAI, PromeAI, Bing gibi farklı araçlardan da faydalandığı tespit edilmiştir.



Şekil 5. Tasarım stüdyosunda kullanılan yapay zeka araçlarının dağılımı (Distribution of AI tools used in the design studio).

YZ'nin stüdyoya dahil edilme süresi yönüyle örnekler incelediğinde, çoğu çalışmada faydalanma süresi belirtilmemiş olmakla birlikte, araştırma 2 ve 4'te 6 hafta, araştırma 15'te 9 hafta, araştırma 20'de 10 hafta ve araştırma 19'da 2 dönem süreyle sürece dahil edildiği belirtilmektedir.

Dahil edilme süresi ve etki oranı arasında genellenebilir anlamlı bir eğilime ulaşılamamıştır. Ancak kısa süreli faydalanma biçimine yer verilen çalışmalarda YZ'den tasarım sürecinin belirli aşamalarında faydalanılmışken, uzun süreli yer verilen araştırma 19'da tüm süreç aşamasına dahil edildiği okunmaktadır. Ancak bir tek çalışma genellenebilir bir eğilimden bahsetmek için yeterli değildir. Öte yandan incelenen araştırmaların büyük oranda vaka çalışması (M2) yönteminde kurgulandığı, takiben deneysel çalışmalardan (M1) da faydalandığı tespit edilmiştir.

İncelenen çalışmalar boyunca, YZ araçları tutarlı olarak tasarım varyasyonlarının sayısını ve çeşitliliğini artırma, tasarım arama alanını keşif üretimiyle genişletmek, kavramsal aşamanın desteklenmesi noktalarına katkıda bulunduğu tespit edilmiştir. Ancak , fikir üretme partneri olarak (Y1) kullanılmasının her zaman gelişmiş tasarım kalitesi ya da yaratıcılığı geliştirmekle (E5) paralel olmadığı birkaç çalışmada (araştırma 5,6,14,15,17,18,19,20,21) belirtilmiştir.

Benzer şekilde, YZ araçlarının süreci hızlandırarak zaman verimliliği sağlaması da her zaman geliştirilmiş tasarım kalitesiyle ilişkilendirilmemiştir. YZ'nin stüdyo ortamlarına katkıları yanı sıra birkaç çalışma (araştırma 6,10,15,19,21,) tasarım mantığını korumak, YZ tarafından üretilen çıktıların tutarlı kavramlara entegre edilmesi ve etik kaygılar gibi dezavantajlı durumlara da değinmiştir.

YZ'nin, eğitmen-öğrenci etkileşimi (E4) üzerindeki etkilerine yönelik olarak ise, bu araçların stüdyo iletişimini yeniden şekillendirme potansiyeline değinilmiştir. Bu doğrultuda, YZ kullanımı için ders yürütücüsüyle birlikte teknik rehber ya da mentorluğun gerekliliği vurgulanmıştır (araştırma 6,8).

4. SONUÇ (CONCLUSION)

Bu çalışmada incelenen literatür, YZ uygulamalarının tasarım stüdyosu süreçlerinde çok boyutlu etkiler ürettiğini göstermektedir. Analiz edilen makaleler, yapay zekânın stüdyo ortamında fikir üretme partneri olarak tasarım süreci rolü, öğrenme çıktıları ve performans göstergelerine etkileri ve erken kavramsal tasarım aşamasının desteklenmesi olmak üzere üç temel alan üzerinde belirgin etkiler oluşturduğunu ortaya koymaktadır.

Bulgular, YZ araçlarının erken tasarım aşamalarında fikir üretme partneri ve görselleştirme aracı rolleriyle öne çıktığını; alternatif üretimini artırdığını ve öğrencilerin dışsallaştırmakta zorlandıkları fikirleri somutlaştırmalarına katkı sağladığını göstermektedir. Öğrenme boyutunda ise YZ kullanımının yaratıcılığı ve kavramsal keşfi desteklediği, tasarım problemine ilişkin arama alanını genişlettiği ve karşılaştırmalı değerlendirme olanaklarını artırdığı belirtilmektedir. Bununla birlikte, üretim hızındaki artışın her zaman tasarım kalitesine ya da yaratıcılığa doğrudan yansımadağı vurgulanmaktadır. Tasarım aşamaları açısından yapay zekânın yaygın olarak erken kavramsal evrede kullanıldığı görülmektedir.

Araştırma sorularından ilki “YZ’nin tasarım stüdyosu süreçleri ve dinamiklerini değiştirme potansiyeli” üzerinden yapılan değerlendirme, YZ kullanımının tasarım sürecinin özellikle erken aşamalarında yoğunlaştığını göstermektedir. Bu durum, başlangıç aşamasının çok sayıda alternatif üretimine açık yapısıyla ve yapay zekânın hızlı varyasyon üretme kapasitesiyle ilişkilendirilmektedir.

Bir diğer araştırma sorusu, “YZ müdahalelerinin öğrenci performansı ve öğrenme sonuçları üzerindeki ölçülebilir etkilerine” odaklanmaktadır. İncelenen literatürde YZ destekli araçların öğrenci performansını artırdığına yönelik bulgulara yer verilmekle birlikte (Kee vd., 2025; Lee& Kang, 2025; Montenegro, 2024), YZ destekli tasarım süreçlerinde öğrenci kontrolünün korunması, öğrenme sonuçlarının değerlendirilebilmesi açısından belirleyici bir ölçüt olarak öne çıkmaktadır.

Son olarak, eğitim-öğrenci etkileşimi bağlamında veriler sınırlı olmakla birlikte, YZ’nin stüdyo pedagojisinde üstlendiği roller göz önünde bulundurulduğunda, Chen’in (2025) konuya yönelik görüşüyle paralel olarak, bu araçların yalnızca bir üretim aracı olmakla kalmayıp, öğrenci ve eğitim arasında üçüncü bir pedagojik aktör olarak konumlanma potansiyelinin de tartışılması gerekmektedir.

Bulgular ayrıca, etkili bir entegrasyon için eleştirel akıl yürütmenin desteklenmesi, etik sorumluluklara duyarlılık, öğrenci bağımlılığının önlenmesi ve yapılandırılmış süreçlerin geliştirilmesi gerektiğini ortaya koymaktadır. Bu bulgular Kadenhe Nyasha vd., 2025 ve Günaydın vd.,

2024 tarafından gerçekleştirilen araştırmanın sonuçlarını desteklemektedir.

İncelenen sınırlı sayıda çalışma üzerinden literatürün değerlendirmesi, mevcut çalışmaların çoğunlukla kısa süreli uygulamalara, erken aşama tasarım görevlerine ve sınırlı örneklem gruplarına odaklandığını ortaya koymaktadır. Bu durum, Salazar Rodriguez vd., 2025 tarafından da desteklendiği üzere yapay zekânın tasarım stüdyosundaki etkilerine ilişkin uzun vadeli pedagojik sonuçların henüz yeterli düzeyde olmadığını göstermektedir. Her ne kadar bu çalışma ilgili konuya yönelik bir değerlendirme sunsa da veri setinin sınırlı sayıda çalışmadan oluşması araştırmanın temel kısıtlarından biridir.

Bu nedenle gelecekteki araştırmaların, uzun dönemli stüdyo süreçlerini takip eden, tasarım karar alma davranışını ölçen, YZ entegrasyon düzeylerini sistematik olarak karşılaştıran, YZ'nin eğitmen yönünden potansiyelleri ve eğitmen-öğrenci iletişimindeki etkilerini test eden çalışmalara odaklanması gerekmektedir.

Sonuç olarak çalışma, YZ araçlarının tasarım stüdyosundaki rollerini, pedagojik etkilerini ve yoğunlaştığı tasarım aşamalarını incelenen örneklem üzerinden sistematik biçimde sınıflandırarak konuya analitik bir bakış sunmakta; mevcut durumu ve geliştirilmesi gereken alanları ortaya koyarak YZ destekli tasarım stüdyolarının yapılandırılmasına yönelik bir referans oluşturmaktadır.

Çıkar Çatışması Beyanı (Conflict of Interest)

"Tasarım Stüdyosu Pedagojisinde Yapay Zekâ Uygulamalarının Sistematik Analizi" başlıklı yazı başka bir yerde yayınlanmamıştır ve başka bir yerde aynı anda yayınlanmak üzere gönderilmemiştir.

Yapay Zekâ Kullanım Beyanı (AI Use Disclosure)

Bu makalenin hazırlanma sürecinde Yapay Zeka araçlarından sadece abstract bölümünde, dil düzenleme amacıyla faydalanılmıştır. YZ bilimsel fikir üretimi, veri analizi, yorumlama veya özgün araştırma içeriği oluşturma amacıyla kullanılmamıştır. YZ tarafından sağlanan tüm öneriler, tarafımda gözden geçirilip onaylanmıştır. Makalenin nihai halinin doğruluğu, bütünlüğü ve özgünlüğü sorumluluğum dahilindedir.

Referanslar (References)

- Agarwal, M. K. (2024). Paradigm shift in architectural pedagogy incorporating artificial intelligence. *International Journal for Research in Applied Science and Engineering Technology*, 12(4), 1315-1328. <https://doi.org/10.22214/ijraset.2024.60055>.
- Buldaç, M. (2024). Deneysel tasarım sürecinde yapay zekâ araçlarının kullanımı: İç mimarlık eğitiminde bir ders modeli çıktıları. *Sanat ve Tasarım Dergisi*, 14(2), 69-91. <https://doi.org/10.20488/sanattasarim.1602366>.
- Cao, Y., Gao, X., Yin, H., Zhou, K. Y. (2024). Reimagining tradition: A comparative study of artificial intelligence and virtual reality in sustainable architecture education. *Sustainability*, 16(24). <https://doi.org/10.3390/su162411135>.
- Chen, B. (2025). Beyond tools: Generative AI as epistemic infrastructure in education. <https://doi.org/10.48550/arXiv.2504.06928>.
- Çiçek, S., Özkar, M. (2025). Evaluating AI-generated design solutions in a basic design studio. *International Journal of Technology and Design Education*, (2025). <https://doi.org/10.1007/s10798-025-10033-y>.
- Elrefaie, H. (2025). Integrating artificial intelligence in architectural education: Final-year graduation project case study. *International Design Journal*, 15(6), 419-431. doi: 10.21608/idj.2025.413071.1410.
- Fawzy Almaz, A., El-Azim El Agouz, E. (2024). The future role of artificial intelligence (AI) design's integration into architectural and interior design education is to improve efficiency, sustainability, and creativity. *Civil Engineering and Architecture*, 12(3). <https://doi.org/10.13189/cea.2024.120336>.
- Fawzy Aly Anber Anber, M. (2025). The impact of AI-powered platforms and tools on architectural education. *Journal of Architecture, Arts and Humanistic Sciences*, 10(52), 54-67. <https://doi.org/10.21608/mjaf.2024.259661.3306>.
- Goodfellow, I., Pouget Abadie, J., Mirza, M., Xu, B., Warde-Farley, D., Ozair, S., Bengio, Y., (2020). Generative adversarial networks, *Communications of the Acm*, 63(11), 139-144.
- Günaydın Donduran, C., Kasalı, A., Doğan, F. (2024). Artificial intelligence as a pedagogical tool for architectural design education. *Journal of Design Studio*, 6(2), 219-229. <https://doi.org/10.46474/jds.1533480>.
- Iranmanesh, A., Lotfabadi, P. (2024). Critical questions on the emergence of text to image artificial intelligence in architectural design pedagogy. *AI&Society*(40), 3557-3571. <https://doi.org/10.1007/s00146-024-02111-x>.
- İsmail mahmoud, N., Fawzy Helmy Almaz, A., Jahin, H. (2025). The role of artificial intelligence in changing the traditional design form of

- children's museums: Towards integrating artificial intelligence technologies in architectural design education. *Journal of Engineering Research*, 9(3). <https://doi.org/10.70259/engJER.2025.932010>.
- İşbilir, A., Bölükbaşı, M. (2025). Yaratıcı senaryo yazımında yapay zekânın rolü: İç mimarlık eğitiminde yenilikçi bir yaklaşım. *İstanbul Sabahattin Zaim Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, 7(1), 40-49. <https://doi.org/10.47769/izufbed.1633624>.
- Jin, S., Tu, H., Li, J., Fang, Y., Qu, Z., Xu, F., . . . Lin, Y. (2024). Enhancing architectural education through artificial intelligence: A case study of an AI-assisted architectural programming and design course. *Buildings*, 14(6). <https://doi.org/10.3390/buildings14061613>.
- Kadenhe Nyasha, Al Musleh, M., & Lompot, A. (2025). Human- AI co-design and co-creation: A review of emerging approaches, challenges, and future directions. *Proceedings of the AAAI Symposium Series*, 6(1), 265-270. <https://doi.org/10.1609/aaais.v6i1.36061>.
- Karadağ, D. (2025). AI in architectural education: Rethinking studio culture. *PLANARCH - Design and Planning Research*, 9(2), 243-253. <https://doi.org/10.54864/planarch.1749891>.
- Karadağ, D., Ozar, B. (2025). A new frontier in design studio: AI and human collaboration in conceptual design. *Frontiers of Architectural Research*, 14(6), 1536-1550. <https://doi.org/10.1016/j.foar.2025.01.010>.
- Kee, T., Kuys, B., King, R. (2024). Generative artificial intelligence to enhance architecture education to develop digital literacy and holistic competency. *JARINA*, 3(1), 24-41. <https://doi.org/10.24002/jarina.v3i1.8347>.
- Lam, N. (2022). Explanations in AI as claims of tacit knowledge. *Minds & Machines* (32), 135-158.
- Lee, S., Kang, S. (2025). The influence of generative AI with prompt engineering on creative design in architectural education. *Journal of Asian Architecture and Building Engineering*, 1-16. <https://doi.org/10.1080/13467581.2025.2552446>.
- Lekesiz, G., Müezzinoğlu, C. (2025). An approach to AI-supported learning in architectural education: Case of speculative space design. *A/Z ITU Journal of the Faculty of Architecture*, 22(1), 217-231. <https://doi.org/10.58278/0.2025.81>.
- Montenegro, N. (2024). Integrative analysis of text-to-image AI systems in architectural design education: Pedagogical innovations and creative design implications. *Journal of Architecture & Urbanism*, 48(2), 109-124. <https://doi.org/10.3846/jau.2024.20870>.
- Özorhon, G., Nitelik Gelirli, D., Lekesiz, G., Müezzinoğlu, C. (2025). AI assisted architectural design studio (AI a ADS): How artificial intelligence join the architectural design studio? *International Journal of Technology*

and *Design Education*(35), 1999-2023.
<https://doi.org/10.1007/s10798-025-09975-0>.

- Sadek, M. R., Abdel Gelil Mohamed, N. (2023). Artificial intelligence as a pedagogical tool for architectural education: What does the empirical evidence tell us? *MSA Engineering Journal*, 2(2).
<https://doi.org/10.21608/msaeng.2023.291867>.
- Salazar Rodriguez, J., Joyce, S. C., & Julfendi. (2025). Using customized GPT to develop prompting proficiency in architectural AI-generated images.
<https://arxiv.org/abs/2504.13948>.
- Seyman Güray, T., Uyan, B. (2025). Collaboration with generative artificial intelligence in the early stages of design studio: A model proposal. *Journal of Architectural Sciences and Applications*, 10(1), 434-450.
<https://doi.org/10.30785/mbud.1649820>.
- Wang, J., Shi, Y., Chen, X., Lan, Y., Liu, S. (2025). Teaching with artificial intelligence in architecture: embedding technical skills and ethical reflection in a core design studio. *Buildings*, 15(17).
<https://doi.org/10.3390/buildings15173069>.
- Wirawan Dharmatanna, S., Shanggrama Wijaya, E. (2025). The study of AI integrated simulation in building information modelling (BIM) use at architectural design studio. *JARINA*, 4(1).
<https://doi.org/10.24002/jarina.v4i1.9415>.
- Yıldırım, A., Şimşek, H. (2021). *Sosyal bilimlerde nitel araştırma yöntemleri (12th ed.)*. Şeckin Yayıncılık.
- Zahra, S., Samra, M., El Gizawi, L. (2025). Working toward advanced architectural education: Developing an AI-based model to improve emotional intelligence in education. *Buildings*, 15(3).
<https://doi.org/10.3390/buildings15030356>.
- Zeytin, E., Öztürk Kösençig, K., Öner, D. (2024). The role of AI design assistance on the architectural design process: An empirical research with novice designers. *Journal of Computational Design*, 5(1), 1-30.
<https://doi.org/10.53710/jcode.1421039>.

Visual Complexity Analysis of Mimar Kemalettin's Educational Buildings

Zeynep İldeniz Köksalan¹, Murat Şahin²

ORCID NO: 0000-0001-7060-5660¹, 0000-0001-6733-1136²

^{1,2}Firat University, Faculty of Architecture, Architecture Department, Elazığ, Türkiye

The First National Architecture Period emerged during the transition from the Ottoman Empire to the Republic of Turkey, a period marked by the intensification of the search for national identity, which significantly affected the field of architecture. The architectural understanding of this period stands out especially in the facade designs of public buildings. Mimar Kemalettin is recognised as one of the leading figures of this movement, which synthesised Seljuk and Classical Ottoman architectural elements with Neo-Classical design principles. This study aims to analyze, through a comparative approach, the similarities and differences in the facade designs of eighteen educational buildings attributed to Mimar Kemalettin, some of which were constructed, while others remained at the design stage. The average visual complexity of the facade drawings was calculated using the fractal analysis method. In this research, educational buildings are divided into three categories, namely primary schools, madrasas, and higher education institutions. The results were evaluated chronologically and comparatively according to these three categories. When the average visual complexity of educational buildings is examined chronologically, no linear change is observed. However, there is a tendency for complexity to increase over time in higher education institutions and madrasas, while a decreasing trend is evident in primary schools. This indicates that the architect's design approach varied over time according to the educational building's category. When the average visual complexity of educational buildings is compared categorically, primary schools and madrasas are found to exhibit "similar" characteristics. In contrast, madrasas and higher education institutions display "dissimilar" qualities, and likewise, "dissimilar" features are also identified between primary schools and higher education institutions. It was also observed that educational buildings in the higher education institution category exhibit more complex facade characteristics. In conclusion, these findings indicate that Mimar Kemalettin adopted a design approach that varied according to educational level.

Received: 04.06.2025

Accepted: 28.10.2025

Corresponding Author:

z.ildenizkoksalan@outlook.com

Köksalan İldeniz, Z. & Şahin, M. (2026). Visual complexity analysis of Mimar Kemalettin's educational buildings. *JCoDe: Journal of Computational Design*, 7(1), 153-178. <https://doi.org/10.53710/jcode.1713219>

ROR ID: 059636586

Keywords: Education Building, First National Architectural Period, Fractal Analysis, Mimar Kemalettin



Mimar Kemalettin'in Eğitim Yapılarının Görsel Karmaşıklık Analizi

Zeynep İldeniz Köksalan¹, Murat Şahin²

ORCID NO: 0000-0001-7060-5660¹, 0000-0001-6733-1136²

^{1,2} Fırat University, Faculty of Architecture, Architecture Department, Elazığ, Türkiye

Birinci Ulusal Mimarlık Dönemi, Osmanlı İmparatorluğu'ndan Türkiye Cumhuriyeti'ne geçiş sürecinde, mimarlık alanını önemli ölçüde etkileyen ulusal kimlik arayışlarının yoğunlaştığı bir dönemde ortaya çıkmıştır. Bu dönemin mimari anlayışı, özellikle kamu yapılarının cephe tasarımlarında öne çıkmaktadır. Mimar Kemalettin, Selçuklu ve Klasik Osmanlı mimari unsurlarını Neo-Klasik tasarım ilkeleriyle sentezleyen bu hareketin önde gelen isimlerinden biri olarak tanınmaktadır. Bu çalışma, Mimar Kemalettin'e atfedilen, hem inşa edilmiş hem de tasarım aşamasında kalmış, on sekiz eğitim yapısının cephe tasarımlarındaki benzerlikler ve farklılıkları karşılaştırmalı bir yaklaşımla analiz etmeyi amaçlamaktadır. Cephe çizimlerinin ortalama görsel karmaşıklık değerleri fraktal analiz yöntemi uygulanarak hesaplanmıştır. Eğitim yapıları, ilkokullar, medreseler ve yüksek eğitim kurumları olmak üzere üç kategoriye ayrılmıştır. Bulgular kronolojik olarak ve kategorik olarak karşılaştırmalı olarak değerlendirilmiştir. Eğitim yapılarının ortalama görsel karmaşıklık değerleri kronolojik olarak incelendiğinde, doğrusal bir değişim gözlemlenmemektedir. Ancak, yüksek eğitim kurumu ve medreselerde karmaşıklığın zamanla arttığı, ilkokullarda ise azaldığı yönünde bir eğilim dikkat çekmektedir. Bu durum, mimarın zaman içindeki tasarım yaklaşımının eğitim yapısının kategorisine bağlı olarak farklılaştığını göstermektedir. Eğitim yapılarının ortalama görsel karmaşıklık değerleri kategorik olarak karşılaştırıldığında, ilkokullar ile medreselerin "benzer" özellikler gösterdiği tespit edilmiştir. Medreseler ile yüksek eğitim kurumu yapılarının "farklı" nitelikler sergilediği görülürken, ilkokullar ile yüksek eğitim kurumu yapıları arasında "farklı" özelliklerin bulunduğu tespit edilmiştir. Ayrıca yüksek eğitim kurumu kategorisindeki eğitim yapılarının daha karmaşık cephe özellikleri sergilediği gözlenmiştir. Sonuç olarak, bu bulgular Mimar Kemalettin'in eğitim kademesine göre farklılaşan bir tasarım yaklaşımını benimsediğini göstermektedir.

Teslim Tarihi: 04.06.2025

Kabul Tarihi: 28.10.2025

Sorumlu Yazar:

z.ildenizkoksalan@outlook.com

Köksalan İldeniz, Z. & Şahin, M.

(2026). Mimar Kemalettin'in eğitim yapılarının görsel karmaşıklık analizi.

JCoDe: Journal of Computational Design, 7(1), 153-178.

[https://doi.org/](https://doi.org/10.53710/jcode.1713219)

[10.53710/jcode.1713219](https://doi.org/10.53710/jcode.1713219)

Anahtar Kelimeler: Eğitim Yapıları, Birinci Ulusal Mimarlık Dönemi, Fraktal Analiz, Mimar Kemalettin

ROR ID: 059636586

1. INTRODUCTION

The emergence of the First National Architecture Period dates back to a transformative period marked by significant social, cultural, and architectural changes during the transition from the Ottoman Empire to the Republic of Turkey. The globally reverberating effects of nationalism, modernisation efforts, and nation-building triggered a new architectural movement, the First National Architecture Period (Bozdoğan, 2008). This period, which lasted from 1908 to 1930, was perceived as a means of expressing national identity (Sözen, 1984). The characteristics of this period were clearly emphasised in the facade designs of public buildings (Hasol, 2017). Mongeri's quote, "Let us see the facades, not the plans," is shown as the primary source of this point of view (Ünsal, 1973).

Mimar Kemalettin was one of the leading figures of the First National Architecture Period and stood out with his "public architect" identity (Tanyeli, 2007). He was influential in the design of many public buildings of different typologies, including educational buildings. In the literature, there are studies analysing the buildings of the First National Architecture Period (Ekinci, 2015; Sıkıçakar, 1991). However, studies on Mimar Kemalettin and educational buildings focus on documentation and conservation concerns (Koçak, 2023; Yavuz, 2009; Yazar & Kishalı, 2019; Yazıcı Metin et al., 2023).

In contemporary architectural research, evaluating historical buildings through measurable methods provides an analytical contribution to the field. In this context, fractal analysis is a significant method for quantifying visual complexity and comparing different facade compositions. In the literature, studies such as Ediz and Ostwald's research on the Süleymaniye Mosque (Ediz & Ostwald, 2012), Kuruçay's examination of thirteen mosques designed by Mimar Sinan (Kuruçay, 2020), Kanatlar's analysis of Sedat Hakkı Eldem's professional periods through selected residential works (Kanatlar, 2012), Erkan and Haştemoğlu's study of the Berlin–Baghdad railway stations (Erkan & Haştemoğlu, 2015), and Wen et al.'s analysis of the residential plans of Wright, Le Corbusier, and Mies van der Rohe (Wen & Kao, 2005) demonstrate that fractal analysis has been widely applied in the comparative evaluation of architectural works across different periods, geographies, and scales.

A review of the literature further reveals that studies on the First National Architectural Period primarily focus on the typological and image analyses of public buildings. However, research on the educational buildings of this period has largely been confined to documentation and description, while mathematical analyses of the facade compositions are quite rare. Quantitatively examining the visual complexity of the facades of educational buildings is crucial for a more comprehensive understanding of the architectural approach of the period. Nevertheless, a study analysing the facade designs of educational buildings designed during this period using fractal analysis methods has not been conducted. This gap underscores both the originality and the significance of the present study.

Using fractal analysis methods, this study aims to evaluate the similarities in the average visual complexity values on the facades of primary schools, madrasas, and higher education institutions known to have been designed by Mimar Kemalettin. The aim is to compare the visual complexity values of educational buildings. Within the scope of the study, forty-eight facade drawings belonging to a total of eighteen buildings by Mimar Kemalettin, either constructed or remaining at the design stage, were examined. Among these, eight remained at the design stage, while ten were realized. The facades of these buildings were categorized and analyzed. In this study, the fractal analysis method, as one of the morphological analysis approaches, was employed to quantitatively reveal the similarities and differences in the facade composition and organization of Mimar Kemalettin's educational buildings. The evaluations demonstrated the changes and variations observed in these buildings. Furthermore, the study holds significance as it provides a basis for comparing the fractal values of cultural heritage buildings at different scales within the framework of physical and socio-cultural norms.

2. BACKGROUND TO THE RESEARCH

This section begins by summarising key changes in the education system during the First National Architectural Period. It then examines the life and educational structure of Mimar Kemalettin. During the modernization period, educational developments primarily began at the military and higher education levels (Tekeli, 2011). The societal changes during the Second Constitutional Era accelerated the reform

of the education system. While sultani, idadi, military, and civil rüşdiye schools were opened at the secondary level, mekteb-i ibtidai schools became institutions offering modern education at the primary level. Traditional institutions like sıbyan schools and madrasas were also subject to curricular modernization. However, this led to a division of educational institutions into three categories before the Republic: madrasas, Tanzimat schools, and foreign schools. According to Ziya Gökalp's sociology of education, this division is reflected in society as three different groups: sofi, Levantine, and Tanzimatist (Celkan, 1977). With the proclamation of the Law on the Unification of Education (Tevhid-i Tedrisat) in 1924, madrasas were closed, and all educational institutions were placed under the Ministry of National Education, thereby ensuring educational unity (Parmaksızoğlu, 1948).

2.1 Mimar Kemalettin and Educational Buildings

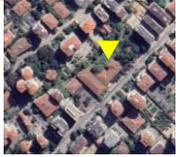
Mimar Kemalettin (1870-1927) was a Turkish architect who witnessed many significant events during his lifetime. His architectural career began in 1887 when he enrolled at the Hendese-i Mülkiye (Yavuz, 1981a). At this institution, he developed an interest in drawing and architecture and received training from experts such as Professor Jasmund (Çetintaş, 1944). It is known that he assisted Jasmund in the Sirkeci Station project (Çetintaş, 1944; Yavuz, 2015). In 1891, Kemalettin Bey was appointed as Professor Jasmund's assistant at Hendese-i Mülkiye Mektebi and taught design courses for four years, during which he also established his private office (Gövsa, 1946). His early designs reflect eclectic styles. In 1895, he was sent to Berlin to specialize as the Ottoman state architect (Doğuoğlu Fındıkgil, 2009). After completing a two-year higher education program at Charlottenburg Technische Hochschule, he worked in Germany for about two and a half years (Yavuz, 1981a). Between 1909 and 1919, the expansion of the powers of the Construction and Restoration Technical Committee of the Ministry of Foundations (Evkaf Nezareti) enabled the reflection of the national architectural idea in new public buildings. During this period, Mimar Kemalettin became a highly active figure in construction (Yavuz, 1981b).

Archival documents and period practices indicate that Kemalettin Bey, as the Chief Architect of the Ministry of Foundations, played an influential role in the design of educational buildings during his tenure (Yavuz, 2009). Furthermore, since the Ministry of Foundations

functioned like an architectural school during this period, names such as Mimar Nihat and Ali Talat are also mentioned in relation to certain projects (Batur & Cephaneçigil, 2009). A total of eighteen educational buildings attributed to Mimar Kemalettin - some of which were constructed, while others remained at the planning stage - are examined in this study. These buildings are dated between 1909 and 1927. These buildings are mainly located in Istanbul. However, there are educational building designs in Ankara, Medina, and Edirne (Yavuz, 2009). The educational buildings designed by Mimar Kemalettin can be categorised under three headings: primary education institutions, madrasas, and higher education institutions (Köksalan & Şahin, 2024). The characteristic features of the facades of these educational buildings include varying window forms on different floors and continuous string courses that follow the lines of the windows. A prominent projection typically accentuates the front facade. Tiled hipped roofs are also a common feature (Table 1).

School	Year and Location	Photograph	
Reşadiye Primary School	İstanbul, 1910		 (Demirtaş & Uysal, 2012)
Fethiye Madrasa	İstanbul, 1909-1919		 (Fethiye Medresesi, 2019)
Bostancı Primary School	İstanbul, 1913-1914		 (Kültür Envanteri, 2023)
Medreset'ül Kuzat	İstanbul, 1913		 (Medreset ü'l-Kuzât, n.d.)
Ayazma Primary School	İstanbul, 1913-1917		 (Ayazma Mektebi, 2022)

Table 1: Table showing locations and photographs of constructed schools

Göztepe Primary School	İstanbul, 1914			(Kültür Envanteri, 2021)
Abdülhamid-i Evvel Madrasa	İstanbul, 1912-1915			(Yavuz, 2009)
Madrasa in Medina	Medina, 1914-1915			(Dar Al-Qalam, 2020)
Mimar Kemal Primary School	Ankara, 1926-1927			(Köksalan, 2024a)
Gazi Education Institute	Ankara, 1927-			(Köksalan, 2024b)

Reşadiye Primary School (**Figure 1a**) is Mimar Kemalettin's first educational building design. Its facade composition is distinguished by its octagonal plan and the onion-domed prayer room section. (Yazar & Kishalı, 2019). Just above the flat-arched entrance door, there is a crescent and star motif. Square-framed geometric reliefs, panels, and penci-arched¹ windows are among the facade ornaments (Demirtaş & Uysal, 2012). The front facades of the Bostancı (**Figure 1c**), Ayazma (**Figure 1d**), and Göztepe (**Figure 1f**) primary schools are highlighted by a protruding main entrance (Yavuz, 2009). However, the side and rear facades differ in similarity. In the "School for the Deaf and Blind"² (**Figure 1b**), pointed arches are used on the ground floor, while rectangular windows are found on the first floor. Entrances are provided from side axes, and the arched, stair-accessed entrances are topped with balconies. The masses that protrude from the front facade and vary in height give the structure a dynamic appearance. Both the "Six-classroom school" (**Figure 1g**) and the Karaağaç Primary School

¹ A term for the five-centered arches common in the period.

² This project is referred to as "School for the Deaf and Blind" in the text and is indicated as "Dilsiz ve Âmâlara Mahsus Mektep" in the archives.

(Figure 1e) were designed with an “I” plan layout. The “Six-Classroom School” is a two-story building, whereas the Karaağaç Primary School is a single-story structure featuring wide, penci-arched windows (Yavuz, 2009). The primary school design in İstinye (Figure 1h) stands out with its tower-like mass. In the design of Fünun-u Cedid Primary School (Figure 1i), various sizes and shapes of twin windows, penci-arched, and flat-arched window forms were used. The Mimar Kemal Primary School (Figure 1j) is the only primary school designed during the Republican period. It includes window string courses and has a more modest appearance compared to the other primary school buildings.

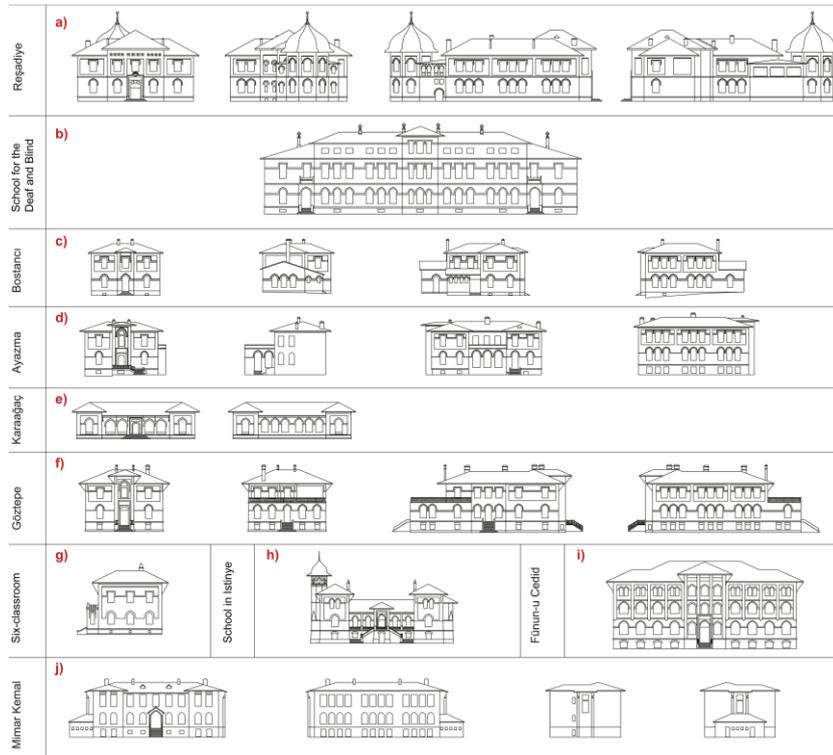
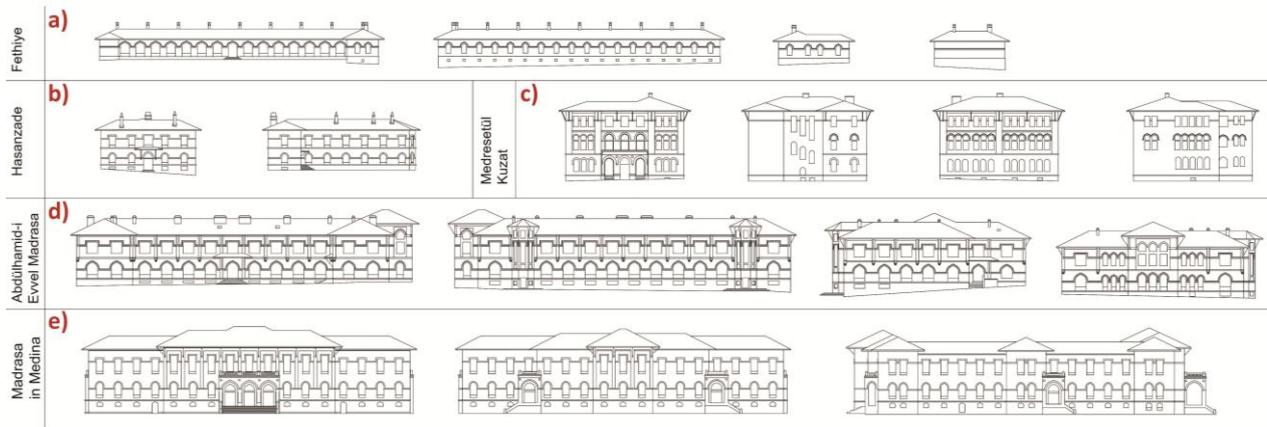


Figure 1: Primary Schools
a) Reşadiye (Demirtaş & Uysal, 2012),
b) School for the Deaf and Blind (Batur & Cephaneçigil, 2009),
c) Bostancı (MEB Arşivi, 2013),
d) Ayazma (MEB Arşivi, 2014),
e) Karaağaç (Yavuz, 2009),
f) Göztepe (Yamaner, 2019; Yavuz, 2009)
g) Six-classroom school (Yavuz, 2009),
h) School in İstinye (Yavuz, 2009),
i) Fünun-u Cedid (Batur & Cephaneçigil, 2009),
j) Mimar Kemal (Yıldız, 2014)

Fethiye Madrasa (Figure 2a) and Hasanzade Madrasa (Figure 2b) are among the architect’s early madrasa designs. For this reason, traces of the old-style madrasa design can be seen in their plan designs (Ahunbay, 1999). In the facade designs, window forms and ornamentation features characteristic of the period are seen (Yavuz, 2009). Medresetü’l-Kuzât (Figure 2c) symbolises the shift from madrasa education to modern education (Yavuz, 1981b). On the front facade, there is a double-winged entrance door with penci arches and windows on the sides. The upper part is decorated with calligraphic plates and rosettes. Mouldings, panels, and inverted tassel decorations following

the window form enrich the facade. While the vertical plaster-like elements continue to the ground-floor moulding, the rear facade is kept simpler. It can be said that Abdülhamid-i Evvel Madrasa (**Figure 2d**) represents an innovative approach to the classical madrasa typology (Batur, 2008). The ground floor has arched windows, while the upper floor has flat lintel windows. Continuous mouldings, plasterwork, and carved rosettes adorn the facade. There are penci-arched windows on the ground floor and flat lintel windows on the upper floor. Continuous mouldings, plasters, and carved rosettes decorate the facade. Madrasa in Medina (**Figure 2e**) has basement windows with flat arches, ground-floor windows with penci arches, and first-floor windows with rectangular forms. The main entrance axis is emphasised by increasing the height of the rectangular windows in this section by protruding above the eaves level. There are significant differences between design and construction.

Figure 2: Madrasa Facades
a) Fethiye (MEB Arşivi, 2012),
b) Hasanzade (Batur & Cephaneçigil, 2009),
c) Medresetül Kuzat (Temelli, 2004),
d) Abdülhamid-i Evvel (YİKOB Arşivi, 2012),
e) Madrasa in Medina (Yavuz, 2009)

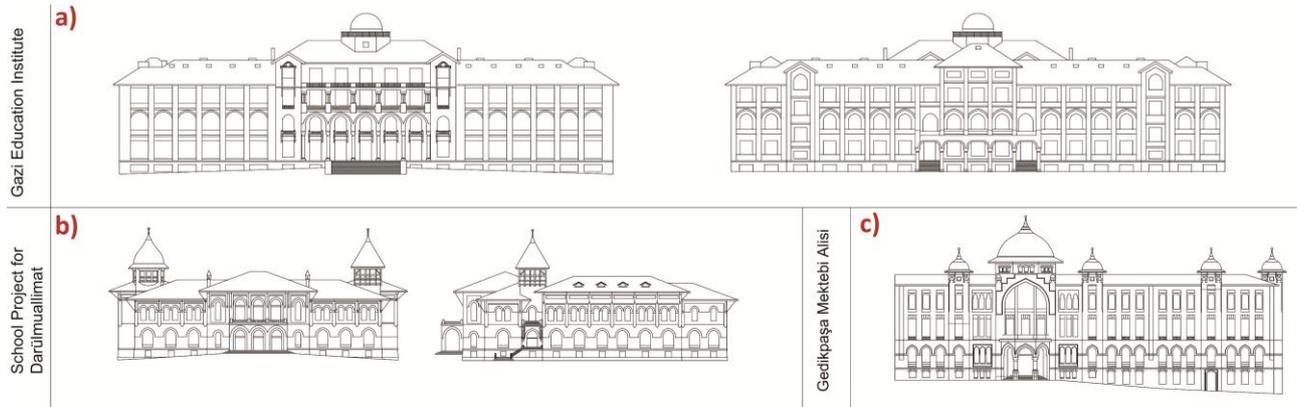


The project for the Dârü'l-Muallimat (School for Female Teachers) (**Figure 3b**) remained in the design phase. In the facade design, penci-arched windows of different sizes and shapes are used. The facade is emphasised by projection and overhang above the eaves level. There are mouldings and panels surrounding the windows. There are inverted tassel-like ornamental elements at the ends of the plaster-shaped vertical elements. Corner towers are a remarkable feature of the design. Gedikpaşa Mekteb-i Alisi (**Figure 3c**) also remained in the design phase. Tower-shaped elements, covered with small-scale domes that overhang at the eaves, create a rhythmic appearance. Window forms included depressed, pointed, flat, and Bursa-arched windows (Arslan Çinko, 2020). Continuous mouldings following the window form are

seen on the ground floor. On the facade of Gazi Education Institute (**Figure 3a**), a semi-open area in front of the entrance features a portico with marble columns (Duru, 2024; Yavuz, 2009). On the upper floor, this section becomes a covered balcony, and on the third floor, it becomes an open terrace. In the Gazi Education Institute, Turkish triangle-shaped column capitals are used on the rear facade, and muqarnas column capitals are used on the front facade.

Figure 3: Facades of Higher Education

- a) Gazi Education Institute (Duru, 2024)
- b) School for Darülmuallimat (SALT Research, n.d.),
- c) Gedikpaşa Mektebi Alisi (Yavuz, 2009)



3. METHOD: FRACTAL ANALYSIS

This study employs the fractal analysis method to calculate the complexity dimensions of facade compositions in educational buildings designed by Mimar Kemalettin. Phase 1 involved a literature review, while Phase 2 examined 18 of his educational buildings using archival and written sources. In Phase 3, facade drawings were prepared in CAD and analyzed with FraLac. Phase 4 focused on obtaining, classifying, and discussing the findings. Finally, Phase 5 summarized the results, highlighted contributions, and the findings were then compared and evaluated (**Figure 4**).

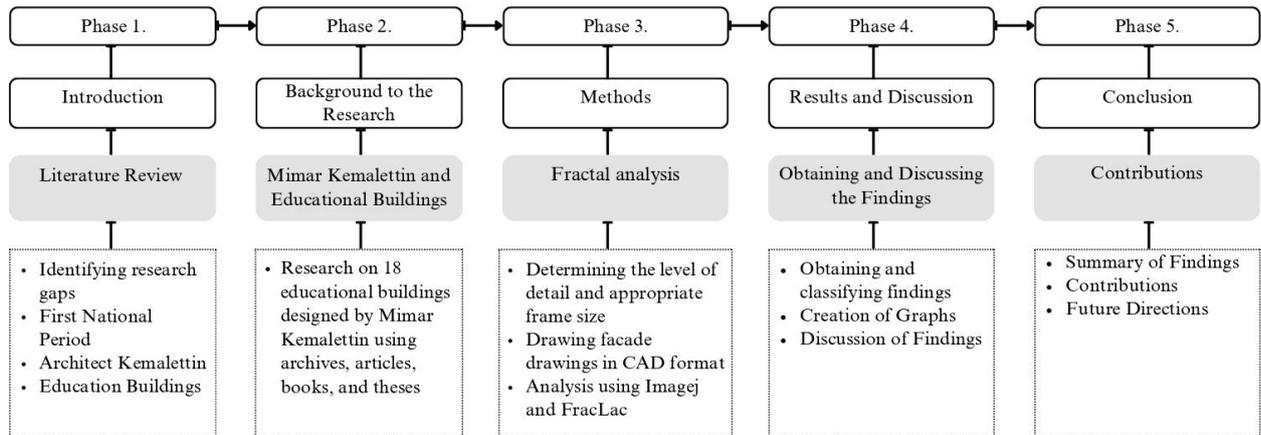


Figure 4: Research workflow

The calculation of fractal geometry and fractal dimension is based on Mandelbrot’s work, questioning roughness (Mandelbrot, 1982). Fractal dimension and fractal geometry are two complementary yet distinct concepts. Fractal geometry refers to the complex forms produced by the self-similarity and repetition of objects of different scales. Numerical values that can be calculated to compare the similarity of forms are called the fractal dimension (Barnsley, 2014; Bovill, 1996).

It is well known that complex and contradictory elements often come together in architecture (Venturi, 2023). In this respect, Bovill’s study is an important reference for discussing fractals and complexity within the same architectural context (Bovill, 1996). The fractal analysis method enables the mathematical evaluation of the visual complexity of architectural structures. Research in the literature shows that fractal analysis focuses on building examples of a period, an architect, or an architectural movement. In the literature, studies examine the intuitive use of fractal constructions in historical buildings (Ediz & Çağdaş, 2005; Ediz & Ostwald, 2012). Many studies use fractal analysis to measure visual complexity. These studies often question the connections between different historical design approaches and the similarities in architectural facades and plans (Lionar & Ediz, 2020; J. L. Vaughan, 2017). In addition, there are also studies that aim to question architects’ search for design over the years in chronological order (Dawes et al., 2023; Kanatlar, 2012; Kuruçay & Ediz, 2025; M. Ostwald et al., 2008; J. Vaughan & Ostwald, 2022).

The box-counting method is one of the most common techniques for calculating the fractal dimension, which quantifies the richness of repetition and detail in two-dimensional objects or textures. This method allows the calculation of the complexity of facade and plan design in architecture (M. J. Ostwald & Vaughan, 2016). This method can be used to understand the degree to which a design has multi-level detail, but it does not provide information about design quality and aesthetic values (M. Ostwald & Tucker, 2007). The numerical values range between 1 and 2 and are expressed by the fractal dimension (D) (Mandelbrot, 1982). The reason for this is that fractals are not expressed as integers, unlike Euclidean geometry. Increasing the fractal dimension indicates greater complexity, while decreasing it indicates less complexity (Torrens & Alberti, 2000). When applying the box-counting method, the level of detail in the object's representation affects the results. The level of detail was examined in five layers in Ostwald and Vaughan's study (M. J. Ostwald & Vaughan, 2016).

4. RESULTS AND DISCUSSION

Within the scope of the research, forty-eight facade drawings from eighteen buildings were evaluated. The fractal analysis method allows for comparative evaluation of the formal properties of the facades by converting them into digital data. The fractal dimensions of the examined facades were obtained using the FraCLac plugin of ImageJ software (Zarnowiecka, 1998). The "Grid Design" section enables the selection of the grid method to be used in the analysis of the image, as well as the determination of the number of subdivisions in the horizontal and vertical directions and the scale. The "Multifractal Options" section is employed for conducting fractal dimension analyses on multiple files. The "Graphics Options" section is used to organize results, while the "Files" section provides settings for saving the outputs of analyses (Şahin et al., 2025).

When fractal dimension calculations were performed, elevation drawings were prepared in AutoCAD 2021 based on reference sources, at the outline + primary form representation level. The size of the rectangular frame of the drawings prepared for analysis was scaled using the ratio $1.41421 (\sqrt{2})$, and the drawing was positioned in the center (Lionar, 2021). Fractal analysis data were obtained using ImageJ. Within the scope of the study, in the grid design section, the grid

position was set to 12, as suggested by the Fraclac plugin. Since the aim is to perform a detailed fractal analysis and examine a mathematical relationship, “Power Series” was chosen as the scaling method. Regression was selected in the graphic options section, data details were determined in the files section, and analysis data were obtained (Figure 5).

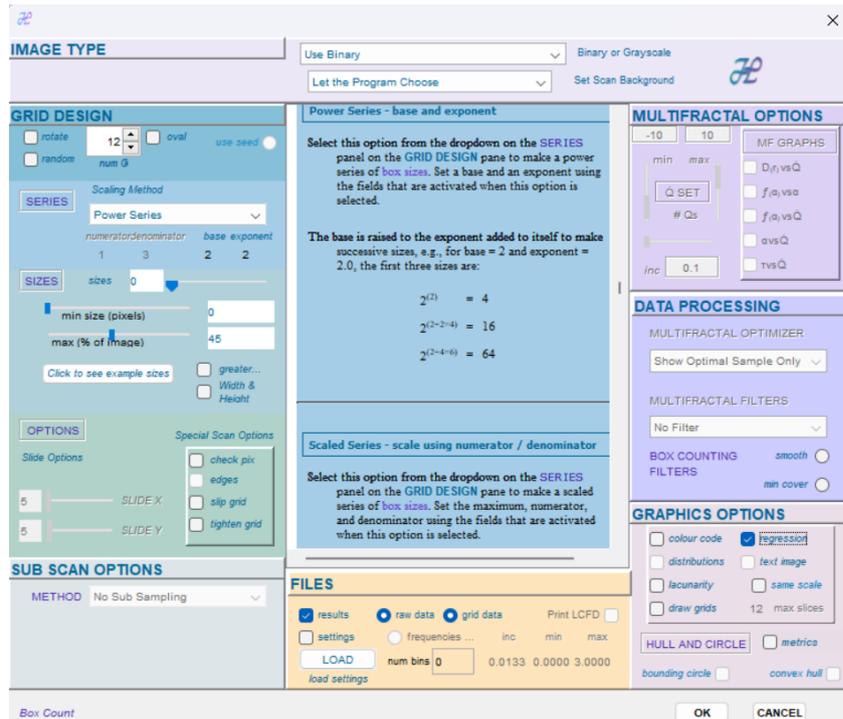


Figure 5: Interface View of the Fraclac Plugin in Image-J Software

While evaluating the findings, visual complexity values closest to 1 are defined as “lowest visual complexity” and values closest to 2 are defined as “highest visual complexity”. Since the fractal dimension value will vary depending on the level of detail of the drawing, the comparison was made by considering the percentage difference in fractal dimension values (Kuruçay, 2020). In the study, the similarity between the fractal dimension values obtained as a result of the analyses was evaluated with reference to the table below (Table 2).

Table 2: Fractal dimension parameters (Lionar, 2021)

Fractal Dimension Difference%	Similarity status
%0 to %1	very similar
%1 to %4	similar
greater than 4%	dissimilar

The fractal dimension values for eighteen designs, both completed and those remaining in the design phase, were found as shown in the table below. The findings were evaluated using the average fractal dimension values (D) as a reference. Educational structures were examined under three headings based on their education levels: primary education, madrasas, and higher education institutions (**Table 3**).

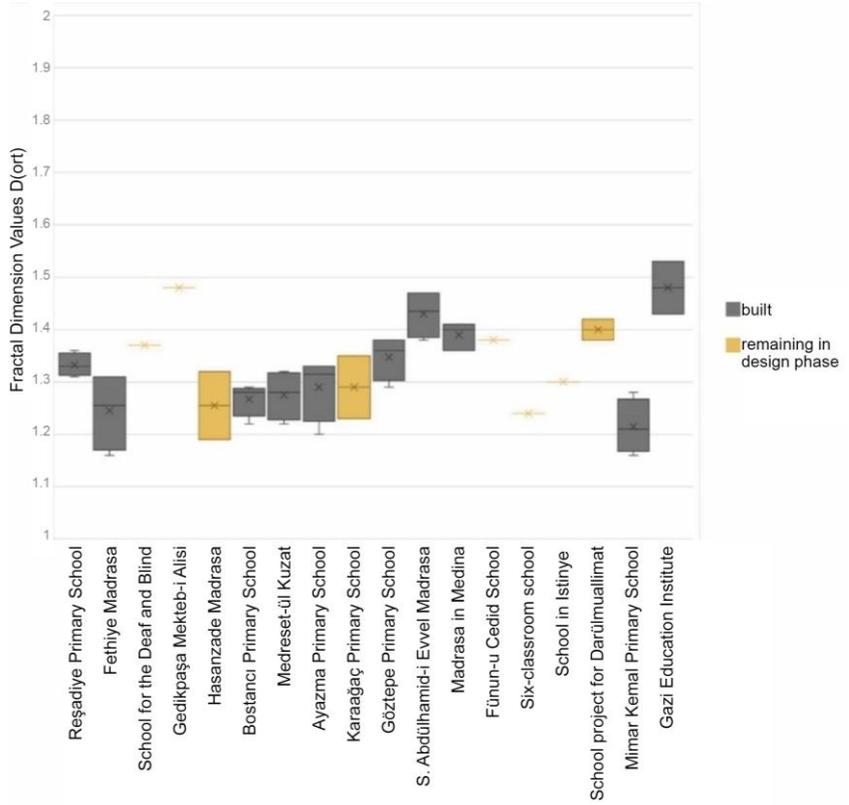
Table 3: Complexity values of educational buildings (created by author)

Category	Date	Name	Front Elevation	Rear Elevation	Right Elevation	Left Elevation	D (ort) ³
Primary School	1910	Reşadiye	1.31	1.32	1.34	1.36	1.33
	1910	School for the Deaf and Blind	1.37	-	-	-	1.37
	1912	Bostancı	1.29	1.22	1.28	1.28	1.26
	1913-1917	Ayazma	1.30	1.20	1.33	1.33	1.29
	1909-1919	Karaağaç	1.35	1.23	-	-	1.29
	1914	Göztepe	1.29	1.34	1.38	1.38	1.34
	-	Fünun-u Cedid	1.38	-	-	-	1.38
	-	Six-classroom school	-	-	1.24	-	1.24
	-	School in İstinye	1.30	-	-	-	1.30
	1926-1927	Mimar Kemal	1.28	1.23	1.19	1.16	1.21
Madrasa	1909-1919	Fethiye	1.31	1.31	1.16	1.20	1.24
	1912	Hasanzade	1.19	-	-	-	1.25
	1913	Medresetü'l-Kuzât	1.31	1.22	1.32	1.25	1,27
	1912-1915	Abdülhamid-i Evvel	1.47	1.47	1.40	1.38	1,43
	1914-1915	Madrasa in Medina	1.41	1.36	-	1.40	1,39
Higher Education	-	School project for the Dârü'l-Muallimât	1.38	-	1.42	-	1,40
	1911-1912	Gedikpaşa Mekteb-i Alisi	1.48	-	-	-	1,48
	1927-1930	Gazi Education Institute	1.43	1.53	-	-	1,48

It is known that ten of the evaluated educational buildings have been constructed, and eight are in the design phase. According to this data, when educational buildings are evaluated according to their construction status, the average fractal dimension value in the constructed structures is 1.32. It was observed that the average fractal dimension values in the educational buildings remaining in the design phase were 1.33. The relationship between the visual complexity of buildings that remained in the design phase and those that were built was determined to be “very similar” (**Figure 6**).

³ D (ort): average fractal dimension value, the arithmetic mean of the elevations of the Front, Rear, Right and Left elevations. Data for which facade drawings were not available are indicated with a minus sign (-) in the table.

Figure 6: Comparison of fractal dimension averages of educational buildings (built: grey, remaining in design phase: yellow) (created by author)



When considered chronologically, educational buildings were examined in two separate periods: 1909-1919 and the post-1925 era, due to uncertainty surrounding the dates of some designs (Figure 6). The average fractal dimension values of eighteen designs display a fluctuating pattern over time. Although no clear linear continuity is observed, a slight upward tendency emerges in the overall trend. This indicates that the architect's approach to facades did not undergo a radical transformation solely over time. On the other hand, categorical differences are more evident. Higher education institutions and madrasas show an increasing tendency toward visual complexity, whereas primary schools show a declining trend. Thus, it can be concluded that the architect's design approach over the years varied primarily in relation to the category of the educational building.

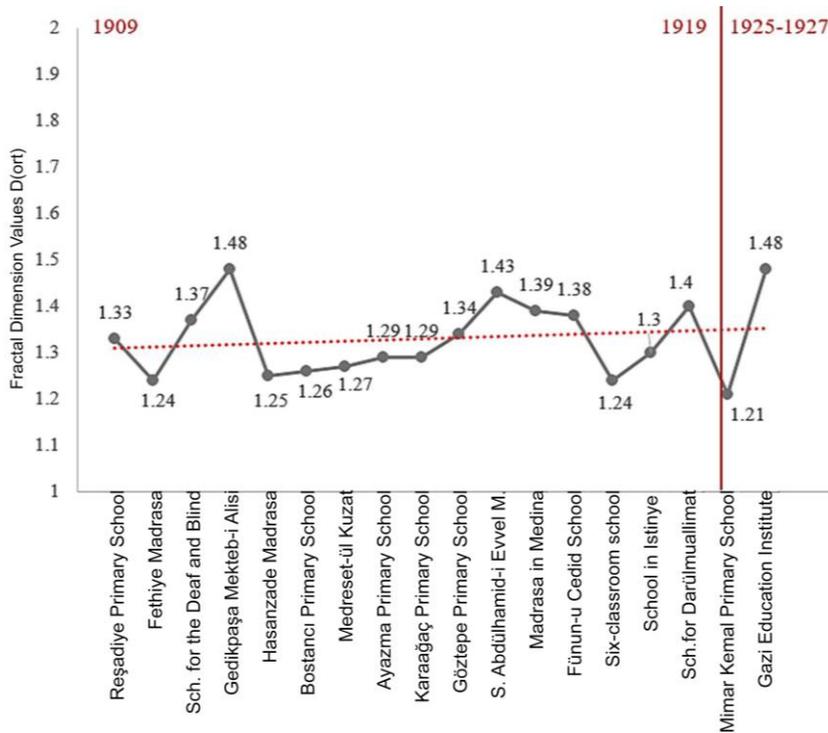


Figure 7: Chart showing the fractal dimensions of educational structures in chronological order (created by author)

When the designs at the primary school level were evaluated, the buildings with the highest average fractal dimension value were determined as Fünun-u Cedid School ($D=1.38$) and School for the Deaf and Blind ($D=1.37$). The fact that Fünun-u Cedid School is a large-scale, multi-storey design and has more window openings on its facade than other primary schools is reflected in the visual complexity value. When the average fractal dimension values are compared between Göztepe, Bostancı, and Ayazma Schools, which are stated to have similar characteristics in the literature, the percentage difference between Bostancı ($D=1.26$) and Ayazma Schools ($D=1.29$) is in the “similar” category with 2.38%. The percentage difference between Ayazma ($D=1.29$) and Göztepe Schools ($D=1.34$) is in the “similar” category with 3.88%, and the percentage difference between Bostancı ($D=1.26$) and Göztepe ($D=1.34$) Schools is in the “dissimilar” category with 6.35%. These results reveal that the visual complexity values of the buildings at the same education level may differ. Although the school project in İstinye ($D=1.30$) has ornamental elements on its facade, it has a simpler visual complexity than the facade of Karaağaç School ($D=1.35$), which is a single-storey design. This is attributed to the higher void ratio on the facade of the Karaağaç School. The lowest average fractal dimension value among the primary schools was found in Mimar Kemal Primary

School (D=1.21). Designed during the Republican era, Mimar Kemal Primary School (1926-1927) features windows devoid of decorative elements, unlike other educational buildings. In addition, the side facade layouts of the building are also quite simple (**Figure 8**).

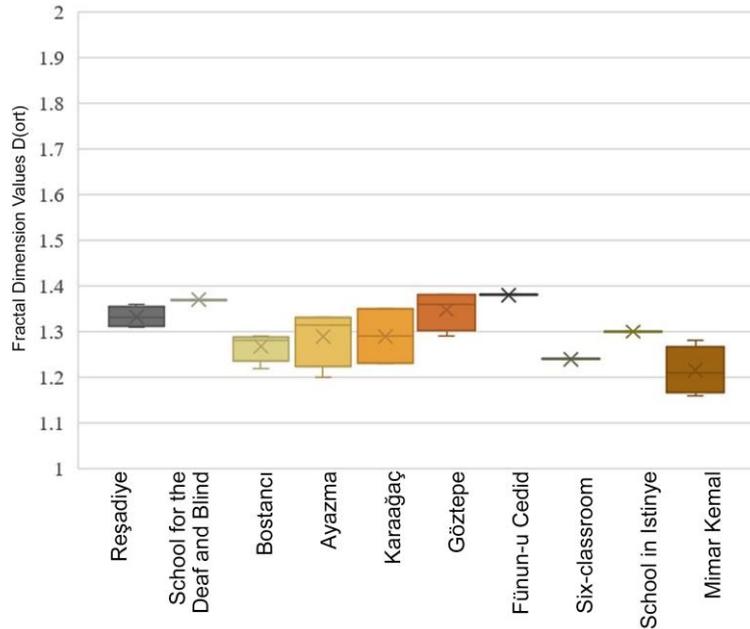


Figure 8: Graph showing fractal dimension values at primary schools (created by author)

When evaluating the madrasa designs, the highest visual complexity value was observed in the Abdülhamid-i Evvel Madrasa project (D=1.43). There are decorative elements such as reverse tassels and plaster on the facade of Abdülhamid-i Evvel Madrasa. The “Madrasa in Medina” has the second-highest visual complexity among the madrasa designs, and its average visual complexity value is “similar” to that of the Abdülhamid-i Evvel Madrasa. Fethiye and Hasanzade Madrasas are “very similar”; Hasanzade and Medrese-tül Kuzat have “similar” visual complexity values. The madrasa building with the lowest average fractal dimension value is Fethiye Madrasa (D=1.24). The simple appearance of the side facades of Fethiye Madrasa supports the findings (**Figure 9a**).

When the designs of higher education institutions are evaluated, Gedikpaşa Mekteb-i Alisi and Gazi Education Institute designs were found to be “very similar” in terms of average fractal dimensions. The lowest visual complexity level was that of the Dar’ül-Muallimat project (D=1.40). In terms of visual complexity, the Darü’l-Muallimat project is

“dissimilar” to the Gedikpaşa Mekteb-i Alisi and Gazi Education Institute (Figure 9b).

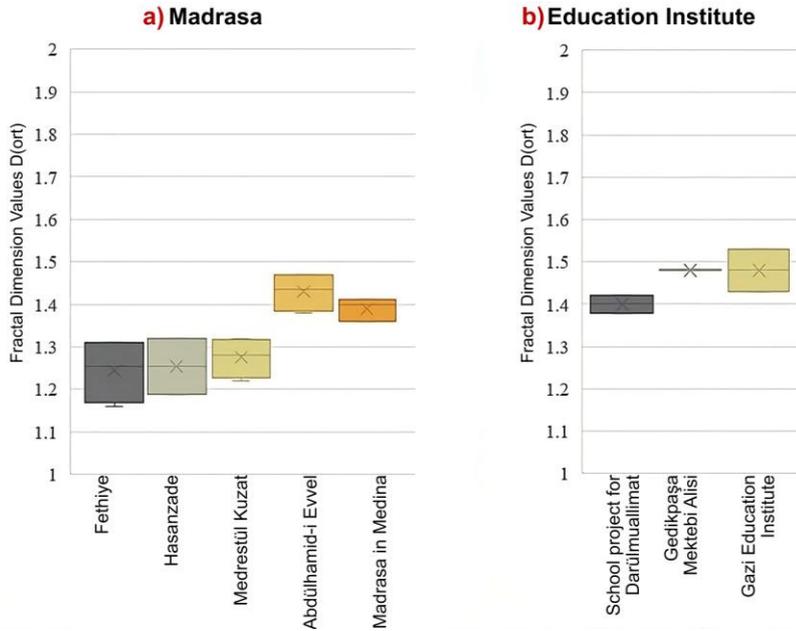


Figure 9: Graphs showing fractal dimensions
a) Madrasas
b) Higher Education Institutions
(created by author)

Considering the findings (Table 4), the fractal dimension values ranged from 1.21 to 1.48. When fractal dimensions are considered according to primary education level, the average fractal dimension values of primary schools are 1.30 and 1.32 for madrasas. The average fractal dimension value for higher education institutions was found to be 1.45. The difference between the average fractal dimension values of primary school and madrasa buildings is considered “similar” at 1.54%. In comparison, the difference between the madrasa and the higher education institution is considered “dissimilar” at 9.85%. In addition, the difference between primary schools and higher education institutions is 11.54%, which is also considered “dissimilar.”

Teaching Level	Name	D (ort)	Average Fractal Dimensions Across Education Levels
Primary School	Reşadiye	1.33	1.30
	School for the Deaf and Blind	1.37	
	Bostancı	1.26	
	Ayazma	1.29	
	Karaağaç	1.29	
	Göztepe	1.34	
	Fünun-u Cedid	1.38	
	Six-classroom	1.24	
	School in Istinye	1.30	
Mimar Kemal	1.21		
Madrasa	Fethiye	1.24	1.32
	Hasanzade	1.25	
	Medresetü'l-Kuzât	1,27	
	Abdülhamid-i Evvel	1,43	
	Madrasa in Medina	1,39	
Higher Education	Dârü'l-Muallimât	1,40	1.45
	Gedikpaşa Mekteb-i Alisi	1,48	
	Gazi Education Institute	1,48	

Table 4: Educational Buildings and Average Fractal Dimensions (created by author)

4.2 Limitations

Within the scope of the research, the restitution projects of the educational buildings built among the eighteen designs were largely reached, but the side facade drawings of the Gazi Education Institute were not available. In addition, all facade drawings of the educational buildings remaining in the design phase have not been accessed. Furthermore, the difficulty in determining the exact design dates for some buildings is a limitation of the research. For this reason, educational buildings were evaluated in two periods: 1909-1919 and after 1925.

5. CONCLUSION

Architect Kemalettin's career, intertwined with government appointments and work primarily on public buildings alongside a technical team of young architects at the Ministry of Foundations, ensured that he played a decisive role in the architectural production of the period (Tanyeli, 2007). This study examines a total of eighteen buildings, ten of which were constructed and eight of which remained in the design phase, by Architect Kemalettin, one of the leading figures

of the First National Architecture Period, between 1909 and 1927, using fractal analysis. These educational buildings are categorized under three headings: primary schools, madrasas, and higher education buildings. The facade drawings were prepared at an outline + primary forms level of detail.

The main findings of the research indicated that the structures remaining in the design phase and the constructed structures have “very similar” characteristics in terms of average visual complexity values. This demonstrates the existence of a consistent fractal order in Architect Kemalettin’s design approach, regardless of whether the project was realized or not. Since the visual complexity values of the eighteen buildings do not exhibit chronological continuity, it is not possible to state conclusively that the architect’s approach changed over time. However, when examined chronologically, the visual complexity values indicate an increasing trend in higher education institutions and madrasas, while a decreasing trend is observed in primary school buildings. Therefore, there are changes in the architect’s design approach. Over time, this can be understood as being related to the categorical differences among educational buildings.

When the buildings were grouped and evaluated by educational level, the average visual complexity values of primary schools and madrasas were found to be “similar.” Madrasas were found to be “dissimilar” compared to higher education institutions. Likewise, primary schools and higher education institutions were also found to be “dissimilar.” The findings indicate that the facades of primary schools and madrasahs were designed with a similar approach, whereas higher education buildings were constructed with a distinctly different design approach. This finding supports Yavuz’s qualitative research (Yavuz, 2009).

In conclusion, these findings indicate that Mimar Kemalettin adopted a design approach that varied according to educational level. This study provides a unique dataset for future research on the educational buildings of the period. Academic studies based on such quantitative data are expected to contribute both to the relevant literature and to a deeper understanding of the architectural identity of the period.

Acknowledgement

This article is based on the master's thesis titled "Evaluation of Facade Arrangements in Architect Kemalettin Buildings by Fractal Analysis Method: An Example of Educational Buildings" completed by Zeynep İldeniz KÖKSALAN under the supervision of Associate Professor Dr. Murat ŞAHİN at Firat University. The research was conducted with the necessary permits granted by the Firat University Rectorate (E-80802877-622.99- 510319, dated July 29, 2024) and the Ministry of National Education (MEB.MT.2024.000011, dated September 11, 2024). The facade drawings were redrawn and analyzed by the author by referring to the sources cited in the article. We would like to thank the Istanbul Investment Monitoring and Coordination Directorate (YIKOB), the Ministry of National Education (MEB), and the Istanbul and Ankara Ministry of National Education, Construction and Real Estate Directorates for sharing the relevant documents that contributed to the development of this study.

Conflict of Interest Statement

The manuscript, entitled "Visual Complexity Analysis of Mimar Kemalettin's Educational Buildings," has not been published elsewhere and that it has not been submitted simultaneously for publication elsewhere.

AI Use Disclosure

All authors declare that no artificial intelligence tools were used in the writing, analysis, or preparation of this article.

Author Contribution

All authors contributed equally to this article.

References

Ahunbay, Z. (1999). *Osmanlı Medreseleri*. Osmanlı, 10, 301-307.

Arslan Çinko, M. (2020). Osmanlı Arşiv Belgeleri Işığında İstanbul/ Gedikpaşa'da Bir Yapı Adasının 19. Yüzyıldan Cumhuriyet'e Değişiminin İrdelenmesi: 'Tiyatrodan, Mektebe...'
Meltem İzmir Akdeniz Akademisi Dergisi, 7(3-4).
<https://doi.org/10.32325/iaad.2020.3>

- Ayazma Mektebi. (2022). *Ayazma Mektebi* [Photograph]. Retrieved January 4, 2025, from <https://semsipasailkokulu.meb.k12.tr/tema/dosyadetay.php?KATEGORINO=3007945&git=1>
- Barnsley, M. (2014). *Fractals Everywhere*. Academic press.
- Batur, A. (2008). Mimar Kemalettin Yapılar Rehberi. *TMMOB Mimarlar Odası İstanbul Büyükkent Şubesi*.
- Batur, A., & Cephaneçigil, G. (2009). *Mimar Kemaleddin Proje Kataloğu*. İstanbul Vakıflar Bölge Müdürlüğü, TMMOB & Vakıflar Genel Müdürlüğü ortak yayını.
- Bovill, C. (1996). Fractal Geometry in Architecture and Design. In *Fractal Geometry in Architecture and Design*. <https://doi.org/10.1007/978-1-4612-0843-3>
- Bozdoğan, S. (2008). *Modernizm ve Ulusun İnşası: Erken Cumhuriyet Türkiye'sinde Mimari Kültür*. Metis yayınları.
- Celkan, H. Y. (1977). *Ziya Gökalp'in Eğitim Sosyolojisi*. [Doctoral dissertation, Atatürk University].
- Çetintaş, S. (1944). Mimar Kemalettin Mesleği ve Sanat Ülküsü. *Güzel Sanatlar*, 5, 160–173.
- Dawes, M. J., Ostwald, M. J., & Lee, J. H. (2023). The Mathematics of 'Natural Beauty' in the Architecture of Andrea Palladio and Le Corbusier: An Analysis of Colin Rowe's Theory of Formal Complexity Using Fractal Dimensions. *Fractal and Fractional*, 7(2). <https://doi.org/10.3390/fractalfract7020139>
- Dar Al-Qalam. (2020). *Dar Al-Qalam Complex in Medina* [Web page]. Retrieved January 5, 2025, from <https://bit.ly/3W8ZBy3>
- Demirtaş, N., & Uysal, Y. (2012). *Reşadiye Numune Mektebi Restitüsyon Raporu ve Projesi*. [Report].
- Doğuoğlu Fındıkgil, M. (2009). *Kemalettin'in Berlin'i*. Mimar Kemalettin ve Çağı: Mimarlık/Toplumsal Yaşam/Politika, TMMOB Mimarlar Odası ve Vakıflar Genel Müdürlüğü Ortak Yayını, Ankara.
- Duru, Ö. (2024). Muallim School and Education Institute Restitution Period Analysis. *Gazi University Journal of Science Part B: Art Humanities Design and Planning*, 12(2), 207-221.
- Ediz, Ö., & Çağdaş, G. (2005). Mimari Tasarımda Fraktal Kurguya Dayalı Üretken Bir Yaklaşım. *İtüdergisi/a Mimarlık, Planlama, Tasarım*, 4, 1.
- Ediz, Ö., & Ostwald, M. J. (2012). The Süleymaniye Mosque : A *Computational Layering in Sinan's Masterwork*. *Architectural Research Quarterly* (arq), 16(2), 171–182. <https://doi.org/10.1017/S1359135512000474>

- Ekinci, S. (2015). *I. Ulusal Mimarlık Dönemine Ait Yapıların Deneysel ve Sayısal Olarak İncelenmesi*. [Master's thesis, Istanbul Technical University].
- Erkan, İ., & Haştemoğlu, H. (2015). Analyse of Building Facades With Fractal Method : Railway Station. *International Journal of Civil Engineering and Technology (IJCIET)*, 6(9), 175–188.
- Fethiye Medresesi. (2019). *Fethiye Medresesi* [Photograph]. Retrieved September 10, 2024, from <https://turkiyenintarihieserleri.com/?oku=4021>
- Gövsal, A. İ. (1946). Mimar Kemalettin. In *Türk Meşhurları Ansiklopedisi* (pp. 1421–1422). Yedigün Neşriyat.
- Hasol, D. (2017). *20. yüzyıl Türxiye Mimarlığı*. Yem Kitapevi, İstanbul.
- Kanatlar, Z. (2012). *Fraktal Boyuta Dayalı Mimari Bir Analiz: Sedat Hakkı Eldem ve Konut Mimarisi*. [Master's thesis, Uludag University].
- Koçak, K. (2023). İstanbul'un Kadıköy İlçesinde Yer Alan Birinci Ulusal Mimarlık Dönemi Eğitim Yapıları Üzerine Bir Değerlendirme. *Turkish Online Journal of Design Art and Communication*, 13(1), 87–107.
- Köksalan, Z. İ. (2024a). *Mimar Kemal İlkokulu* [Photograph]. *Personal archive*.
- Köksalan, Z. İ. (2024b). *Gazi Eğitim Enstitüsü* [Photograph]. *Personal archive*.
- Köksalan, Z. İ. (2025). *Mimar Kemalettin yapılarındaki cephe kurgularının fraktal analiz yöntemiyle değerlendirilmesi: Eğitim yapıları örneği*. [Master's thesis, Fırat University].
- Köksalan, Z. İ., & Şahin, M. (2024). An Evaluation on Plan and Facade Compositions in Architect Kemaleddin's Educational Buildings. *Gazi University Journal of Science Part B: Art, Humanities, Design And Planning*, 12(2), 235–253.
- Kuruçay, E. (2020). *Sinan Mimarisinde Görsel Karmaşıklıkğın Hesaplamalı Analizi*. [Master's thesis, Uludag University].
- Kuruçay, E., & Ediz, Ö. (2025). Mimaride görsel karmaşıklıkğın hesaplamalı analizi: Şehzade Camii, Süleymaniye Camii ve Selimiye Camii. *Gazi Üniversitesi Mühendislik Mimarlık Fakültesi Dergisi*, 40(3), 1495–1508. <https://doi.org/10.17341/gazimmfd.1476466>
- Kültür Envanteri. (2023). *Bostancı Halk Eğitimi Merkezi* [Photograph]. Retrieved May 5, 2024, from <https://kulturenvanteri.com/tr/yer/bostanci-halk-egitimi-merkezi/#17.1/40.955269/29.093958>.
- Kültür Envanteri. (2021). *Göztepe İlkokulu* [Photograph]. Retrieved May 5, 2024, from <https://kulturenvanteri.com/tr/yer/goztepe-ilkokulu/#17.1/40.976917/29.062437>

- Lionar, M. L. (2021). *Fraktal Boyuta Dayalı Çok Katmanlı Bir Analiz: Eldem ve Doshî Mimarlığı*. [Doctoral dissertation, Uludağ University].
- Lionar, M. L., & Ediz, Ö. (2020). Measuring Visual Complexity of Sedad Eldem's SSK Complex and Its Historical Context: A Comparative Analysis Using Fractal Dimensions. *Nexus Network Journal*, 22(3), 701–715. <https://doi.org/10.1007/s00004-020-00482-4>
- Mandelbrot, B. (1982). *The Fractal Geometry Of Nature*. W.H. Freeman.
- MEB Arşivi. (2012). *Fethiye Medresesi Restitüsyon Projesi*, A Proje Mimarlık.
- MEB Arşivi. (2013). *Bostancı Mektebi Restitüsyon Projesi*, Arch-E Mimarlık.
- MEB Arşivi. (2014). *Ayazma Mektebi Restitüsyon Projesi*, Işık Proje.
- Medresetü'l-Kuzât. (n.d.). *Medresetü'l-Kuzât* [Photograph]. Retrieved October 9, 2024, from <https://muzeyum.istanbul.edu.tr/tr/content/koleksiyonlar/nadir-eserler-kutuphanesi-koleksiyonu>
- Ostwald, M. J., & Vaughan, J. (2016). *The fractal dimension of Architecture* (Vol. 26, Issue 5). Birkhäuser Cham. <https://doi.org/10.1007/978-3-319-32426-5>
- Ostwald, M., & Tucker, C. (2007). Measuring Architecture: Questioning the Application of Non-Linear Mathematics in the Analysis of Historic Buildings. *Association of Architecture Schools in Australasia*. <https://doi.org/10.5130/aab.n>
- Ostwald, M., Vaughan, J., & Tucker, C. (2008). *Characteristic Visual Complexity: Fractal Dimensions in the Architecture of Frank Lloyd Wright and Le Corbusier*. January.
- Parmaksızoğlu, İ. (1948). Medrese. *İnönü Ansiklopedisi*, 23, 370–380.
- Şahin, M., Olğun, T. N., & Akbulut, P. (2025). Malatya Ulu Camii Bezemelerinin Morfolojik Analiz Yöntemiyle Değerlendirilmesi. *Art-Sanat*, 23, 156–180.
- SALT Research. (n.d.). *Darülmualimat için yapılan bir proje*. Retrieved October 10, 2024, from <https://archives.saltresearch.org/handle/123456789/192757>
- Sıkıçakar, A. (1991). *Birinci Ulusal Mimarlık Dönemi Giriş Cepheleri Analizi*. [Master's thesis, Istanbul Technical University].
- Sözen, M. (1984). *Cumhuriyet dönemi Türk mimarlığı, 1923-1983* (Vol. 9). Türkiye İş Bankası Kültür Yayınları.
- Tanyeli, U. (2007). *Mimarlığın Aktörleri: Türkiye 1900-2000*. Garanti Galeri.
- Tekeli, İ. (2011). *Türkiye İçin Eğitim Yazıları*. Tarih Vakfı Yurt Yayınları.

- Temelli, U. E. (2004). *İstanbul Üniversitesi Nadir Eserler Kütüphanesi Binasının Güçlendirme Yöntemi*. [Master's thesis, Istanbul Technical University].
- Torrens, P. M., & Alberti, M. (2000). Measuring sprawl. *CASA Working Papers 27. Centre for Advanced Spatial Analysis (UCL)*, London.
- Ünsal, B. (1973). 70. Yaşını İdrak Eden Mimarlar: I. *Arkitekt*, 3, 135–138.
- Vaughan, J. L. (2017). *Measuring Fallingwater: A Computational Fractal Analysis of Wright's Kaufman House in the Context of His Theories and Domestic Architecture* (Issue July). , Sydney, Newcastle.
- Vaughan, J., & Ostwald, M. J. (2022). Examining the position of Wright's Fallingwater in the context of his larger body of work: An analysis using. *Fractal and Fractional*, 6(4), 187.
- Venturi, R. (2023). Complexity and Contradiction in Architecture (1966). In *Anthologie zum Städtebau. Band III: Vom Wiederaufbau nach dem Zweiten Weltkrieg bis zur zeitgenössischen Stadt*.
- Wen, K.-C., & Kao, Y.-N. (2005). An analytic study of architectural design style by fractal dimension method. In *Proceedings of the 22nd International Symposium on Automation and Robotics in Construction (ISARC 2005)* (pp. 1–6). Ferrara, Italy.
- Yamaner, I. (2019). *Göztepe İlkokulu Koruma Projesi*. [Master's thesis, Istanbul Technical University].
- Yavuz, Y. (1981a). Mimar Kemalettin Bey (1870-1927). *ODTÜ Mimarlık Fakültesi Dergisi*, 7(1), 54–76.
- Yavuz, Y. (1981b). *Mimar Kemalettin ve birinci ulusal mimarlık dönemi*. ODTÜ Mimarlık Fakültesi Basım İşliği.
- Yavuz, Y. (2009). *İmparatorluktan Cumhuriyete Mimar Kemalettin 1870-1927*. TMMOB Mimarlar Odası.
- Yavuz, Y. (2015). Evkaf Nezareti İnşaat ve Tamirat Heyet-i Fenniyesi İlk Başmimarı Mimar Kemalettin. *Restorasyon-Konservasyon-Arkeoloji ve Sanat Tarihi Yıllığı*, 11.
- Yazar, N. E., & Kışalı, E. (2019). An example of the effects of the Westernization period on the First National Architecture: the Reşadiye Numune School. *Journal of Architectural Conservation*, 25(3), 252–270. <https://doi.org/10.1080/13556207.2019.1638606>
- Yazıcı Metin, N., Şahin, S., Sönmezer, Ş., Seçkin, S., & Aytaç, N. (2023). İstanbul Fatih'te Birinci Ulusal Mimarlık Üslubundaki Eğitim Yapıları. *Sanat Tarihi Yıllığı*, 32, 453–513. <https://doi.org/10.26650/sty.2023.1215857>

- YİKOB Arşivi. (2012). *Sultan Selim Kız Lisesi Restitüsyon Projesi, NNY Mimarlık, İstanbul İl Özel İdaresi İmar Yatırım ve İnşaat Daire Başkanlığı Etüt Proje Müdürlüğü Arşivi*.
- Yıldız, G. (2014). *Conservation Principles For An Early Republican Period Primary School Building: Mimar Kemal Primary School*. [Master's thesis, Middle East Technical University].
- Zarnowiecka, J. C. (1998). Chaos, databases and fractal dimension of regional architecture. *Proceedings of the 16th ECAADE Conference, Paris*, 267–270.

Selection of Flooring Material in Office Spaces Using Fuzzy Sets

Esra Eres Yalçın¹, Ferhat Pakdamar²

ORCID NO: 0000-0003-3061-046X¹, 0000-0002-5594-3095²

¹Kocaeli University, Faculty of Architecture and Design, Department of Architecture, Kocaeli, Turkey

²Istanbul Technical University, Faculty of Architecture, Department of Architecture, Istanbul, Turkey

Floor covering materials are made for the purposes of protecting the floor layers, being functional and aesthetic, ensuring user safety and comfort. Therefore, in addition to determining the space and user needs well, the investment cost of the material, service life, durability, operating cost, comfort and environmental impact are effective factors in the decision-making phase. When covering materials with different properties are evaluated within the scope of these selection factors, they may have different advantages and disadvantages. In the selection of floor covering materials, it has great importance to consider these properties of the materials together and to make the most appropriate decision among the alternatives. It would be healthier to perform this process, which requires complex decision processes, on a more systematic and realistic level. Therefore, unlike the classical logical computer selection system that makes sharp evaluations as “correct (1)” and “incorrect (0), the fuzzy logic method, which is an approach that evaluates by considering many criteria together just like the human brain and can consider the deficiency in information, was chosen. In the study; it was aimed to create a more realistic decision process in the selection of floor coverings by evaluating the decision criteria in the selection of floor coverings in office spaces with the fuzzy logic approach. In order for the model to work correctly, inputs and outputs were determined in a way that there would be no overlapping data and different number of value sets. In this direction, investment cost (€/m²), service life (year), operating cost (€/m²) and environmental impact criteria (kgCO₂/m²) were the input parameters of the model; carpet, ceramic, PVC and wood coating materials were the output parameters of the model. The selection criteria that constitute the input parameters of the model were defined with fuzzy logic sets, and the fuzzification process was performed by defining triangular membership functions for each selection criterion class over the material value sets. The criterion class was determined for each floor covering material that constitutes the output parameters of the model and the triangular membership function was defined. Two criteria classes were determined for each floor covering material. The selection criterion data that were fuzzified through membership functions were created according to the “or” rule system of fuzzy logic. Floor covering material selection criteria were modeled in the Mamdani inference system in a way that would create input in Matlab according to the determined parameter range. Then, 3 different scenarios were created based on the selection criteria, namely balanced, operating cost focused and environmental impact focused, and these scenarios were evaluated using the model created in the Matlab program. As a result of the evaluations, it was seen that wood was the most suitable choice among wood, PVC, carpet and ceramic flooring materials in all scenarios.

Received: 06.06.2025

Accepted: 25.12.2025

Corresponding Author:
eresyalcin@itu.edu.tr

Eres Yalçın, E. & Pakdamar, F. (2026). Selection of flooring material in office spaces using fuzzy sets. JCoDe: Journal of Computational Design, 7(1), 179-201.
<https://doi.org/10.53710/jcode.1715401>

ROR ID: 059636586

Keywords: Fuzzy Logic, Floor Covering Material, Material Selection.

Ofis Mekanlarında Döşeme Kaplama Malzemesinin Bulanık Kümeler Kullanılarak Seçimi

Esra Eres Yalçın¹, Ferhat Pakdamar²

ORCID NO: 0000-0003-3061-046X¹, 0000-0002-5594-3095²

¹Kocaeli Üniversitesi, Mimarlık ve Tasarım Fakültesi, Mimarlık Bölümü, Kocaeli, Türkiye

²İstanbul Teknik Üniversitesi, Mimarlık Fakültesi, Mimarlık Bölümü, İstanbul, Türkiye

Döşeme kaplama malzemeleri; döşeme katmanlarını koruma, işlevsel ve estetik olma, kullanıcı güvenliği ve konforunu sağlama gibi amaçlarla yapılmaktadır. Bu yüzden mekanın ve kullanıcı ihtiyacının iyi saptanmasının yanında malzemenin yatırım maliyeti, hizmet ömrü, dayanıklılığı, işletme maliyeti, konforu, çevresel etkisi karar verme safhasında etkili etmenlerdir. Farklı özelliklere sahip kaplama malzemeleri bu seçim etmenleri kapsamında değerlendirildiklerinde farklı avantaj ve dezavantajlara sahip olabilmektedirler. Döşeme kaplama malzemesi seçiminde, malzemelerin bu özelliklerinin bir arada düşünülmesi ve alternatifler arasında en uygun kararın verilmesi büyük önem taşımaktadır. Karmaşık karar süreçlerini gerektiren bu işlemin daha sistematik ve gerçekçi bir düzlemde yapılması daha sağlıklı olacaktır. Bu nedenle “doğru (1)” ve “yanlış (0)” olarak keskin değerlendirmeler yapan klasik mantıklı bilgisayar seçim sisteminin aksine tıpkı insan beyni gibi birçok kriteri birlikte ele alarak değerlendirme yapan ve bilgideki eksikliği gözetebilen bir yaklaşım olan bulanık mantık yöntemi seçilmiştir. Çalışmada; ofis mekanlarındaki döşeme kaplaması seçiminde, karar kriterlerinin bulanık mantık yaklaşımıyla değerlendirilerek, döşeme kaplaması seçiminde daha gerçekçi bir karar süreci oluşturulması amaçlanmıştır. Döşeme kaplama malzemeleri için belirlenen seçim kriterleri (yatırım maliyeti, hizmet ömrü, işletme maliyeti ve çevresel etkisi) ve ofis döşemelerinde yaygın olarak kullanılan malzemelere (ahşap, halı, PVC ve seramik) bulanık kümelerle üyelik fonksiyonları tanımlanmış ve oluşturulan kurallar doğrultusunda model tamamlanmıştır. Daha sonra seçim kriterleri üzerinden dengeli, işletme maliyeti odaklı ve çevresel etki odaklı olmak üzere 3 farklı senaryo oluşturulmuş ve bu senaryolar Matlab programında oluşturulan model üzerinden değerlendirilmiştir. Yapılan değerlendirmeler sonucu ahşap, PVC, halı ve seramik kaplama malzemeleri arasında ahşabın tüm senaryolarda ağırlıklı olarak en uygun tercih olduğu görülmüştür.

Teslim Tarihi: 06.06.2025

Kabul Tarihi: 25.12.2025

Sorumlu Yazar:

eresyalcin@itu.edu.tr

Eres Yalçın, E. & Pakdamar, F. (2026). Ofis mekanlarında döşeme kaplama malzemesinin bulanık kümeler kullanılarak seçimi. JCoDe: Journal of Computational Design, 7(1), 179-201. <https://doi.org/10.53710/jcode.1715401>

ROR ID: 059636586

Anahtar Kelimeler: Bulanık Mantık, Döşeme Kaplama Malzemesi, Malzeme Seçimi.



1. GİRİŞ (INTRODUCTION)

Döşeme kaplamaları; döşeme katmanlarını oluşabilecek her türlü dış etkilerden korumak, kullanım güvenliğini sağlamak, kullanıcıya estetik bir görünüm ve yeterli bir konfor sunmak, mekanın işlevine uygun, kolay temizlenebilen düzgün bir yüzey elde etmek gibi amaçlarla yapılarak, döşemenin en üst yüzeyini oluşturmaktadır. Bu bağlamda döşeme kaplaması seçimi; işlevsellik, estetik, kullanıcı konforu ve güvenliği konularıyla doğrudan bağlantılıdır. Döşeme kaplaması seçilirken mekanın ve kullanıcı ihtiyacının iyi analiz edilmesinin yanında seçilen malzemenin maliyeti, hizmet ömrü, dayanımı, sunacağı fiziksel konfor (görsel, işitsel, dokunsal) ve çevresel etkileri gibi birçok kriter göz önünde bulundurulmalıdır. En doğru seçimin yapılabilmesi için; bu kriterlerin birlikte ele alınarak bir sonuca varılması gerekmektedir. Bu yüzden; “doğru (1)” ve “yanlış (0) olarak keskin değerlendirmeler yapan klasik mantıklı bilgisayar seçim sisteminin aksine tıpkı insan beyni gibi birçok kriteri birlikte ele alarak değerlendirme yapan ve bilgideki eksikliği gözetebilen bir seçim yaklaşımının benimsenmesi büyük önem taşımaktadır. Ayrıca bilgilerdeki eksiklikleri karar verme sistemine dahil etmek de karar verme eylemini insan düşünce sistemine daha benzer kılacaktır. Bu çalışma; ofis mekanlarındaki döşeme kaplaması seçiminde karar kriterlerinin bulanık mantık yaklaşımıyla değerlendirilerek, döşeme kaplaması seçiminde daha gerçekçi bir karar süreci oluşturmayı amaçlamaktadır. Böylelikle döşeme kaplaması için karar verilmesi gerektiğinde makineler kullanılacaksa bu sistem sayesinde insan gibi karar verebilme yetisine sahip olacaktır (Zadeh, 1984).

Yapı teknolojisi ve malzemesindeki ilerlemeler doğrultusunda döşeme kaplamalarındaki seçenekler artmıştır. Malzeme seçeneklerinin artması; döşemelerde kaplama seçimi yaparken göz önünde bulundurulması gereken faktörler düşünüldüğünde, projenin gerektirdiği en doğru seçimi yapma noktasında zorluklar yaratmaktadır. Bu durum, malzeme seçimi yapan kişi veya kişileri karar verme sürecinde daha sistematik bir değerlendirme zemini oluşturmaya yöneltmektedir (Alibaba ve diğ., 2004). Ancak bu sayede farklı seçenekler içerisinde en uygun malzemenin seçilerek uygulanması mümkün olacaktır.

İstatistik, matematik, yönetim bilimi gibi disiplinlerin ortak çalışma alanı olan karar kuramı; özellikle belirsizlik içeren durumlarda en iyi seçimi

yapmak için sistematik bir çerçeve sunan bir disiplindir (Cao, 2023).Çoklu karar verme yaklaşımları, karar kuramı çerçevesinde geliştirilmiş karar verme yaklaşımlarıdır (Athawale ve diğ., 2012). Bulanık Mantık (Zadeh, 1965), AHP (Analytic Hierarchy Process/ Analitik Hiyerarşi Süreci) (Saaty, 1987), TOPSIS (Technique for Order of Performance by Similarity to Ideal Solution/ İdeal Çözümüne Benzerliğe Göre Performans Sıralama Tekniği) (Hwang ve Yoon, 1981), VIKOR (Compromise Ranking Method/ Uzlaşma Sıralama Yöntemi) (Opricovic, 1998) çoklu karar verme yaklaşımlarından bazılarıdır.

Döşeme kaplama malzemesi seçimi yaparken göz önüne alınan kriterlerin zaman zaman birbirine karşıt olması, çok fazla sayıda malzeme alternatifinin olması veya bazen subjektif kararlara bağlı olması seçim sürecini karmaşıktırılmaktadır (Mahmoud ve diğ., 1996). Örneğin, bir döşeme kaplaması estetik yönden kullanıcıya avantaj sağlarken maliyet açısından ya da çevresel etki açısından dezavantajlı olabilmektedir. Ya da farklı alternatifler üzerinden seçim yaparken subjektif kriterler ön plana çıkmakta seçilecek malzeme kararı konusunda karmaşa çıkabilmektedir. Döşeme kaplaması seçiminde yaşanabilen bu zorluklar, seçimi yapacak kişi ya da kişileri ya doğru (1) ya da yanlış (0) varsayımına dayanan klasik mantık (Aristoteles Mantığı) seçim yöntemlerinden uzaklaştırmış, seçim sürecinde daha sistematik olan çoklu karar verme yaklaşımlarına yöneltmiştir (Reza ve diğ., 2011). Bir önermenin doğru ya da yanlış olduğu varsayılarak çalışan bilgisayar mantığı, klasik mantığa dayanan bir sistem olup, seçim kriterlerini ya var ya da yok şeklinde, ara değersiz, değerlendirmektedir. Oysaki insan beyninin karar mekanizması birçok kriteri aynı anda dikkate alarak değerlendirme yapmakta, karmaşık durumlar karşısında ortaya çıkan belirsizlikleri yönetebilmektedir. Bu sebeple çok sayıda etkene bağlı olan döşeme kaplaması seçiminde, birçok kriteri değerlendirmeye alan çoklu karar verme ve bulanık mantık yaklaşımlarını kullanmak seçimi yapan kişi ya da kişileri daha doğru bir sonuca götürecektir (Zadeh, 1984).

Döşeme kaplama malzemesi seçiminde klasik yaklaşım çoğu zaman teknik ve maliyet gibi belirli kısıtlar üzerinden şekillenmektedir. Bu nedenle seçim sürecinde; kısıtlı kriterler, teknik şartname gereklilikleri ve bütçe dengesi, göz önünde bulundurulmakta; çevresel etki gibi çok boyutlu faktörler ise bazen ihmal edilmekte ya da kararın son aşamasında değerlendirmeye alınmaktadır (Tegegne ve diğ., 2023).

Geleneksel yöntemlerin net eşikler üzerinden çalışması ve belirsiz, net olmayan verileri değerlendirmekte yetersiz kalması sebebiyle malzeme seçiminde yine çoklu karar verme yaklaşımlarına olan ihtiyaç ön plana çıkmaktadır. Bulanık mantık; belirsiz, sözel veya aralık şeklinde ifade edilen verileri bir matematiğe dökerek seçim yapılmasına olanak sağlayan bir yöntem olarak öne çıkmakta; AHP, TOPSIS gibi yöntemlerle entegre edilerek bulanık AHP, bulanık TOPSIS olarak kullanılabilir. Döşeme kaplama malzemesi seçiminde kriterler, net sınırlar yerine aralıklar ile tanımlanmaktadır. Bu nedenle; performans karşılaştırmalarındaki sayısal/sözel veri türü esnekliği, belirsizlikleri koruyarak hesaplama yapması ve hiyerarşik zorunluluğun olmaması gibi açılardan bulanık mantık; esnek, gerçekçi ve karar verici görüşlerini daha doğru yansıtan bir yöntem olarak öne çıkmaktadır. Bu yönüyle bu çalışmada bulanık mantığın, döşeme kaplaması seçiminde metodolojik olarak daha gerçekçi sonuçlar sağlaması amaçlanmıştır.

2. DÖŞEME KAPLAMA MALZEMESİ SEÇİM KRİTERLERİ (FLOOR COVERING MATERIAL SELECTION CRITERIA)

Döşeme kaplama malzemesi seçilirken mekanın işlevi ve kullanıcı ihtiyacı doğrultusunda malzemelerin teknik performansları, maliyetleri, estetik özellikleri, çevresel etkileri, konfor ve güvenlik kriterleri göz önünde bulundurulmaktadır (Hall., 1997; Toydemir ve diğ., 2000). Bu kriterlerin birlikte değerlendirilerek optimum kararın verilmesi noktasında çoklu karar verme ve bulanık mantık yöntemleri kullanılmaktadır. Çoklu karar verme yöntemleri arasında hiyerarşik yapının olduğu durumlarda önem ağırlığı belirleme konusunda AHP, alternatiflerin olumlu ve olumsuz yönlerini belirleyerek dengeli bir seçim yapma konusunda TOPSIS ön plana çıkmaktayken, öznel kriterlerin ölçülemeyen “düşük”, “orta”, “yüksek” gibi ifadelerini sayısallaştırması konusunda da Bulanık Mantık ön plana çıkmaktadır (Zadeh, 1968). Bir mekan için döşeme kaplaması seçilirken karar; malzemenin yatırım maliyeti, hizmet ömrü, aşınma ve dayanımı, işletme maliyetleri etkisi, kullanıcı konforu, çevresel etki kriterleri kapsamında değerlendirilmektedir (Tuscher ve diğ., 2024). Bu kriterlerin bazılarının ifadesinde nicel, bazılarında ise nitel veriler kullanılmaktadır. Kesin ifadelerle çalışan AHP ve TOPSIS yöntemlerinde, kullanıcı konforu gibi öznel kriterlerin değerlendirilmesi zorlaşabilmektedir. Bulanık mantıkta ise öznel ya da belirsiz AHP ve TOPSIS yöntemlerinin klasik uygulamaları kesin verilere dayandığından, öznel veya belirsiz kriter

değerlendirmeleri için bulanık AHP ve bulanık TOPSIS yaklaşımları geliştirilmiştir. Bu çalışmada; seçim kriterleri arasında belirli bir hiyerarşik yapı bulunmadığından ve performans temelli bir değerlendirme hedeflenmediğinden doğrudan farklı seçim senaryolarına açık olması yönünden bulanık mantık kullanılmıştır. Bulanık mantık ile veriler kademelendirilerek seçim modeline dahil edilebilir ve değerlendirilen diğer kriterlerle daha bütüncül bir sonuç çıkarabilmektedir (Zadeh, 1965). Bulanık mantık bu yönüyle değerlendirildiğinde yapı sektöründe yalnızca malzeme seçimi alanlarında değil; yüklenici/tedarikçi seçimi, risk ve maliyet yönetimi, yapı sağlığı izleme, sismik risk değerlendirme gibi birçok alanlarda kullanıldığı görülmektedir (Nguyen ve Fayek, 2022).

Yatırım maliyeti kriteri; bir malzemenin ilk satın alma ve uygulama maliyetidir. Döşeme kaplama malzemesi seçiminde bu kriter, proje bütçesi kapsamında değerlendirilerek en uygun seçimin yapılması gereklidir (Tikul, 2014; Ajustree ve diğ., 2020). Kaplama malzemelerinin yatırım maliyeti; malzeme, uygulama, nakliye ve zemin hazırlığı maliyetlerinin analiz edilmesiyle ve birim alan başına düşen toplam maliyetin (dolar (\$), euro (€) ya da TL (₺) olarak) hesaplanmasıyla belirlenmektedir.

Hizmet ömrü kriteri; bir malzemenin ondan beklenen özelliklerin (kaymazlık, su geçirmeme vb.) kaybetmeden ne kadar süre kullanılabilirliği. Hizmet ömrü uzun olan bir döşeme kaplama malzemesi uzun yıllar boyunca büyük bir onarıma ya da değişime ihtiyaç olmadan kullanılabilir. Ayrıca yüksek yatırım maliyetli bir malzemenin hizmet ömrü bir diğer alternatif malzemeye göre daha uzun ise o malzeme, aynı ya da daha düşük yatırım maliyetli alternatif malzemeye göre uzun vadede maliyet yönünden daha avantajlı olacaktır. Bina kullanımında ekonomik verimlilik göz önüne alındığında hizmet ömrü kriteri önemli bir konudur. Bu kriter, üreticilerin ilgili döşeme kaplama malzemelerinin hizmet ömrüyle ilgili yaptıkları testler ve değerlendirmeler sonucu yayınladıkları raporlar doğrultusunda karşılaştırılabilir.

Malzemenin aşınma ve yıpranma kriteri; döşeme kaplama malzemesinin kullanım yoğunluğuna bağlı olarak dayanıklılığını göstermektedir (Derler ve diğ., 2015). Özellikle sirkülasyonun yoğun olduğu mekanlarda dayanıklılığı yüksek kaplama malzemeleri tercih

edilmelidir. Bu sayede kaplama malzemesinin kullanım süresi boyunca estetik ve fonksiyonel açıdan bozulmaması sağlanacaktır (Silva ve diğ., 2004). Bu kriter; üreticilerin döşeme kaplama malzemelerine, ilgili standartlar kapsamında dayanıklılık ve aşınma ile ilgili yaptıkları testlerin sonuçları aracılığıyla karşılaştırılabilmektedir (TS EN 14411, 2013; TS EN 14342, 2009). Bu karşılaştırma sonucunda malzemelerin aşınma ve yıpranma kriterleri kullanıcılar ya da malzeme seçimi yapan kişiler tarafından “yüksek”, “orta” ve “düşük” şeklinde ifade edilebilmektedir.

İşletme maliyetleri etki kriteri; bir malzemenin kullanım aşamasındaki temizlenme, bakım ve onarım maliyetleridir (Tikul, 2014; Heralová, 2011). Binanın maliyet; işletme süresince döşeme kaplama malzemesinin görevini yerine getirebilmesi için yapılan temizlik, bakım ve onarım sırasında harcanan elektrik, su vb. harcamalarını da kapsamaktadır. Bu maliyetler gerektiği durumlarda tek seferlik olabileceği gibi düzenli aralıklarla da ortaya çıkabilmektedir. Bu kriter, üreticilerin ilgili döşeme kaplama malzemeleriyle ilgili yayınladıkları bakım, onarım ve temizlik tariflerini içeren teknik şartnameler doğrultusunda hesaplanabilmektedir. Döşeme kaplama malzemelerinin işletme maliyetleri, birim alana düşen maliyet (dolar (\$), euro (€) ya da TL (₺)) bazında karşılaştırılabilmektedir.

Kullanıcı konforu kriteri; görsel, işitsel, dokunsal konfor kapsamında estetik, renk, doku, ses yalıtımı, ısı yalıtımı, kaymazlık gibi özellikler üzerinden değerlendirilmektedir (Abeyundara ve diğ., 2009; Kim, 2018; Kim, 2025; Carvalho ve diğ., 2021; Waluś ve diğ., 2022). Bu kriter; döşeme kaplama malzemelerin taşıdığı bu özellikler bütününde yapılan değerlendirmeler sonucunda ortaya çıkmaktadır. Kullanıcı konforunun değerlendirilmesinde, üretici teknik dokümanları ilgili standart ve yönetmelik değerleri ile karşılaştırılarak belirlenebildiği gibi, kullanıcı anketleriyle de belirlenebilmektedir. Yapılan değerlendirmeler öznel nitelik taşıdığından, kullanıcı konforu kriteri, kullanıcılar ya da malzeme seçimi yapan kişiler tarafından “yüksek”, “orta” ve “düşük” şeklinde ifade edilebilmektedir (Tuscher ve diğ., 2024).

Çevresel etki kriteri; bir malzemenin üretim, kullanım ve imha süreçlerindeki karbon ayak izi ve çevre zararını kapsamaktadır (Nicoletti ve diğ., 2002). Bu yüzden döşeme kaplama malzemeleri seçiminde geri dönüştürülebilir sürdürülebilir malzemelerin tercih edilmesi büyük önem taşımaktadır. Bu kriter kapsamında; döşeme kaplama

malzemelerin yaşam döngüsü değerlendirilmesi Bina Bilgi Modellemesi (BIM) aracılığıyla yapılabilmektedir (Tuscher ve diğ., 2024). Bir döşeme kaplama malzemesinin yaşam döngüsü boyunca neden olduğu toplam sera gazı emisyonlarının hesaplanmasıyla ölçülen karbon ayak izi, karbondioksit eş değeri (CO₂e) biriminde ifade edilmektedir. Ölçüm için genellikle Yaşam Döngüsü Değerlendirmesi (LCA) yöntemleri ve ISO 14040 ve EN 15804 gibi uluslararası standartlar kabul edilmektedir (Jijnsson ve diğ., 1997; Almeida ve diğ., 2016; EN 15804, 2008; TS EN ISO 14040, 2007).

3. DÖŞEME KAPLAMA MALZEMELERİ (FLOOR COVERING MATERIALS)

Ahşap, seramik, halı, PVC, vinil ve mantar ofis yapılarında yaygın olarak kullanılan döşeme kaplama malzemeleridir. Bu malzemeler; yatırım maliyeti, hizmet ömrü, aşınma ve yıpranma özelliği, işletme maliyeti, kullanıcı konforu ve çevresel etki kriterleri kapsamında farklı özellikler gösterebilmektedir (Ros-Dosdá ve diğ., 2019). Bu farklar; Tuscher, Hanák, Navrátilová ve Tichá'nın kaleme aldığı, "Usage of Building Passports and BIM in Multi-Criteria Evaluation" başlıklı, makalede yer alan farklı döşeme kaplama malzemelerine ait seçim kriter değerleri baz alınarak, aşağıdaki tablo aracılığıyla karşılaştırılmalı olarak ifade edilmiştir (Tuscher ve diğ., 2024) **(Tablo 1)**.

Tablo 1'de halı, vinil, seramik, PVC, mantar ve ahşap döşeme kaplama malzemelerinin yatırım maliyeti, €/m² cinsinden verilmiştir. Yatırım maliyeti açısından ahşap (77,6 €/m²) en yüksek maliyeti taşıırken, halı (15,20 €/m²) en düşük yatırım maliyetli döşeme kaplama malzemesidir. Yıl olarak ifade edilen hizmet ömürleri bakımından seramik (40 yıl) en uzun hizmet ömrüne sahipken, halı (10 yıl) en kısa hizmet ömrüne sahiptir. Aşınma ve yıpranma özelliği açısından "yüksek", "orta" ve "düşük" olarak derecelendirilen döşeme kaplama malzemeleri arasından; halı ve PVC kaplama en yüksek aşınma etkisi gösterirken, ahşap ve seramik en düşük aşınma göstermektedir. Döşeme kaplama malzemelerinin işletme maliyetleri €/m² cinsinden verilmiş olup, ahşap ve mantar (9,9€/m²) en yüksek, seramik (2,4 €/m²) en düşük işletme maliyetine sahiptir. Kullanıcı konforu açısından yine "yüksek", "orta" ve "düşük" olarak derecelendirilen döşeme kaplama malzemeleri arasından; mantar ve ahşap yüksek, PVC ve seramik düşük kullanıcı konforu seviyesine sahiptir. Döşeme kaplama malzemeleri çevresel etkileri bakımından kgCO₂/m² cinsinden değerlendirildiğinde ise halının

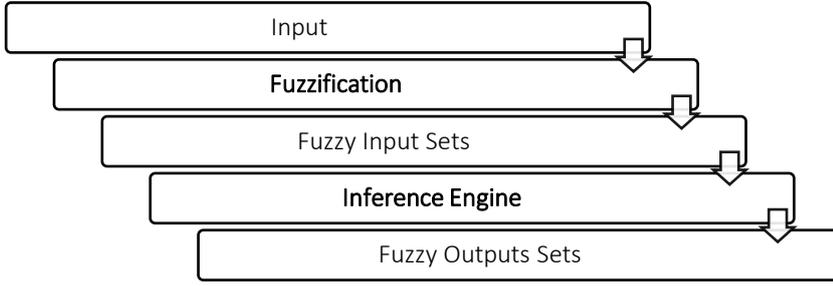
(1,52 €/m²) en düşük, seramiğin en yüksek (6,39 €/m²) çevresel etkiye sahip olduğu görülmektedir.

Döşeme Kaplama Malzemesi Seçim Kriteri	Halı	Vinil	Seramik	PVC	Mantar	Ahşap
Yatırım Maliyeti (€/m ²)	15,2	32,6	54,4	25,95	61,15	77,6
Hizmet Ömrü (yıl)	10	40	50	20	40	40
Aşınma ve Yıpranma Özelliği	Yüksek	Orta	Düşük	Yüksek	Orta	Düşük
İşletme Maliyeti (€/m ²)	4,4	6,9	2,4	6,9	9,9	9,9
Kullanıcı Konforu	Orta	Orta	Düşük	Düşük	Yüksek	Yüksek
Çevresel Etki (kgCO ₂ /m ²)	1,52	5,43	6,39	3,83	3,26	3,11

Tablo 1: Döşeme Kaplama Malzemelerinin Seçim Kriterleri (Selection Criteria for Flooring Materials) (Tuscher ve diğ., 2024).

4. BULANIK MANTIK (FUZZY LOGIC)

Bulanık mantık L. Askerzadeh tarafından tanımlanan, kesin bir şekilde ifade edilemeyen belirsizlik içeren önermeleri matematiksel olarak tanımlayan bir sistemdir (Pakdamar ve Güler, 2012). Klasik mantık net ve keskin sınırlara sahipken bulanık mantıkta yaklaşıklık mevcuttur. İkili sistem üzerine kurulu klasik mantıkta, bir ifade ya “doğru” (1) ya da “yanlış” (0)’tır. Bu yüzden belirsiz veya karmaşık durumlar bu mantıkta modellenememektedir. Bulanık mantıkta ise elemanların bir kümeye üyeliği, 0 ile 1 arasında bir değer alır ve bu sayede belirsiz ya da karmaşık durumlar bu yaklaşımla modellenebilir. Bu yaklaşım insan beyninin düşünme sistemine benzeyen bir yapıya sahiptir. Girdiler ve çıktılar üyelik fonksiyonları aracılığıyla bulanıklaştırılır (fuzzification). Girdiler ve çıktılar arasındaki bilinen ilişkiler kural cümleleriyle tanımlanır. Bulanık çıktı değerleri, ihtiyaç olması durumunda ağırlık merkezi bulma gibi yöntemlerle kesin bir sonuca dönüştürülür (defuzzification) (**Şekil 1**) (Zadeh, 1968).



Şekil 1: Bulanık Mantık Süreci Akış Şeması (Fuzzy Logic Process Flowchart).

5. BULANIK KÜMELERLE ÜYELİK FONKSİYONLARININ TANIMLANMASI (BULANIKLAŞTIRMA) (IDENTIFICATION OF MEMBERSHIP FUNCTIONS WITH FUZZY SETS (FUZZIFICATION))

Ofis mekanlarında döşeme kaplama malzemesinin bulanık kümeler kullanılarak seçimi sürecinde hazırlanacak model, Tablo 1’de yer alan malzeme seçim kriterleri ve kaplama malzemesi değer kümeleri üzerinden hazırlanmıştır. Modelin doğru çalışabilmesi amacıyla çakışan veri ve farklı sayıda değer kümesi olmayacak şekilde girdi ve çıktılar belirlenmiştir. Her bir çıktı için tam kesinlikte ve çakışmasız bir kural tabanı oluşturulabilmesi amacıyla, referans makale verilerindeki bazı malzeme alternatiflerinin ortak girdi değerlerine ve bazı kriterlerin düşük üyelik fonksiyonlu küme sayısına sahip olmasından kaynaklanan çakışmaları gidermek için model kapsamı optimize edilmiştir. Bu nedenle Tablo 1’de aynı hizmet ömrüne sahip ahşap, mantar ve vinil malzemeleri arasında model için doğal zemin kaplamaları arasında en temsili ve yaygın malzeme olan ahşap malzeme model kapsamına dahil edilmiş, mantar ve vinil malzeme modele dahil edilmemiştir. Seçim kriterleri arasından; aşınma ve yıpranma özelliği ile kullanıcı konforu kriterlerinin diğer kriterlere kıyasla düşük üyelik fonksiyonu küme sayısına sahip olmaları nedeniyle bu kriterler modele dahil edilmemiştir. Bu doğrultuda yatırım maliyeti (€/m²), hizmet ömrü (yıl), işletme maliyeti (€/m²) ve çevresel etki kriterleri (kgCO₂/m²) modelin girdi parametrelerini; halı, seramik, PVC ve ahşap kaplama malzemeleri ise modelin çıktı parametrelerini oluşturmaktadır.

Modelin girdi parametrelerini oluşturan seçim kriterleri, bulanık mantık kümeleriyle tanımlanmış, malzeme değer kümeleri üzerinden her bir seçim kriteri sınıfına, üçgen üyelik fonksiyonları tanımlanarak bulanıklaştırma işlemi yapılmıştır. Referans makaleden alınan malzeme değer kümelerine, bulanık mantık uygulaması doğrultusunda veri

işleme temelinde bulanıklaştırma işlemi yapılmış, üçgen fonksiyonların minimum, maksimum ve tepe noktaları belirlenmiştir. Yatırım maliyeti (€/m²) için dört kriter sınıfı belirlenmiş olup, 1. derece en yüksek, 4. derece ise en düşük maliyet sınıfını ifade etmektedir. Hizmet ömrü (yıl) için dört kriter sınıfı belirlenmiş, 1. derece en uzun, 4. derece ise en kısa hizmet ömrü sınıfını ifade etmektedir. İşletme maliyeti (€/m²) dört kriter sınıfı belirlenmiş olup, 1. derece en yüksek, 4. derece ise en düşük işletme maliyeti sınıfını ifade etmektedir. Çevresel Etki (kgCO₂/m²) için dört kriter sınıfı belirlenmiş, 1. derece en yüksek, 4. derece ise en düşük çevresel etkiyi ifade etmektedir (**Tablo 2**).

Model Girdi Parametreleri			
Döşeme Kaplama Malzemesi Seçim Kriteri	Kriter Sınıfı	Malzeme Değer kümeleri	Tanımlanan üçgen üyelik fonksiyonları
Yatırım Maliyeti (€/m ²)	1.derece	77,6	[40.18 66 1e+04]
	2.derece	54,4	[20.58 40.18 66]
	3.derece	25,95	[7.6 20.58 40.18]
	4.derece	15,2	[-1e+04 7.6 20.58]
Hizmet Ömrü (yıl)	1.derece	50	[30 45 1e+04]
	2.derece	40	[15 30 45]
	3.derece	20	[5 15 30]
	4.derece	10	[-1e+04 5 15]
İşletme Maliyeti (€/m ²)	1.derece	9,9	[5.651 8.4 1e+04]
	2.derece	6,9	[3.4 5.651 8.4]
	3.derece	4,4	[1.2 3.4 5.651]
	4.derece	2,4	[-1e+04 1.2 3.4]
Çevresel Etki (kgCO ₂ /m ²)	1.derece	6,39	[3.47 5.11 1e+04]
	2.derece	3,83	[2.16 3.47 5.11]
	3.derece	3,11	[0.76 2.16 3.47]
	4.derece	1,52	[-1e+04 0.76 2.16]

Tablo 2: Bulanık Kümelerle Üyelik Fonksiyonlarının Tanımlanması-Girdi (Defining Membership Functions with Fuzzy Sets-Input) .

Model Çıktı Parametreleri		
Döşeme Kaplama Malzemeleri	Kriter Sınıfı	Tanımlanan üçgen üyelik fonksiyonları
Halı	Halı	[0 <u>100</u> 200]
	Halı_değil	[-100 <u>0</u> 100]
Seramik	Seramik	[0 <u>100</u> 200]
	Seramik_değil	[-100 <u>0</u> 100]
PVC	PVC	[0 <u>100</u> 200]
	PVC_değil	[-100 <u>0</u> 100]
Ahşap	Ahşap	[0 <u>100</u> 200]
	Ahşap_değil	[-100 <u>0</u> 100]

Tablo 3: Bulanık Kümelerle Üyelik Fonksiyonlarının Tanımlanması- Çıktı (Defining Membership Functions with Fuzzy Sets-Output).

Modelin çıktı parametrelerini oluşturan her bir döşeme kaplama malzemesi için kriter sınıfı belirlenmiş ve üçgen üyelik fonksiyonu tanımlanmıştır. Her bir döşeme kaplama malzemesi için iki kriter sınıfı belirlenmiştir. Bu kriter sınıflarından biri örneğin halı malzemesi için halı seçme durumunu, diğeri ise seçmeme durumunu ifade etmektedir (Tablo 3).

6. PROBLEMİN KURALLARININ YÖNTEME UYARLANMASI (ADAPTING THE RULES OF THE PROBLEM TO THE METHOD)

Üyelik fonksiyonları aracılığıyla bulanıklaştırılan seçim kriteri verileri, bulanık mantığın “veya” kural sistemine göre aşağıdaki gibi oluşturulmuştur.

- Kural:** IF (Yatırım_Maliyeti_(€/m²) is 4.derece) OR (Hizmet_Ömrü(yıl) is 4.derece) OR (İşletme_Maliyeti(€/m²) is 3.derece) OR (Çevresel_Etki(kgCO₂/m²) is 4.derece) THEN (Halı is Halı) (Seramik is Seramik_değil)(PVC is PVC_değil)(Ahşap is Ahşap_değil) (1)
- Kural:** IF(Yatırım_Maliyeti_(€/m²) is 2.derece) OR (Hizmet_Ömrü(yıl) is 1.derece) OR (İşletme_Maliyeti(€/m²) is 4.derece) OR (Çevresel_Etki(kgCO₂/m²) is 1.derece) THEN (Halı is Halı_değil) (Seramik is Seramik)(PVC is PVC_değil)(Ahşap is Ahşap_değil) (1)

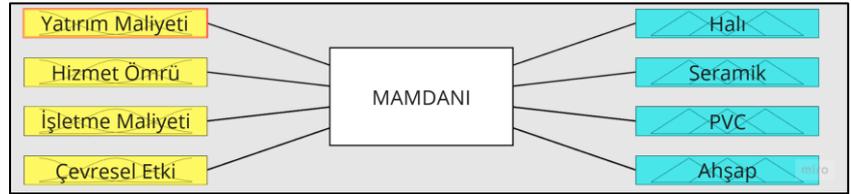
3. **Kural:** IF(Yatırım_Maliyeti_(€/m²) is 3.derece) OR
(Hizmet_Ömrü(yıl) is 3.derece) OR
(İşletme_Maliyeti(€/m²) is 2.derece) OR
(Çevresel_Etki(kgCO₂/m²) is 2.derece) THEN
(Halı is Halı_değil)(Seramik is Seramik_değil)(PVC is PVC)(Ahşap is Ahşap_değil) (1)

4. **Kural:** IF(Yatırım_Maliyeti_(€/m²) is 1._derece) OR
(Hizmet_Ömrü(yıl) is 2.derece) OR
(İşletme_Maliyeti(€/m²) is 1.derece) OR
(Çevresel_Etki(kgCO₂/m²) is 3.derece) THEN
(Halı is Halı_değil)(Seramik is Seramik_değil)(PVC is PVC_değil)(Ahşap is Ahşap) (1)

7. MODELLEME VE DURULAŞTIRMA (MODELING AND DEFUZZIFICATION)

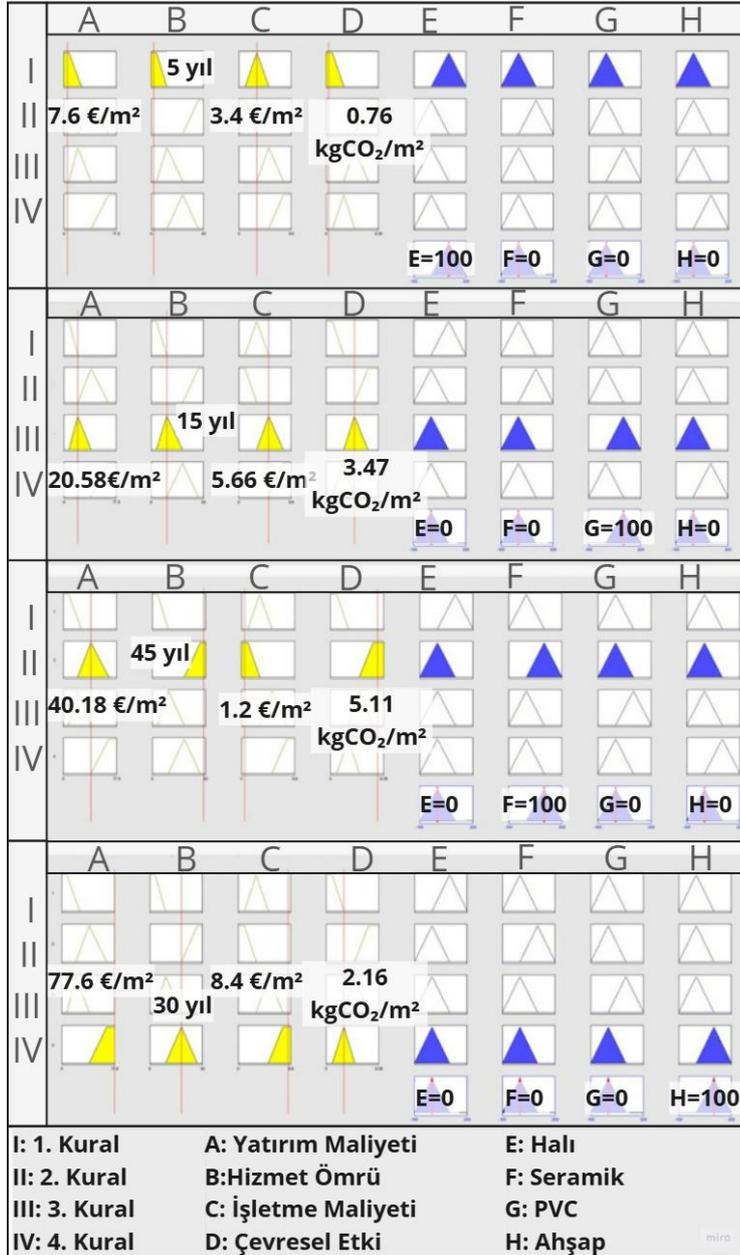
Döşeme kaplama malzemesi seçim kriterleri, belirlenen parametre aralığına göre Matlab'de girdi oluşturacak şekilde Mamdani çıkarım sisteminde modellenmiştir. Döşeme kaplama malzemesi alternatiflerinin çıktı olarak düzenlendiği modelde bir önceki bölümde yonteme uyarlanan problem kuralları modele dahil edilmiş ve model oluşturulmuştur (Şekil 2).

Şekil 2: Belirlenen Girdi ve Çıktıların Mamdani Çıkarım Sisteminde Modellenmesi, Matlab Arayüzü (Modeling of Specified Inputs and Outputs in Mamdani Inference System, Matlab Interface).



Oluşturulan modelde, modelin çalıştığını doğrulamak amacıyla ayrı ayrı tüm çıktılarına tanımlanan üçgen fonksiyon aralığında 100 değerini verecek kurallar denenerek gerekli kontroller yapılmıştır. Halı için yatırım maliyeti 7.6 €/m², hizmet ömrü 5 yıl, işletme maliyeti 3.4 €/m² ve çevresel etki değeri 0.76 kgCO₂/m² olarak girilmiş ve “Halı=100, Seramik=0, PVC=0, Ahşap=0” sonucu elde edilmiştir. PVC için yatırım maliyeti 20.58 €/m², hizmet ömrü 15 yıl, işletme maliyeti 5.65 €/m² ve çevresel etki değeri 3.47 kgCO₂/m² olarak girilmiş ve “Halı=0, Seramik=0, PVC=100, Ahşap=0” sonucu elde edilmiştir. Seramik için yatırım maliyeti 40.18 €/m², hizmet ömrü 45 yıl, işletme maliyeti 1.2 €/m² ve çevresel etki değeri 5.11 kgCO₂/m² olarak girilmiş ve “Halı=0, Seramik=100, PVC=0, Ahşap=0” sonucu elde edilmiştir. Ahşap için

yatırım maliyeti 77.6 €/m², hizmet ömrü 30 yıl, işletme maliyeti 8.4 €/m² ve çevresel etki değeri 2.16 kgCO₂/m² olarak girilmiş ve “Halı=0, Seramik=0, PVC=0, Ahşap=100” sonucu elde edilmiştir. Girilen değerlere göre elde edilen sonuçları oluşturan modelin doğru çalıştığını göstermektedir (Şekil 3).



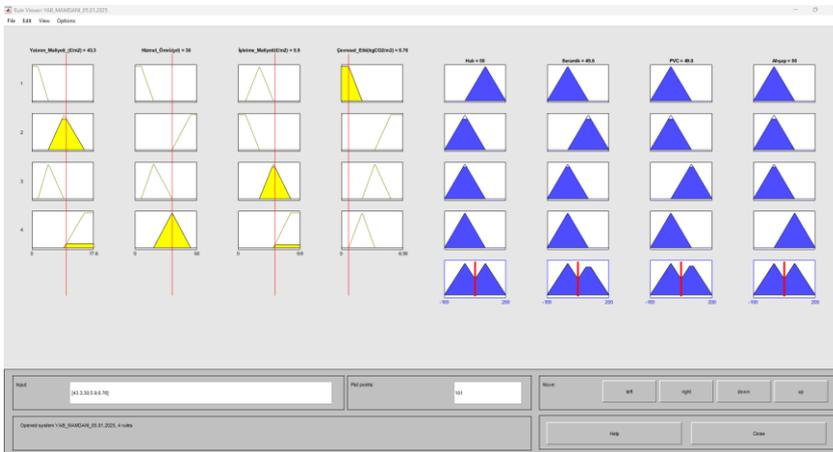
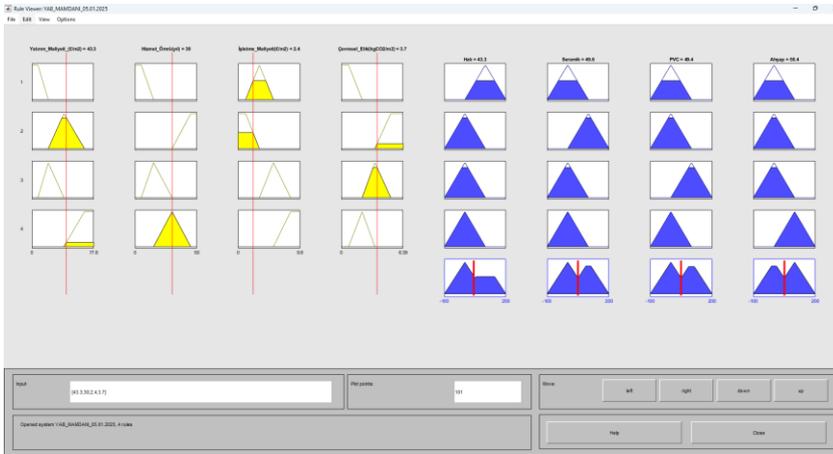
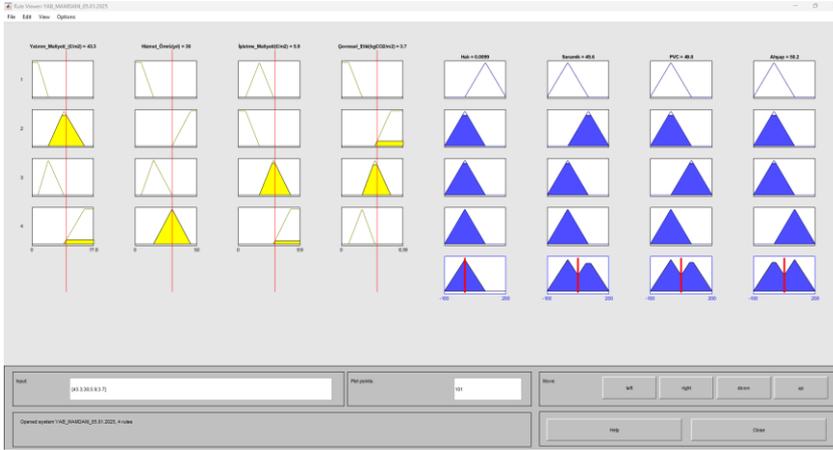
Şekil 3: Modelin Kontrol Edilmesi, Matlab Arayüzü (Checking the Model, Matlab Interface).

8.BELİRLENEN KRİTERLER KAPSAMINDA TERCİH SENARYOLARI (PREFERENCE SCENARIOS WITHIN THE SCOPE OF DETERMINED CRITERIA)

Hazırlanan modelde denenmek üzere üç farklı senaryo belirlenmiştir. 1.senaryoda seçim kriterleri üzerinden dengeli; 2. senaryoda işletme maliyeti odaklı, 3. senaryoda ise çevre odaklı bir yaklaşım benimsenmiştir. 1. senaryoda yatırım maliyeti 43.3 €/m², hizmet ömrü 30 yıl, işletme maliyeti 5.9 €/m² ve çevresel etki değeri 3.7 kgCO₂/m² olarak girilmiş ve “Halı=0, Seramik=49.6, PVC=49.8, Ahşap=50.2” sonucu elde edilmiştir. 2. senaryoda yatırım maliyeti 43.3 €/m², hizmet ömrü 30 yıl, işletme maliyeti 2.4 €/m² ve çevresel etki değeri 3.7 kgCO₂/m² olarak girilmiş ve “Halı=43.3, Seramik=49.6, PVC=49.4, Ahşap=50.4” sonucu elde edilmiştir. 3. senaryoda yatırım maliyeti 43.3 €/m², hizmet ömrü 30 yıl, işletme maliyeti 5.9 €/m² ve çevresel etki değeri 0.76 kgCO₂/m² olarak girilmiş ve “Halı=50, Seramik=49,6, PVC=49.8, Ahşap=50” sonucu elde edilmiştir (**Şekil 4**).

Seçim kriterleri üzerinden dengeli bir yaklaşım benimsenen 1. senaryoda en uygun seçimin ahşap sonrasında sırasıyla PVC ve seramik olduğu görülmüştür. Bu senaryoda halının uygun bir seçim olmadığı görülmüştür. İşletme maliyeti odaklı oluşturulan 2. senaryoda ise en uygun seçimin ahşap sonrasında sırasıyla seramik, PVC ve halı olduğu görülmüştür. Çevre odaklı oluşturulan 3. senaryoda ise en uygun seçimin ahşap ve halı sonrasında sırasıyla seramik ve PVC olduğu görülmüştür.

Döşeme kaplaması alternatiflerine bakıldığında, seçim kriterlerine göre her malzemenin kendine özgü avantajlı ve dezavantajlı yönleri olduğu görülmektedir. Fakat tüm senaryolara bakıldığında ağırlıklı olarak ahşabın en uygun kaplama malzemesi olduğu görülmüş, halının ise 3. senaryoda ahşapla birlikte en uygun kaplama malzemesi alternatifi olduğu görülmüştür.



Şekil 4: Senaryo 1,2,3, Matlab Rule Viewer Arayüzü (Scenarios 1,2,3, Matlab Rule Viewer Interface).

Çalışmada; model girdilerindeki hassas değişiklerin çıktı üzerindeki etkilerini incelemek için tercih edilen $\pm 10\%$ duyarlılık analizi uygulanmıştır. Mevcut senaryo değerlerinde $\pm 10\%$ değişiklikler

yapılarak veriler modele girilmiş, sonuçlar mevcut senaryo değerleriyle karşılaştırılmıştır. Çıkan sonuçların eşleşme durumuna göre TP(Doğru Pozitif), TN(Doğru Negatif), FP(Yanlış Pozitif), FN (Yanlış Negatif) değerleri üzerinden hesaplamalar yapılmıştır. Yapılan hesaplamalar sonucunda; modelin doğruluk oranı (Accuracy) 0.667, kesinlik (Precision) 1, duyarlılık (Recal) 0.667 ve F1 skoru 0.8 olarak bulunmuştur. Sonuçlar doğrultusunda modelin genel olarak güvenilir olduğu ancak küçük kriter değişimlerinde alternatifler arasında kaymaların olabildiğini görülmüştür. Bu kayma modelin tutarsızlığından değil, alternatiflerin birbirine yakınlığından kaynaklanması sebebiyle modelin kriterlere duyarlılığını ortaya koymaktadır (**Tablo 4, 5, 6, 7**).

Tablo 4: Mevcut Senaryo Verileri (Current Scenario Data).

Mevcut Senaryo Verileri					
Senaryo	Yatırım Maliyeti	Hizmet Ömrü	İşletme Maliyeti	Çevresel Etki	Tahmin (max puan)
1	43,3	30	5,9	3,7	Ahşap
2	43,3	30	2,4	3,7	Ahşap
3	43,3	30	5,9	0,76	Halı

Tablo 5: ±%10 Değişim Tablosu (±10% Change Table).

±%10 Değişim Tablosu					
Senaryo	Yatırım Maliyeti(-%10)	Hizmet Ömrü (+%10)	İşletme Maliyeti (-%10)	Çevresel Etki (-%10)	Varyasyon Tahmini (max puan)
1a	38,97	33	5,31	3,33	Seramik
2a	38,97	33	2,16	3,33	Seramik
3a	38,97	33	5,31	0,684	Halı
Senaryo	Yatırım Maliyeti(+%10)	Hizmet Ömrü (-%10)	İşletme Maliyeti (+%10)	Çevresel Etki (+%10)	Varyasyon Tahmini (max puan)
1b	47,63	27	6,49	4,07	Ahşap
2b	47,63	27	2,64	4,07	Ahşap
3b	47,63	27	6,49	0,836	Halı

Senaryo	Tahmin (max puan)	Varyasyon Tahmini (max puan)	±%10 Değişim Senaryoları
1	Ahşap	Seramik*	1a
		Ahşap	1b
2	Ahşap	Seramik*	2a
		Ahşap	2b
3	Hali	Hali	3a
		Hali	3b
TP:4	FN*:2	FP:0	TN:0

Tablo 6: Model Tahmin ve Varyasyon Sonuçlarının Karşılaştırılması (Comparison of Model Estimation and Variation Results).

Accuracy	$(TP+TN)/\text{Toplam}$	$(4+0)/6$	0.667	%66.7
Precision	$TP/(TP+FP)$	$4/(4+0)$	1	100%
Recall	$TP/(TP+FN)$	$4/(4+2)$	0.667	%66.7
F1	$(2 \times TP)/(2TP+FP+FN)$	$2 \times (1 \times 0,667)/(1+0,667)$	0,8	80%

Tablo 7: F1 Skor tablosu (F1 Scoreboard).

9. SONUÇ (CONCLUSION)

Çalışmada ofis mekanlarında yaygın olarak kullanılan kaplama malzemelerinin seçiminde bulanık mantık yaklaşımı kullanılarak, malzeme alternatiflerinin yatırım maliyet, hizmet ömrü, işletme maliyeti ve çevresel etki kriterleri açısından değerlendirilmesi sağlanmıştır. Girdi olarak belirlenen seçim kriterlerine ve çıktı olarak belirlenen kaplama malzemelerine referans alınan malzeme değer kümeleri kapsamında bulanık kümelerle tanımlanmıştır. Bu veriler ışığında Matlab’de belirlenen tanımlanan kurallar doğrultusunda farklı senaryolara göre malzeme seçim sıralaması yapılmıştır. 3 farklı senaryoya göre yapılan değerlendirmeler sonucunda; ahşabın her 3 senaryo, içinde ağırlıklı en uygun tercih olduğu görülmüştür. Halinin 3. Senaryo için ahşap ile PVC ve seramiğe göre daha uygun malzemeler olduğu görülmüştür. Düşük çevresel etki ve yatırım maliyeti değerinden dolayı avantajlı, hizmet ömrü açısından dezavantajlı olan halinin daha farklı senaryolar için uygun bir malzeme olabileceği saptanmıştır. Seramik ise uzun hizmet ömrü ve düşük işletme maliyeti açısından avantajlı bir malzemeyken, çevresel etki değerinden dolayı dezavantajlı bir malzeme olduğu görülmektedir. Tüm bu avantaj ve dezavantajlar, bulanık mantık sayesinde birlikte değerlendirilmiş ve bu sayede uygun tercih sırası elde edilmiştir.

Çalışma bulanık mantık modelinin çok kriterli karar verme süreçlerinde etkili bir yöntem olduğunu göstermiştir. Bulanık mantığın kullanılması “doğru (1)” ve “yanlış (0) olarak keskin değerlendirmeler yapan klasik mantıklı bilgisayar seçim sisteminin aksine tıpkı insan beyni gibi birçok kriteri birlikte ele alarak değerlendirme yapılmasını sağlamıştır. Sonuç olarak ofis mekanların döşeme kaplama malzemesi seçim sürecinde bulanık mantık yaklaşımının kullanılması daha gerçekçi bir karar süreci oluşturulmuştur.

Günümüzde; malzeme seçimi sürecinde çok boyutlu ve birbirinden bağımsız gibi görünen kriterlerin doğru ve esnek bir karar mekanizmasıyla ele alınması, döngüsel ekonomi ve yenilikçi tasarım yaklaşımlarının hayata geçirilmesinde büyük bir öneme sahiptir. Bulanık mantık yaklaşımıyla oluşturulan döşeme kaplama malzemesi seçim modeli sayesinde malzemelerin; çevresel etkileri, hizmet ömürleri, işletme ve yatırım maliyetleri birlikte değerlendirilerek hem çevresel hem de ekonomik sürdürülebilirliğin sağlanması konusunda güçlü bir araç olarak değerlendirilebilir. Model kapsamı, her çıktı için çakışmasız bir kural tabanı oluşturulmasını sağlamak amacıyla malzeme alternatifleri ve seçim kriterleri açısından optimize edilmiş olup; daha

yüksek hassasiyetli ve ayırt edici bir veri seti kullanılması durumunda ise değişkenlerin modele kolayca entegresi mümkündür. Bu sayede model diğer mimarlık, mühendislik karar verme süreçlerine entegre edilmesinin de önünü açmaktadır. Gelecek çalışmalarda, bu çalışmada varsayımsal olarak oluşturulan senaryoların vaka çalışmalarıyla desteklenmesi modelin mimari gerçeklikle ilişkisini güçlendirecektir. Bu bağlamda ileride yapılacak çalışmalarda; oluşturulan model üzerinden yapılabilecek geliştirmeler sayesinde, inşaat sektöründe sürdürülebilir malzeme kullanımının artırılması konusuna daha fazla katkı sağlanabilecektir.

Çıkar Çatışması Beyanı (Conflict of Interest)

"Ofis Mekanlarında Döşeme Kaplama Malzemesinin Bulanık Kümeler Kullanılarak Seçimi " başlıklı yazı başka bir yerde yayınlanmamıştır ve başka bir yerde aynı anda yayınlanmak üzere gönderilmemiştir

Yazar Katkısı (Author contribution)

Bu makalede tüm yazarlar eşit oranda katkı sağlamıştır.

Yapay Zekâ Kullanım Beyanı (AI Use Disclosure)

Bu makalenin hazırlanması sürecinde üretken yapay zekâ veya YZ destekli araçlar dil düzenleme, metin kontrolü amacıyla kullanılmıştır. Hiçbir YZ aracı bilimsel fikir üretimi, veri analizi, yorumlama veya özgün araştırma içeriği oluşturma amacıyla kullanılmamıştır. YZ tarafından sağlanan tüm öneriler makalenin bütünlüğü ve özgünlüğü kapsamında yazar tarafından gözden geçirilip, onaylanmıştır.

Referanslar (References)

- Abeyundara, U.G.Y., Babel, S., Piantanakulchai M. (2009). A matrix for selecting sustainable floor coverings for buildings in Sri Lanka. *Journal of Cleaner Production*, 17, 231-238.
<https://10.1016/j.jclepro.2008.05.002>
- Ajusree, P.A., Jenson, J. (2020). Environmental and Economic Impact Assessment of Flooring Materials. *Springer Nature Switzerland AG*
https://doi.org/10.1007/978-3-030-26365-2_8
- Alibaba, H.Z., Özdeniz M. B., (2004). Abuilding elements selection system for architects. *Building and Environment*, 39, 307-316.
<https://10.1016/j.buildenv.2003.09.010>
- Almeida, M. I., Dias, A. C., Demertzi M., Arroja, L. (2016). Environmental profile of ceramic tiles and their potential for improvement. *Journal of*

Cleaner Production, 131, 583-593.
<http://dx.doi.org/10.1016/j.jclepro.2016.04.131>

Athawale, V. M., Chakraborty, S. (2012). Material selection using multi-criteria decision-making methods: a comparative study. *Design and Applications*, 226(4), 266–285.
<https://doi.org/10.1177/146442071244897>

Cao, S. (2023). A Review of Decision Theory and Methods. *The Frontiers of Society, Science and Technology*, 5, 3, 58-63.
<https://10.25236/FSST.2023.050311>

Carvalho, C., Couceir O., M., Montagna, G., Morais, C., Mendonça, R. (2021). Textiles in Architecture: Floors and Wall Coverings. *Lecture Notes in Networks and Systems* 260, 632–637. https://doi.org/10.1007/978-3-030-80829-7_78

Derler, S., Huber, R., Kausch, F., Meyer, V.R. (2015). Effectiveness, durability and wear of anti-slip treatments for resilient floor coverings. *Safety Science*, 76, 12–20. <http://dx.doi.org/10.1016/j.ssci.2015.02.002>

EN 15804, (2008). *Sustainability Of Construction Works - Environmental Product Declarations - Product Category Rules*.

Hall, W. (1997). *Floring*. Time-Saver Standards for Architectural Design Data, C-79.

Heralová, R. S. (2011). *Life cycle costing as innovative a decision-making tool in the construction design phase*. Business & IT, 1, 46-62.

Hwang, C., Yoon, K. Multiple Attribute Decision Making Methods and Applications. *Lecture Notes in Economics and Mathematical Systems*.

Jönsson, A., Tillman, A. M., Svensson, T. (1997). Life Cycle Assessment of Flooring Materials: Case Study. *Building and Environment*, 32, 3, 245-255.

Kim, I. (2025). Surface engineering for safer walking environments: Optimising floor coatings for enhanced slip resistance. *Results in Engineering*, 25, 103987. <https://doi.org/10.1016/j.rineng.2025.103987>

Kim, I. (2018). Investigation of Floor Surface Finishes for Optimal Slip Resistance Performance. *Safety and Health at Work*, 9, 17-24.
<http://dx.doi.org/10.1016/j.shaw.2017.05.005>

Mahmoud, M. A. A., Aref, M., Al-Hammad, A. An Expert System for Evaluation and Selection of Floor Finishing Materials. *Expert Systems With Applications*, 10, 2, 281-303.

Nicoletti, G. M., Notarnicola B., Tassielli G. (2002). Comparative Life Cycle Assessment of flooring materials: ceramic versus marble tiles. *Journal*

of *Cleaner Production*, 10, 283-296. [https://doi.org/10.1016/S0959-6526\(01\)00028-2](https://doi.org/10.1016/S0959-6526(01)00028-2)

Nicoletti, G. M., Notarnicola B., Tassielli G. (2002). Comparative Life Cycle Assessment of flooring materials: ceramic versus marble tiles. *Journal of Cleaner Production*, 10, 283-296. [https://doi.org/10.1016/S0959-6526\(01\)00028-2](https://doi.org/10.1016/S0959-6526(01)00028-2)

Nguyen, P.H.D, Fayek, A.R. (2022). Applications of fuzzy hybrid techniques in construction engineering and management research. *Automation in Construction*, 134. <https://doi.org/10.1016/j.autcon.2021.104064>

Opricovic, S., *Multicriteria Optimization of Civil Engineering Systems*.

Pakdamar, F., Güler, K. (2012). Evaluation of Flexible Performance of Reinforced Concrete Structures Using A Nonlinear Static Procedure Provided by Fuzzy Logic. *Advances in Structural Engineering*, 15, 12. <https://doi.org/10.1260/1369-4332.15.12.2173>

Reza, B., Sadiq, R., Hewage, K. (2010). Sustainability assessment of flooring systems in the city of Tehran: An AHP-based life cycle analysis. *Construction and Building Materials*, 25, 2053-2066. <https://doi.org/10.1016/j.conbuildmat.2010.11.041>

Ros-Dosdá, T., Celades I., Vilalta, L., Fullana-i-Palmer, P., Monfort, E. (2019). Environmental comparison of indoor floor coverings. *Science of the Total Environment*, 693, 133519. <https://doi.org/10.1016/j.scitotenv.2019.07.325>

Saaty, R. W. (1987). The Analytic Hierarchy Process-What And How It Is Used. *Mathl Modelling*, 9, 161-176.

Silva, G., Munoz A., Feliu C., Vicent, M. Barbera J., Soler, C. (2004). *New Method For Accelerated Evaluation Of Ceramic Floor Tile Durability On Exposure To Abrasio*. Castellon, 353-366.

Tegegne, D., Abera, m., Alemayehu E. (2023). Selection of Sustainable Building Material Using Multicriteria Decision-Making Model: A Case of Masonry Work in Lideta Subcity, Addis Ababa. *Hindawi Advances in Civil Engineering*, 1, 9729169. <https://doi.org/10.1155/2023/9729169>

Tikul, N., (2014). Environmental and Economic of Flooring Building Materials. *Applied Environmental Research*, 36, 2, 47-59.

Toydemir, N., Gürdal, E., Tanaçan, L. *Yapı Elemanı Tasarımında Malzeme*. (2000), Literatür Yayıncılık.

TS EN ISO 14040, (2007). *Çevre Yönetimi - Hayat Boyu Değerlendirme - İlkeler Ve Çerçeve*.

- TS EN 14342, (2009). *Ahşap Yer Döşemeleri – Karakteristikler, Uygunluğun Değerlendirilmesi Ve İşaretleme.*
- TS EN 14411, (2013). *Seramik Karolar - Tarifler, Sınıflandırma, Özellikler, Uygunluk Değerlendirmesi Ve İşaretleme.*
- Tuscher, M., Hanák, M., Navrátilová, V., Tichá A. (2024). Usage of Building Passports and BIM in Multi-Criteria Evaluation. *Procedia Computer Science*, 239, 1086–1094.
<https://doi.org/10.1016/j.procs.2024.06.273>
- Walus, K. J., Warguła, L., Wieczorek, B., Krawiec P. (2022). Slip risk analysis on the surface of floors in public utility buildings. *Journal of Building Engineering*, 54, 104643.
<https://doi.org/10.1016/j.jobe.2022.104643>
- Zadeh, L.A., (1994). *Making Computers Think Like People.* IEEE Spectrum.
- Zadeh, L.A., (1968). *Fuzzy Algorithms.*, Information And Control, 8, 338-353.
- Zadeh, L.A., (1965). *Fuzzy Sets.*, Information And Control, 12, 94-102.

