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BÖLÜM 1

VIRTUAL AUTONOMY: THE ISSUE OF CREATIVE FREEDOM IN ARCHITECTURE IN THE AGE OF AI

FAZIL AKDAĞ[1]

Introduction

The digital transformation of the architectural discipline is also bringing about radical changes in design processes. Algorithmic design tools, AI-powered software, and parametric modeling techniques are both expanding and challenging architects' traditional design practices. In this context, the concept of creative freedom is emerging as a newly relevant area of discussion in architecture. Especially in the age of artificial intelligence, the extent to which design decisions are attributable to the creative agency of the architect versus digital tools tends to become uncertain. Although architects have much more powerful computational tools than before, the level of autonomy/subjectivity these tools bring is debatable. On the one hand, algorithms can free the designer from routine tasks, allowing for more creative exploration; on the other hand, the partial delegation of control over the design process to

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machines raises concerns that the architect's subjective creativity could dissolve within a "virtual" autonomy.

This research aims to examine the aforementioned dilemma from a theoretical and critical perspective. It examines how the architect's creative freedom and design autonomy are being redefined in the digital age, within an interdisciplinary framework spanning from the philosophy of technology to digital architecture theory, and from artificial intelligence ethics to posthumanist thought. The views of Martin Heidegger and Andrew Feenberg on the philosophy of technology help us understand the impact of digital tools on architectural design, while the digital architecture approaches of theorists such as Mario Carpo, Antoine Picon, and Neil Leach allow us to evaluate the new creative practices brought about by algorithmic design. Thinkers in the field of artificial intelligence ethics, such as Luciano Floridi and Kate Crawford, question the balance between technological autonomy and human control, while posthumanist writers like N. Katherine Hayles and Rosi Braidotti open doors for us to rethink the human condition and the nature of the creative subject in the digital age. Throughout the research, the concepts of creative freedom and autonomy are examined within the context of digitalization, and the transformation of architecture in the age of artificial intelligence is discussed in light of theoretical background and current examples.

Theoretical Background

This section summarizes key approaches from the fields of technology philosophy, digital design theory, and posthumanist thought to conceptually frame the phenomenon of algorithmization and artificial intelligence in architecture. In this way, the problem of creative freedom is placed in a historical and theoretical context, and a foundation is defined for the analyses in the subsequent chapters.

Technology, Autonomy, and Being: Heidegger and Critical Theory

Martin Heidegger was one of the first philosophers to deeply examine the impact of technology on the human condition and creativity. In his famous text, "The Question Concerning Technology," Heidegger reveals how modern technology transforms our understanding of the world and humanity. According to him, modern technology frames the world as a "readiness" or "stock" (German: Bestand) – he explains this concept with the term Gestell (framing). We now begin to see nature, and even people, only as inputs for technical processes, as resources or raw materials. This framing phenomenon, according to Heidegger (1954), narrows the more essential and poetic relationship between humans and being, thus limiting our horizon of experience. While technology reduces everything to an object to be controlled and calculated, human creative thinking also faces the danger of being trapped in this narrow mold. According to Blitz (2014), Heidegger characterizes this aspect of modern technology as a kind of danger, while also reminding us that "the essence of technology is in no way technical," and emphasizes that in order to establish a free relationship with technology, we must recognize and overcome its dangers. Instead of wholesale rejection of technology, understanding its essence and seeing the challenge it brings might be a way to regain lost creative freedom (Blitz, 2014). Heidegger's approach can be seen as a warning against the risk of unquestioning surrender to digital tools in architecture, reducing design to a mere calculation and optimization activity. The architect's existential and poetic relationship with the work can be damaged if technology is used solely for efficiency and control (Sharr, 2007).

In contrast to Heidegger's pessimistic observations, critical theorists in the field of technology philosophy, such as Andrew Feenberg, have developed a more optimistic and interventionist approach. Feenberg argues that there is no single determinism in the development of modern technology, and that social and human values can be incorporated into technology design (Feenberg, 1999). His "instrumentalization theory" analyzes both the primary (formal-instrumental) dimension of technology – its functional, rational core – and its secondary (contextual) dimension – its use imbued with social values (Brey, 2003). According to Feenberg (1999), technology is neither fully autonomous nor entirely free from social control; with proper design and participatory governance approaches, technology can be transformed to serve human purposes. For example, Feenberg (1999) emphasizes human agency by stating, "technology is neither a purely deterministic force nor a completely neutral tool; the social and normative character of technology can be changed through choices made in the design processes." This perspective is also critical in the use of digital tools in architecture: if algorithmic design software and artificial intelligence tools are developed solely for efficiency and optimization of form, the architect's creative initiative may be sidelined (Soulikias et al., 2021; Al-Rqaibat et al., 2025). However, as Feenberg points out, when the feedback and values of users – in this context, architects and designers – are reflected in technology, digital tools can evolve to support human creative freedom. Indeed, while Feenberg acknowledges that scientific-technical activities must operate autonomously to a certain extent according to their own logic, he emphasizes that this autonomy cannot be absolute (Feenberg & McCarthy, 2023). For example, complex technologies like computers and software should be designed with a balance between the logic of designers' expertise and the needs of ordinary users. Otherwise, the technical system becomes a "black box" disconnected from the user's world, which restricts human freedom. Feenberg's view can be echoed in architecture as follows: algorithmic design tools should be balanced with the architect's intuition and knowledge of the social context. In other words, no matter how advanced software becomes, the autonomy it offers should not be left unlimited; a compromise must be reached between human creative intuition and the "common sense" of technical optimization. This compromise represents a healthy balance where architectural design blends both technical rationality and human creativity (Li et al., 2025).

In summary, while Heidegger expresses deep concern about the nature of technology, stating that creative freedom is at risk, Feenberg points to the possibilities for human-centered transformation of technology. These two perspectives offer us a critical lens through which to evaluate our relationship with digital tools in architecture: Digital autonomy should neither be demonized as an absolute threat nor viewed as an inherently liberating blessing. The important thing is to recognize the risks inherent in technology and shape it in a way that aligns with our design values. The architect's creative freedom can be protected by a consciousness that both consciously utilizes technology and, when necessary, defines its limits.

Digital Architectural Theory and Creativity: Carpo, Picon, and Leach

To understand the practice and aesthetics of architecture in the digital age, it is necessary to examine the views of architectural historians and theorists who have explored this transformation theoretically. Mario Carpo examines the development of digital architecture in two phases, which he calls the "first" and "second digital turns" (Carpo, 2017a). The first digital transformation defines the new form repertoire that entered architecture in the 1990s with the introduction of CAD (computer-aided design) and similar tools (Oxman, 2006). During this period, digital tools were used more for production and representation; as a result, a style emerged in architecture where curved, complex forms exploded. Carpo (2017a) states that this smooth curve aesthetic of the 1990s was a symbol of the early digital age, but that today the products of "digitally intelligent architecture" no longer look this way. The second digital transformation, characterized by the acceleration of methods such as artificial intelligence, algorithmic optimization, and big data-based prediction entering design, has gained momentum in the last decade (Moussaoui, 2025). In this new phase, digital tools are not only included in the design process for drawing or visualization, but also directly as thinking tools (Carpo, 2017b). According to Carpo (2017b), today's architects have adopted "tools for thinking" rather than "tools for making"; designers are incorporating the machine's way of thinking into the design process through computational simulation and optimization techniques. For example, with parametric modeling, the designer allows the algorithm to search for possible form solutions by defining specific constraints. Thanks to machine learning and simulation techniques, the search for form moves beyond mere geometric intuition and becomes a kind of data-driven exploration process (Carpo, 2017a). As a result, the complexity of the resulting forms has deepened to the point where it is now alien to the organic logic of the human mind (Mukkavaara & Sandberg, 2020). Carpo (2017a) states that the physical forms produced by contemporary digital architecture contain a form of artificial intelligence that is "outside the tradition of modern science" and "alien to the organic logic of our minds." In other words, algorithmic processes can yield solutions so complex and nuanced that it becomes difficult for the designer to fully understand them in terms of cause and effect. This situation indicates a shift in the subject of the creative process: The architect is no longer just designing the form, but is also in a position to calculate, select, and curate (Brown, 2025; Nourian et al., 2023). Creativity slides into a shared space between humans and machines. Carpo's identification requires a redefinition of the architect's creative autonomy: While the designer benefits from the vast search space offered by the algorithmic tool, they are also responsible for evaluating and interpreting the resulting outputs. This actually shows that the architect's role is undergoing a transformation – rather than being the author of the design process, the architect can become a co-author (Chew et al., 2024).

This state of co-creation brought about by algorithmic design also shakes the traditional concept of authorship in architectural works. Antoine Picon points out that digital culture has brought the issues of authorship and belonging in architecture back to the forefront. According to Picon, the rise of digital and computational design methods complicates the architect's claim to individual ownership of the work; even the concept of "ownership" itself, more than authorship, is being challenged in the digital production age (Fok and Picon, 2017). For example, in a parametric design process, it is difficult to see the resulting form as the work of a single person; the design team, the algorithms they use, and even pre-written code or libraries embedded within the algorithm are all part of the process (Schnabel, 2007; Hubers, 2011). Picon therefore states that digital and computational design methods open up a new space for collective creativity in architectural products, both legally and aesthetically (Picon, 2010). Specifically, open-source platforms, online design communities, and shared algorithms make architectural design knowledge shareable, blurring the boundaries of individual creativity. Thus, creative freedom, while on the one hand granting access to an increasing pool of resources, on the other hand makes it more difficult for the work to shine as the vision of a single subject. The issue of ownership and authorship highlighted by Picon raises the question of what constitutes the architect's original contribution in the digital age: How much of the work can an architect claim ownership of when selecting from drafts generated by an AI tool? Or, conversely, by programming the algorithm, the architect indirectly realizes specific design intentions, perhaps making a more original creative move than ever before? This dilemma continues to be debated in architectural theory (Picon, 2016; Jurcys & Fenwick, 2023).

Another prominent figure in the field of digital architecture, Neil Leach, known for his theoretical contributions, evaluates the introduction of artificial intelligence into architectural practice with both enthusiasm and caution. Leach argues that "artificial intelligence is terrifying because it is also incredible," and that it is unthinkable for the architectural profession not to be affected by this technology (Leach, 2023). Accordingly, many architects are under the misconception that artificial intelligence is only relevant at the level of image-generating tools (e.g., rapid renders with Midjourney) and will not bring about a significant transformation in the profession. However, Leach (2023) predicts that artificial intelligence will have a disruptive impact on the architectural workforce, design processes, and even the social role of architecture in the medium and long term. Indeed, even today, the fact that large offices are starting to use AI-supported design tools is changing the competitive landscape. In an interview, Leach (2023) stated that architecture firms have already begun working with artificial intelligence models and platforms, which raises new questions on many fronts, from the distribution of workload to legal responsibilities. For example, who owns the copyright to a design image generated by artificial intelligence? Or, if a large portion of a project's design process is handled by automation, how will the professional development of young architects be affected? Leach also touches upon the power of artificial intelligence to mimic design patterns, suggesting that the creative privilege of the profession will be questioned. By raising the question, "Can artificial intelligence be creative?" and avoiding a definitive answer, it suggests that human creativity might also be, in a sense, an algorithmic process. Leach's (2023) provocative thesis is this: "Perhaps what we call human 'creativity' is a process we find magical because we don't fully understand it; yet, in the face of sufficiently advanced technology, this too might seem like a kind of algorithmic magic." This perspective points to a more modest approach, outside the traditional understanding that exalts human creativity. According to Leach (2023), artificial intelligence may possess a different form of "intelligence" than humans and can push the boundaries of human perception, opening up new aesthetic horizons. He even states that there is a "second Copernican revolution" in the field of architecture, just as humanity accepted that it was not at the center of the universe with Copernicus, it will now have to accept that it is not the most intelligent being. This so-called revolution could also remove humans from being the sole authority in the design world and place artificial intelligence in the position of a kind of "creative partner." While this situation may seem to limit the architect's creative freedom at first glance, Leach (2023) argues that the real issue is changing our perspective: "Instead of judging artificial intelligence creativity by human standards, perhaps we should evaluate human creativity by artificial intelligence standards and recognize its limitations," he suggests, proposing to move beyond anthropocentrism. Of course, while this approach expands the subject of the creative process in architecture, it also complicates issues of responsibility and meaning. While Leach is excited about the potential that artificial intelligence brings to architecture, he also sees its unsettling aspects, as this transformation is disrupting many of the concepts we are accustomed to.

In light of these theoretical approaches, it becomes clear that the architect's creative act in the digital age is no longer a "completely autonomous" endeavor in the old classical sense. The architect is constantly interacting with digital tools, working in the border region between humans and machines. Creativity is conditioned by technological frameworks on the one hand (as Heidegger warned), and on the other hand, technology is reshaped and liberated through the intelligent guidance of human agency (as Feenberg hoped). The findings of Carpo and Picon define a new design ecosystem where creative freedom is collectivized and transmitted through intermediaries (algorithms). Neil Leach, on the other hand, states that we cannot escape this transformation; rather, we must accept it and expand our definition of creativity. The theoretical background tells us this: Digital architecture has neither completely eliminated creative freedom nor increased it in an absolute sense; however, it has transformed its nature. To understand this transformation through concrete practices and examples, let's now examine the applications of algorithmic design in architecture and the concept of architectural autonomy.

Algorithmic Design and Architectural Autonomy

The rise of algorithmic design in architecture means that design processes are carried out using rule-based, computational, and repeatable methods. With the widespread adoption of parametric modeling in the 2000s, architects began to hand over partial control of the design to computers by defining specific parameters and relationships. For example, tools that can turn the curves that determine the form of a building's shell into parameters and quickly generate different variations have essentially presented the architect with a "space of possibilities." The task of choosing from these possibilities still depended on the architect's critical filter. However, the recent use of artificial intelligence techniques – particularly methods like machine learning and generative adversarial networks (GANs) – in design indicates that this balance could shift even further in favor of machines. Algorithmic design now includes not only combinations of predefined parameters but also intelligence that learns from large datasets to develop new design suggestions (Chang et al., 2021; Li et al., 2024). In this context, we need to rethink the concept of creative autonomy in architecture: How is the architect's freedom of decision-making influenced by the suggestions and constraints offered by algorithms? On the one hand, algorithmic tools are expanding the creative horizons of architects by enabling them to explore forms that were previously impossible.

On the other hand, as it becomes unclear which steps in the design process are under human control and which occur automatically, the architect's dominance over the process can become blurred. Creative freedom is not just about unlimited formal variety; it also concerns the conscious awareness and intentionality of decisions. If an AI tool can provide thousands of design solution suggestions for a problem in seconds, to what extent will the architect be able to reflect their own values and goals when choosing from them? This question implies that design autonomy can be eroded, perhaps invisibly (Schneider et al., 2024; El Moussaoui, 2025).

A concrete example of this can be seen in the recent shift of large architectural firms towards AI-assisted concept generation. Offices known for their digital leadership, such as Zaha Hadid Architects (ZHA), have begun using text-to-image generating AI tools in the competition and preliminary design phases. ZHA director Patrik Schumacher stated that they used AI tools like Midjourney and DALL-E to quickly generate sketches for project ideas, which provided original concepts suitable for the firm's style (Parametric Architecture, 2023). For example, when a text input such as "a museum design in the style of Zaha Hadid, with flowing forms" is provided, artificial intelligence can generate extremely striking and innovative images within a few seconds. Among these images, the architects stated that they selected and detailed about 10-15% of them for modeling. Schumacher says this method offers the design team unusually unconventional options that wouldn't normally occur to them, and in a sense, artificial intelligence can now visualize the ideas they were trying to describe verbally in design meetings (Parametric Architecture, 2023). This situation can be interpreted as the architect delegating a portion of their creative role to the tool. However, those who have put this into practice, like Schumacher, argue that AI-generated images are also curated by the architect, and therefore authorship rights are not infringed upon, pointing out that the final selection and development are done by the architect. However, critics point out that in such a method, the architect's design intent can become blurred, and the question of whose creativity the final product is the result of will arise (Schumacher, 2010; 2016).

Another way algorithmic design affects architectural autonomy is through optimization processes. Today, when determining the form or structure of a building, instead of a single design, algorithms can scan hundreds of variations and recommend the most suitable solutions based on specific performance criteria. For example, a genetic algorithm that changes parameters such as the height and thickness of a bridge shell can find the best alternatives based on the load-bearing and material usage targets set within the software (Carpo, 2017b). While designer Octopus monitors this process through add-ons like Galapagos, they are essentially delegating the discovery of the final form to the algorithm. In such processes, the architect's role is to define the initial parameters and goals, and then evaluate the solutions found by the algorithm and select the appropriate one. Here a subtle distinction emerges: Is the freedom to make decisions still with the individual, or has the individual become merely a rubber stamp? Some theorists suggest that optimization algorithms can find truly innovative solutions by exploring the design space independently of human biases, thus grounding the architect's creativity on an objective basis (Moussaoui, 2025; Albukhari, 2025). According to this view, the algorithm can reveal forms that the architect might miss, even those not found in traditional design knowledge; the architect then acts as a creative editor by making choices among these forms. In contrast, a critical perspective argues that optimization seeks a single "best" solution based on defined goals, and that the designer's intuitive and aesthetic judgments can be sidelined in this process (Caetano, Pereira, & Leitão, 2023). If the design problem is expressed only in measurable criteria (e.g., minimum material, maximum transparency, etc.), the algorithm might overlook poetry or contextual nuances while seeking perfection within this narrow framework. The architect's creative freedom lies precisely in these immeasurable qualities – adding an aesthetic touch to the curve of an arch, capturing a rhythm in a facade pattern that no one can "optimize."

Another important point is how the architect's professional autonomy will be affected in the age of artificial intelligence. Traditionally, the architect was considered the authority and coordinator of the design process, and was held most responsible for the final form of the building. However, today, in large projects, interdisciplinary teams such as software developers, data analysts, and simulation experts play an active role in the design process. Systems powered by artificial intelligence are becoming tools that can be used not only by the architect but perhaps also directly by the client or contractor. For example, parametric planning software can provide a developer with various layout options simply by entering plot data, even without an architect. In such a scenario, the architect's decision-making space may narrow and their professional autonomy could be undermined. Neil Leach (2023), using the example of England, states that the architect's traditional authority in the construction process has already diminished, that in the design-build model the architect now works for the contractor, and that AI could further increase this loss of authority. According to Leach (2023), the status issues the profession already struggles with will become even more complex with artificial intelligence, because at some point, clients might ask, "Why don't we just get an AI-powered solution directly?" At this point, architects will need to be able to convey the unique value of their own creative contributions to society. On the other hand, some architects and academics emphasize that collaboration with artificial intelligence is an opportunity for creative freedom. By automating routine and technical matters, the architect can dedicate more time to strategic and conceptual thinking. Because it can quickly visualize design alternatives, it used to be that after choosing a design, you'd vaguely keep other possibilities in mind, but now you can concretely compare them side by side. This can lead to more informed design decisions. For example, if artificial intelligence generated hundreds of variations for a facade pattern, the architect could better analyze not only which one looks good, but perhaps which one creates a specific atmosphere. Additionally, artificial intelligence can help the architect break their own biases. Every designer, consciously or unconsciously, has certain formal habits. The AI tool, on the other hand, can encourage the designer to step outside their comfort zone by bringing unexpected combinations and forms. In this sense, creative freedom may have paradoxically increased with the support of a machine (Li et al., 2025; Kwon & Ahn, 2024).

In conclusion, algorithmic design and artificial intelligence applications have a two-way impact on issues of creative freedom and autonomy in architecture. The architect is now transforming into a different type of creative subject than before: a cybernetic designer who thinks with both human and machine intelligence. As the creative process shifts from being the work of a central genius to the product of a distributed system, the architect's role within this system also evolves into a guiding, selecting, and integrating one. In this evolutionary process, it is vital that the architect does not lose their own voice and uses technology consciously. Precisely for this reason, the next chapter will need to discuss the ethical dimension of architecture in the age of artificial intelligence and the limits of human control.

Ethical Discussions

The transformation brought about by digital and AI-assisted design methods in architecture is not merely an aesthetic or procedural matter; it also carries a profound ethical dimension. To protect creative freedom and maintain autonomy in a healthy way, it is necessary to develop ethical principles and awareness regarding the use of technology (Liang et al., 2023; Hofman, 2024). This section will address prominent ethical debates in architecture in the age of artificial intelligence: the issue of bias, transparency and accountability, human control versus artificial autonomy, and professional and societal impacts will be explored under these headings.

First, there is the issue of biases that may be embedded in the decisions and outputs of artificial intelligence systems. Every algorithm trained on data reflects the patterns within that data; if the dataset is not balanced or inherently contains existing power dynamics, artificial intelligence can also reproduce these biases. Kate Crawford (2021) emphasizes that artificial intelligence systems are often presented as neutral and objective tools, but in reality, they serve and intensify existing power structures. Crawford's Atlas of AI (2021) highlights the human labor, environmental costs, and political preferences behind artificial intelligence, drawing attention to the purposes for which and by whom these technologies are developed. It is important to keep in mind that an artificial intelligence tool used in architecture is also not unbiased in a similar way. For example, an AI that generates design suggestions might mostly produce popular aesthetic trends or styles that are dominant in the dataset. If famous architectural images from the last 10 years were used as training data, the AI might always repeat certain stylized forms. In this case, while the architect's creative freedom appears to be choosing from seemingly countless options, it may actually be limited by the algorithm's biases. Furthermore, AI tools are controlled by large technology companies or software firms, which carries the risk of the commercialization and monopolization of architectural knowledge. As Crawford points out, technical systems claim objectivity but can actually reinforce existing power systems (Crawford, 2016). In architectural design, this can be at every level, from urban spaces to building typologies: if a residential development planning tool continues by learning from past data, it may inadvertently perpetuate existing segregations and social injustices. At this point, the architect's ethical responsibility should be to question the assumptions and biases inherent in the digital tools being used. It becomes the architect's responsibility to critically evaluate the solutions suggested by artificial intelligence and to consider whether the "most optimal" design is truly good for humans and society (Schneider et al., 2024; Liang et al., 2023).

Another important ethical principle is transparency (explicability) and accountability. In architecture, the traceability of decisions is part of professional ethics, especially in public projects. If an AI tool automates certain parts of the design, these processes must be documented and understandable. Luciano Floridi has proposed that the principle of "explainability" in artificial intelligence ethics should be considered as a fifth principle alongside the traditional four ethical principles (beneficence, non-maleficence, autonomy, justice) (Floridi, 2019). Especially in a world where autonomous systems are becoming widespread, it becomes critical for people to understand the logic of these systems and be able to question them when necessary. Similarly in architecture, it should be clear according to which criteria an algorithm designs, what data it uses, and how it establishes an optimization framework. Otherwise, let's say a structural design algorithm optimized the column layout of a building and a problem arose during construction, who would be responsible? Are you an architect, a software developer, or the data provider? Accountability is perhaps one of the most difficult questions in the age of artificial intelligence, because when the results are the product of collective production, the perpetrator also becomes diffuse. Therefore, as Floridi (2019) also stated, regulations and principles are essential to ensure that the development of artificial intelligence systems does not undermine human autonomy and responsibility. The European Union's ethical guidelines also state that "autonomous systems should be designed in a way that does not undermine people's freedom to set their own standards and live accordingly" (Floridi et al., 2018). In architectural design practice, this principle also means protecting the realm of human creativity: AI tools should remain in an assistant role, and final critical decisions should always be under the control of the human designer. Axiomatic scenarios mean the exclusion of human subjectivity from the design process, which is undesirable both ethically and creatively (Tsamados, Floridi, & Taddeo, 2025; Sellen & Horvitz, 2023).

Floridi et al. (2018) also touch upon the issue of "human control." As AI-powered systems become more widespread, it may not be practical to "include" humans in every decision; however, it must be well-designed which decisions are left completely autonomous and which require human approval. For example, in architecture, could an AI tool automatically select materials? Perhaps it could; if sustainability optimization is being performed, it could recommend the material with the lowest carbon footprint. However, an architect's assessment may be needed for non-quantitative aspects such as the material's feel and user experience. As Floridi (2019) conceptualized it, human agency and artificial agency do not have to be a zero-sum game; if properly designed, artificial intelligence can support and expand human agency. The concept of "augmented intelligence" perfectly captures this: artificial intelligence is ethically valuable when it serves as a tool that multiplies human capabilities. However, if it excessively narrows a person's decision-making space or makes them passive, then it begins to harm human autonomy (Floridi et al., 2018). For architects, viewing artificial intelligence as a supportive tool in the design process and retaining critical moments of creativity (such as conceptual decisions and choices about the meaning of space) in human hands should be an important ethical principle. As Floridi (2019) also points out, while it is possible to delegate some functions, leaving everything to automation can lead to a loss of human control and, consequently, an increase in unexpected errors. For example, if a fully autonomous design system makes a serious error one day (miscalculation, inability to read context, etc.), humanity may have lost the ability to intervene and correct it. Therefore, the principle of human-in-the-loop is advocated in design processes: no matter how advanced artificial intelligence becomes, humans must be present as the final authority for review and approval (Tsamados, Floridi, & Taddeo, 2025).

One dimension of ethical debates is also related to professional and social justice. The impact of artificial intelligence on the architecture sector is not limited to design products; it is also felt in terms of labor and education. The new generation of architects will have to be skilled in using AI-powered design tools. This will also affect the direction of vocational training. On the one hand, it can be argued that architects will focus on more creative roles because AI will handle mundane and repetitive tasks, thus increasing the intellectual satisfaction of the profession. Actually, this is a frequently cited argument: "Automation will free up architects to spend more time on creative work." However, Neil Leach (2023) questions this view, stating that the construction industry produces a limited number of projects and that increasing work efficiency with AI could reduce the need for architects, as the size of the pie remains constant. For example, if we can handle the same volume of work with fewer people, where will young architects or interns gain experience? This situation could raise barriers to entry into the profession and create an unemployment problem in the sector. In an interview, Leach (2023) stated, "AI won't take our jobs; someone who knows AI will take our jobs," indicating that an unequal competition is on the horizon. In other words, a professional gap could open up between those who adapt to technology and those who don't. This is also an ethical issue because intra-professional solidarity and knowledge sharing are important. Perhaps the architectural community should develop principles for the fair use of AI tools and implement educational policies that facilitate access to these technologies for young architects.

On a societal level, the impact of AI-assisted design on users also requires ethical evaluation. If a building's form is optimized by AI but users' daily experience is ignored, inhumane spaces can result. Perhaps a posthumanist perspective encourages us to stop placing humans at the center and consider all living beings and the environment, but as a practical art, architecture directly impacts human life. Therefore, regardless of the parameters, the ethical responsibility of design is to consider human well-being, social benefit, and environmental sustainability. Artificial intelligence cannot know these values directly; it is still humans who must teach them. Thinkers like Rosi Braidotti reject approaches that condemn technology entirely, arguing that how it is used is what matters (Braidotti, 2019). Braidotti states that technology can be used for good, particularly from a feminist and posthumanist perspective, but that current power inequalities must also be recognized. When she says, "Good robots are possible, but some compromises are necessary," she is actually explaining that technology should be directed in a way that does not harm vulnerable groups in society, but rather benefits them as well (Braidotti, 2019). Similarly in architecture, if AI tools are just a toy that maximizes the profits of big capital and produces prestige projects, they will not benefit society as a whole. However, if these tools are used to create, for example, more affordable housing designs, energy-efficient structures, and spaces accessible to people with disabilities, it can serve as a beautiful example of the ethical use of technology (Tzortzis et al., 2024; Qolomany et al., 2019).

In conclusion, as we discuss the creative freedom of architecture in the age of artificial intelligence, we see that it is inextricably intertwined with ethical questions. Creative freedom is not just the architect's personal expression, but also a freedom defined by their responsibilities. When using digital tools, the architect must both reflect their own human values in the design and be aware of the limitations and pitfalls of these tools. Perhaps the concept of virtual autonomy expresses precisely this tension: digital tools open up a certain space of freedom for us, but this freedom can be virtual – unless we make it real with ethical principles. In a sense, the architect's autonomy in the digital age depends on their capacity for self-discipline and the ability to use technology wisely. Insights gained from fields such as philosophy of technology, digital architecture theory, artificial intelligence ethics, and posthumanism can serve as a guide in this new era.

Conclusion

In the age of artificial intelligence, the issue of creative freedom in architecture has prompted us to reconsider fundamental questions about the essence of architecture. Traditionally, the architect was an autonomous creative figure known for their individual genius and artistic talent, with complete control over the design. However, the digital revolution and the subsequent rise of artificial intelligence have both blurred and enriched this image. The term "virtual autonomy" implies that the architect is now in a creative interaction within a digital environment, surrounded by algorithms. This autonomy is, in a way, virtual, because the tools through which the architect dominates the design also impose their own directions and frame the design process. On the other hand, when handled correctly, this virtual autonomy offers new possibilities that will increase the architect's freedom – exploring forms previously unimaginable in the design world, being part of a collective creativity by sharing knowledge, and freeing oneself from routine tasks to focus on more conceptual issues.

As we examined in the theoretical background of the research, Heidegger's critique of technology reminds us to be cautious, warning us about how digital tools can reduce our world to an "information reserve," while Feenberg's critical theory shows us possible ways to rehumanize technology. Theorists like Mario Carpo and Antoine Picon demonstrate that digital design has caused a tectonic shift in architecture, transforming many concepts from authorship to ownership. Neil Leach, on the other hand, argues that architecture must undergo a second Copernican revolution in the face of artificial intelligence, abandoning anthropocentric arrogance and developing new models of creative collaboration. Posthumanists like N. Katherine Hayles and Rosi Braidotti also redefine the structure and boundaries of the subject, proposing a more equitable and conscious relationship between humans and artificial intelligence. As Braidotti (2013) states, "the posthuman condition forces us to think critically and creatively about what we are actually becoming." This also applies to architecture: As architects in the digital age, we must question what kind of creators we have become.

An important lesson we learned from the discussions about algorithmic design and architectural autonomy is that human creativity has a high capacity for adaptation and transformation. Architects have successfully integrated new tools and techniques into their design visions for centuries. From the sketch pencil to CAD, then to BIM, and now to artificial intelligence, each innovation initially sparked a sense of alienation, but over time it has become an integral part of the creative process. Artificial intelligence will likely become a natural component of architectural practice and will be considered "normal" for future generations of architects. However, the direction of this transformation is not automatic; that is, where technology will take us largely depends on how we direct it. If architects and design educators instrumentalize artificial intelligence with the awareness of protecting creative freedom, this technology can become a tool for liberation. For example, it could take over the tedious parts of the design and act as an assistant, providing the architect with materials to fuel their imagination. However, otherwise, if artificial intelligence is used without questioning and without supervision, there is a risk of transforming architecture into an automaton that produces banal and monotonous solutions.

As seen in the ethics discussions section, the principles of transparency, fairness, and human control must be applied to ensure the sustainability of creative freedom. Within the framework proposed by Luciano Floridi, artificial intelligence systems should serve human subjects and not devalue them. Kate Crawford's warnings advise us not to forget the social context of digital design and to take into account the power dynamics behind technology. The ethical dimension of creative freedom reminds us that the architect is responsible not only for their own artistic expression but also for the users, cities, and ecology. If a structure designed with artificial intelligence violates human-centered design principles, it should be considered an ethical failure even if it is an aesthetic success.

In conclusion, the issue of creative freedom addressed under the title "Virtual Autonomy" is a critical matter that will shape the identity of architecture in the digital age. There is no definitive and simple answer to this problem; rather, it needs to be re-evaluated within constantly evolving technological and social conditions. Perhaps what's important is to keep the question alive: Who is the architect, and what does creative action mean? If we continue to ask this question honestly within the context of the digital revolution, we can believe that architecture can adapt to innovations without losing its essence. Creative freedom, no matter how much conditions change, is the architect's indispensable core value. In the age of artificial intelligence, protecting and enriching this freedom should be the collective effort of our generation and those that follow.

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BÖLÜM 2

THE DEFİNİNG DYNAMİCS OF SPATİAL DESİGN AND THEİR RE-İMAGİNİNG THROUGH TRANSMEDİA NARRATİVE

MUSTAFA ALPER DÖNMEZ[1]

INTRODUCTION

Architectural studio courses are generally carried out through academics conveying their knowledge, experiences, and design approaches to students by means of studio course project work through hand drawings, schematic representations, and verbal critiques. Throughout architectural studio courses, many building types and building complexes that differ in terms of function, scale, topography, and climatic conditions are addressed; this process contributes to academics continuously developing and specializing their levels of technical and theoretical knowledge regarding various architectural problems. However, due to the gradual structure of studio education, students coming from lower levels are renewed each term and do not yet possess the necessary design knowledge and experience required to advance to a higher level. For this reason, it is observed that similar design mistakes are repeatedly made in the

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projects prepared by students. This situation necessitates that studio instructors repeatedly make the same conceptual and technical explanations each term, which in turn leads to significant time loss during the course process.

In line with these issues, it was considered that creating a knowledge source that systematically explains the mistakes frequently made by students, the reasons for these mistakes, and the proposed solutions, and presenting this information to students before starting studio courses would be beneficial. For this purpose, an elective course titled “Spatial Analysis and Sketching in Residential Buildings” was offered in the Department of Architecture at KTUN. Within the scope of the course, an attempt was made to convey information to students through a written data set prepared by the instructor. In this way, it was aimed to strengthen students’ understanding of recurring mistakes even before taking a studio course.

However, in practice, it has been observed that written data does not fully correspond to students' mental world, and that complex spatial relationships, in particular, are not sufficiently understood when explained solely through written text. Therefore, points that are difficult to understand during the course are supported with schematic drawings and actionable demonstrations. However, the transition to online education in universities after the earthquakes centered in Kahramanmaraş on February 20, 2023, has further complicated information transfer because the verbal and actionable support used in face-to-face education cannot be used in the online environment. In light of these conditions, it was concluded that architectural design principles presented in written form need to be visualized to make them more understandable in the online education process. This requirement has made it inevitable to utilize the opportunities offered by contemporary communication tools and support learning processes with multimedia. Therefore, it is anticipated that conducting online courses using transmedia learning techniques will reduce communication breakdowns and increase learning efficiency.

Transmedia storytelling is a technique based on adapting, sharing, and experiencing a specific narrative, concept, or event pattern in different formats by utilizing existing digital technologies. Within the scope of the course, after the instructor conveyed the information from the written dataset to the students, the students were expected to reconstruct and visualize the acquired information. This process allowed students not only to read about architectural concepts but also to recreate them at mental, visual, and experiential levels. The outcomes at the end of the course demonstrated that visual communication significantly supported written and verbal communication in the process of conveying information. In this study, the accuracy of architectural design criteria in the visualization works produced by the students was not questioned; instead, the impact of transferring knowledge and experience to students through a transmedia-based method on learning and teaching processes was examined.

MATERIALS AND METHODS

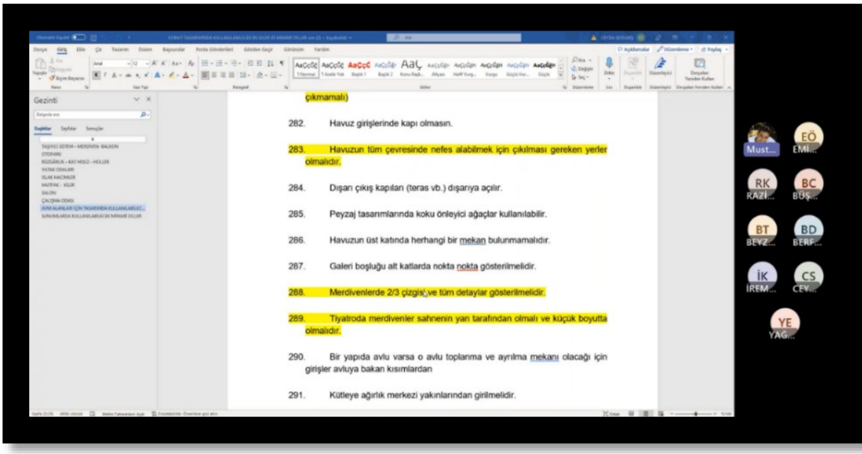
The data used in this study were generated within the scope of the "Spatial Analysis and Sketching in Residential Buildings" course offered by the Department of Architecture at Konya Technical University during the spring semester of 2022–2023. Due to the earthquakes centered in Kahramanmaraş on February 20, 2023, the course was conducted using a distance learning model. Synchronous lessons were conducted via the Microsoft Teams platform, which offers online video conferencing and screen sharing capabilities (Figure 1). Microsoft Teams is a communication tool that allows multiple users to simultaneously share course content, give presentations, and participate in discussions. Within this framework, students authorized by the instructor were able to share their work with all participants and actively participate in in-class assessments. The course lasted for a total of 14 weeks, with 23 students participating.

***Figure 1**: Microsoft Teams class (Online)*

Source: Microsoft Teams

The practical application process for the course "Spatial Analysis and Sketching in Residential Buildings" consists of a total of 14 weeks. Student work is evaluated through mid-term and final exams. During the first four weeks of the course, the instructor provided students with information on architectural space concepts and technical drawing principles. Approximately 330 architectural design criteria and information notes discussed during this process were compiled by the instructor into a Microsoft Word document and distributed digitally to students (Figure 2). This document, provided to students, is referred to as the "Architectural Design Information Package (ADIP)" within the scope of this study.

Figure 2: Architectural Design Information Package (ADIP) Prepared by the Educator



Source: Microsoft Teams

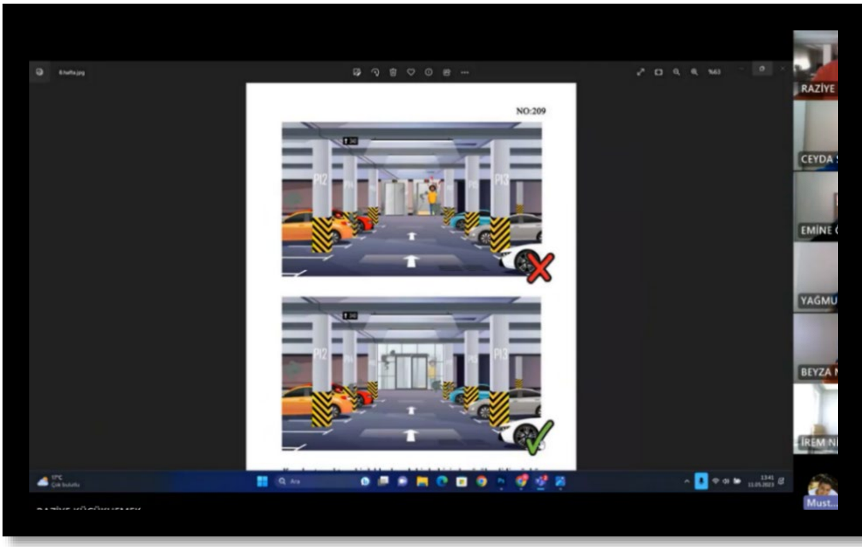
During the remaining 10 weeks of the course, each student was asked to visualize 8 items chosen from the 330 pieces of information in the ADIP according to their areas of interest, as well as 2 original architectural errors they would generate from their own observations. They were then required to present their work in synchronous lessons each week. Because visual memory is directly related to perception, learning, and information acquisition processes, it was anticipated that visualizing the intended instructional content would transfer the information to students both faster and more permanently (Gürsoy, 2023) Accordingly, students were given the freedom to use all digital design tools, including hand drawing, in their visualization work, without any restrictions. This approach encouraged students to experiment with different software, learn new tools, and gain proficiency in digital design environments. Thus, the educator aimed to create a multifaceted learning ecosystem that blended the opportunities offered by digital technologies with students' real-life experiences. The type of software used was excluded from the evaluation process; the assessment was based entirely on design content and production process, not on the tools used. To ensure consistency and prevent confusion in this visual data pool, expected to consist of a total of 230 visualization works, all visuals were requested to be produced in a single presentation format. In this format, it was decided that each piece of architectural information would be represented by one correct and one incorrect example within the same spatial arrangement. The first image shows a flawed architectural design decision, while the second shows the correct design approach (Figure 3). It was thought that comparing these two contrasting examples presented side-by-side would convey the information more clearly, understandably, and quickly.

Figure 3: *Visual example produced from the ADIP*

Source: Created by student R. C. under the supervision of the course instructor.

Furthermore, it was deliberately chosen not to provide any written descriptions of the architectural information intended to be conveyed in the visuals. The main purpose of this approach is to evaluate the extent to which the visuals, presented without any explanatory text, are understood accurately and adequately by the viewers. Thus, only the communicative power of the visual narrative is tested, and the explanatory level of the visualization is measured (Figure 4).

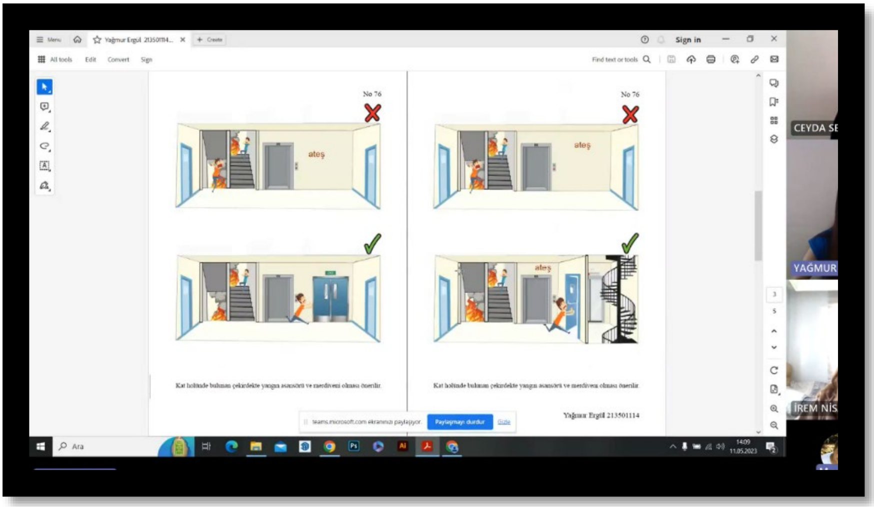
***Figure 4**: Visual example produced from the ADIP*



Source: Created by student R. K. under the supervision of the course instructor.

Following the initial four-week synchronous lecture period, during which the instructor delivered lectures, a ten-week implementation period began in which students visualized one chosen piece of information each week and presented it in online classes (Figure 5). These visual works produced by the students were shared with all participants via screen sharing in synchronous classes; thus, each work had the opportunity to be evaluated within a common discussion platform (Figure 5). The course structure evolved dynamically through student-generated content, and the process achieved a holistic rhythm through participant contributions (Scolari, Rodríguez, & Masanet, 2019).

***Figure 5**: Visual example produced from the ADIP*

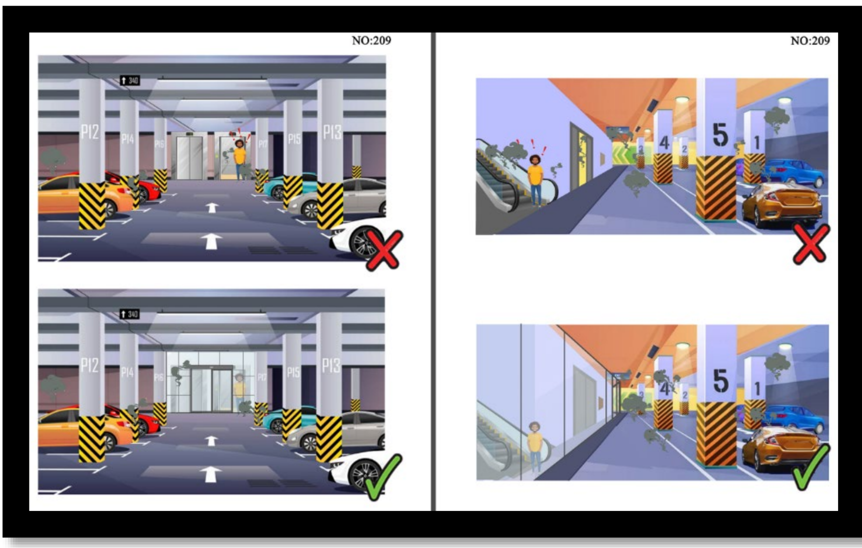


Source: Created by student Y. E. under the supervision of the course instructor.

Participants were encouraged to critically examine the presented visuals and provide feedback on their potential for improvement. This approach ensured that participants actively engaged in the processes of analyzing, interpreting, and learning from visual data. According to the transmedia learning approach, the more students are involved in the designed learning environment, the stronger their connection with the content becomes (Bidarra & Rodrigues, 2016). As Gürsoy (2023) states, empowering the student in their own learning process is therefore of critical importance. While the instructor is responsible for the overall flow and management of the course, allowing students to have a say in their own learning processes and direct their education at the right points is considered a factor that increases the efficiency of education (Dickinson-Delaporte, Gunness, & McNair, 2020).

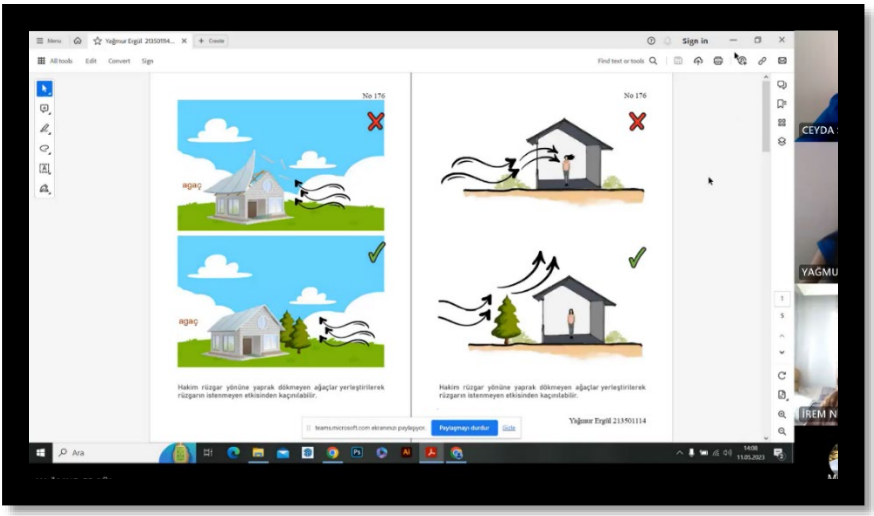
In the synchronous classes, for each visual prepared and presented by a student, participants were asked what architectural design knowledge the work aimed to convey. Participants analyzed, interpreted, and discussed the visuals, creating a "monitoring and testing" environment within the course. While the presenter explained the work, its clarity was evaluated by the other participants. For works that were not clearly understood, improvement suggestions were gathered from participants, and the instructor provided guiding corrections to help further develop the visual. This method encouraged students to analytically evaluate visual material and transform the conveyed information into a fictional narrative within their own mental framework. At the same time, collective intelligence (the wisdom of the mintelligence (utilized to enhance the quality of the visual productions (Landemore, 2012). Instructor revisions were implemented by the students, and the revised works were presented again the following week (Figure 6–7). The updated visuals were re-evaluated, and this cyclical process continued weekly until sufficient clarity was achieved.

Figure 6: *The visual work corrected as a result of the revisions.*



Source: Created by student R. K. under the supervision of the course instructor.

Figure 7: The visual work corrected as a result of the revisions.



Source: Created by student Y. E. under the supervision of the course instructor.

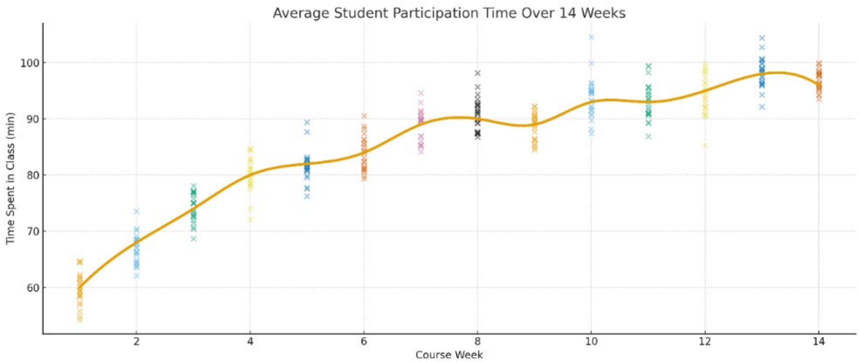
Through this method, a total of 230 pieces of architectural design knowledge—derived from at least 23 different visuals each week—were conveyed to students through visual communication and a culture of discussion. During this learning process, the distribution of course content across different media created an immersive environment that increased student participation and interaction. Throughout the course, the instructor's experience and knowledge were transferred to the students through an interactive approach. At the end of the 14-week period, all works produced by the participants were collected and evaluated. The collected works formed a visual architectural design data pool. This dataset was then preserved to be presented to students who would participate in the upcoming design studio course. In this way, students were able to recognize common design errors before studio work began, preventing the repetition of similar mistakes and enabling a more informed start to the learning process.

RESULT AND DISCUSSION

Due to the earthquakes that occurred on 20 February 2023 in the Kahramanmaraş province of Türkiye, university courses were mandatorily conducted online following the decision of the Council of Higher Education. It is known that the limited conditions inherent to the online education context negatively affect in-class interaction, course participation, the desire to focus, and learning and teaching motivation (Kazak & Karaahmetoğlu, 2023). To mitigate these negative effects, a transmedia learning technique was employed within the course, aiming to create an immersive learning environment in which students could engage with the course content through multiple access points (Rodrigues & Bidarra, 2014).

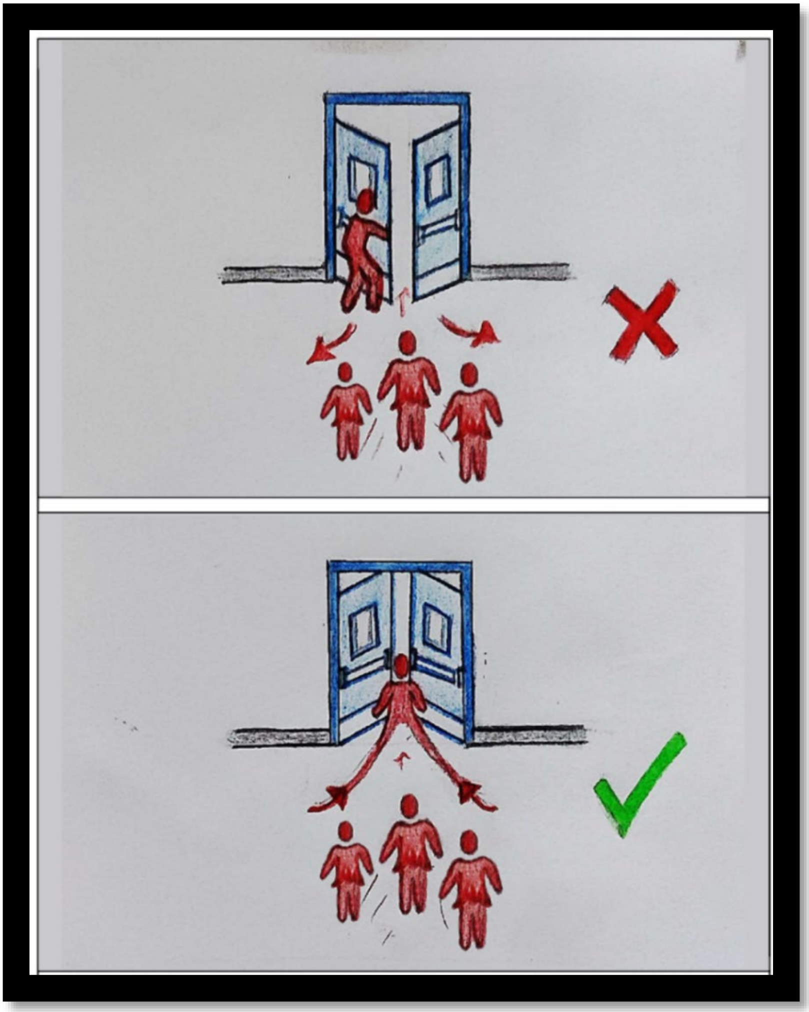
In general, the predominant use of visual presentations during synchronous classes increased students' attention to the course and facilitated the effective transmission of information. The primary reason for this is that visual elements function as powerful communication tools within the practices of knowledge acquisition and learning. According to Yıldırım, (2023), visual communication practices convey the messages they contain to the target audience in sharp, effective, intriguing, and striking ways. In this context, the transmedia learning technique offered a student-centered approach in which learners actively participated in the process, interacted with data, collaborated with other participants, and jointly constructed the final output with enjoyment (Kalogeras, 2014). Another positive outcome that emerged from the integration of architectural design education with transmedia learning was the noticeable increase in students' level of engagement with the course. Interaction is one of the most difficult elements to achieve in online education. When the attendance records of the Housing Units: Spatial Analysis and Sketching course were examined, it was observed that, from the moment the transmedia learning technique began to be implemented, students' in-class interaction steadily increased, with more frequent comments on the visuals and a significant intensification of idea Exchange (Figure 8). As Fleming, (2013) notes, the systematic and effective application of transmedia learning techniques can make any learning environment both enjoyable and engaging.

***Figure 8**: Average time students spend in online classes and the number of participants.*



Throughout the process, students were given the freedom to use any visualization software they preferred, which enabled them to learn new programs and actively use these tools for ten weeks. This practice was observed to provide additional benefits for the students. During the course, it was noted that only one student made use of freehand drawing (Figure 9). It was observed that the other students tended to actively use contemporary digital technologies. Many of them stated that, in addition to conventional visualization tools, they also made effective use of AI-based production and visualization technologies, which have rapidly become prominent today.

***Figure 9**: hand-drawn architectural design work*



Source: *Created by student S. Ö. under the supervision of the course instructor.)*

During the evaluation meeting held at the end of the semester, the majority of the students expressed that they found the course highly efficient, that they understood the content more easily, and that their learning outcomes were more lasting compared to previous experiences.

CONCLUSION

Studio courses constitute the main structure of architectural education. It can be said that all other courses in the curriculum are designed to support and reinforce this primary structure. In particular, the elective and compulsory courses offered within the Department of Building Science are expected to form a foundation for studio courses and contribute directly to them. The learning outcomes gained from the elective courses offered in this field are considered essential for preparing students for studio processes. In this context, it is recommended that the transmedia learning technique used in this study be employed in elective courses opened or to be opened within the Department of Building Science, in order to enhance the transmission of knowledge intended to be conveyed to students.

It has been observed that the transmedia learning technique used in the study is particularly effective in overcoming communication and interaction problems encountered in courses conducted online. The findings indicate that the use of visual education and critical thinking in the construction of design identity enriches students' learning experiences and strengthens their confidence, sense of belonging, and inquiry skills within their field. In courses conducted with the transmedia learning technique, instead of long passive theoretical lectures, an interactive learning experience was created in which students explored across visuals, gathered components of the course from different media, and remained in continuous interaction with the content. This approach increased the motivation of both the instructor and the students, helping sustain their desire to learn.

The integration of a communication method that offered such a high level of interaction into course planning for the first time introduced new perspectives as an alternative to the traditional one-way teaching model. Occasionally allowing students to take over the conduct of the course supported their involvement in their own educational processes, thereby creating an inclusive and participatory learning environment that activated critical thinking.

The integration of transmedia learning dynamics with design education provided students with access to a broad world of knowledge that extends beyond what an instructor alone can offer. Opening this world to exploration added dimensions of creativity, enjoyment, and interaction to the learning process, contributing to the formation of a collective pool of visual knowledge. Throughout this process, students deepened their interest in architectural design criteria and were motivated to explore and define their own designer identities. The intensive use of visual communication within the course created a multilayered and richly textured narrative, establishing a dynamic and productive learning environment that directly engaged students' areas of interest.

Consequently, the effective use of visual communication tools was found to be highly influential in conveying the intended knowledge. Furthermore, conducting the course in an interactive manner and consistently incorporating students' ideas provided significant added value to the instructional process. In light of these findings, it is recommended that the transmedia learning technique be applied not only in design-oriented courses but also in verbally intensive courses where the transmission of knowledge can at times become challenging. The results of the study aim to reveal the productive educational environment that emerges when architectural design education is combined with transmedia learning. Throughout this experimental educational process, students were encouraged to embark on a "knowledge hunt," to build a collective pool of visual information, to deepen their interest in architectural design criteria, and to discover their own designer identities.

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BÖLÜM 3

CHANGES IN SPATIAL NEIGHBORHOOD RELATIONSHIPS: THE CASE OF ASAN STREET IN THE YENIMAHALLE DISTRICT OF ANKARA

1. GİZEM ÖZKAN ÜSTÜN[1]

Introduction

Architecture offers its users a living experience and can influence an individual's relationships with their environment and their behavior. Within living experience lie individual and social relationships. One of these relationships is the neighborhood. While today's rapidly changing world affects daily life, it is also gradually transforming spatial configuration. The neighborhood is defined by the relationships and connections between spaces, the zones they form between them—in short, many of their physical conditions (Erman, 2017; Kellekci & Berköz, 2006). Therefore, it is a concept grounded in space and its quality; it is influenced by changes in space and the city. This study examines the concept of spatial neighborhood and examines it through the transformation of 'Aşan Street' residences in the Yenimahalle district of Ankara. The user transformation that occurred on Aşan Street in Yenimahalle

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following the demolish-build-sell physical transformation continues today. The scope of this study encompasses detached houses with gardens and new apartment buildings in Yenimahalle, which are described as early examples of settlement. It is necessary to examine what the neighborhood has been like in the history of Yenimahalle and/how it has changed. This study first examines how the concept of spatial neighborhood has been addressed in the literature. The spatial history of Yenimahalle, one of the earliest examples of mass housing in Ankara's early period as the capital of the Republic, is examined, and the method and findings are presented.

Spatial Neighborhood

A neighborhood is a local structure composed of a small number of families who know and visit each other and who can mutually help each other (Nirun, 1991, p. 169). According to Keleş, a neighborhood is a settlement within a narrow area dominated by personal relationships, consisting of members who can benefit from common city amenities within walking distance (Keleş, 1998, p. 82). It is an important element of social life and has always been a form of relationship (Alver, 2012, p. 347). It has different definitions depending on physical and psychosocial conditions. The physical definition encompasses service facilities near housing, including healthcare facilities, recreational areas, commercial, cultural, and religious facilities. The psychosocial definition, on the other hand, includes areas that enable users to establish social relationships (Kellekci & Berköz, 2006).

The residential environment conceptually encompasses not only the house but also neighborhood relations and the social environment. Therefore, housing is located within a physical, psychological, and sociocultural environment; together with its environment, it influences the behavior, health, happiness, and well-being of its residents (Kellekci & Berköz, 2006). In this context, it can be said that the relationship an individual establishes with their environment is through space. Behaviors undertaken to meet needs become spatial. Therefore, space carries social and cultural meanings. It creates various meanings and psychological effects on the user; relationships are formed at the sociocultural and sociopsychological levels through the constructed experience. The transition and relationship between spaces also determine the relationship between users. Buildings are patterns formed by the relationships between spaces. Therefore, spatial organization is the organization of relationships rather than function. The neighborhood is also linked to the relationship between spaces and transitions. The proximity and distance of spaces and the number of spatial transitions are factors that influence spatial neighborhood (Erman, 2017).

Neighborhood, based on spatial boundaries, is defined as an indicator of social integration and social relationships. Neighborhood and family relationships meet the needs for security and support within society. A sense of communication and sharing can be established among neighborhood residents. Social and individual characteristics shape neighborhood characteristics. Through neighboring, individuals integrate into society and escape the loneliness of their individual selves (Kısar & Türkoğlu, 2010).

In residential settlements, the built environment (outdoor uses) is a significant factor affecting user satisfaction with the home (Şensoy & Karadağ, 2012). Because residential layouts and outdoor uses influence user satisfaction, they are also the starting points for social interaction at the neighborhood level. Residential gardens can enhance individual communication (Serpil, 1996).

He emphasizes that daily life changes as communication channels develop. Due to the function of the media, individuals live more interconnected across different geographies. The media can present images that become more familiar to individuals than their neighbors (Giddens, 2012, p. 631). Therefore, it can be said that the relationship between neighbourhood and space has an important role that needs to be reconsidered.

Putnam (1995: 69) notes that social ties are gradually weakening in the United States, with fewer people maintaining neighborhood relationships and a sense of trust. Instead of forming communities for social organization, individuals have begun to choose to gather, often for personal development-related matters. Halpern (2005) also found deterioration in trust in neighborhood relations in his research in the United Kingdom. The definition of collective actions and mutual assistance as neighborliness is becoming less and less accepted by individuals (Giddens, 2012: 722).

After the 1950s, industrialization, modernization, and rapid urbanization led to the emergence of new forms of neighborhood relations in Türkiye, resulting in changes in neighborhood expectations, frequency of contact, places of meeting, forms of contact, and forms of cooperation (Koyuncu, 2009). This situation points to a neighborhood issue that deserves further discussion, considering the current pace of urbanization and paradigm shifts in urban life (economic challenges, the pandemic, etc.).

In this context, observing the evolution of the concept of spatial neighborhood through architectural changes in a region of Turkey with strong neighborhood relations can spark significant discussion. Therefore, this study examines spatial neighborhood through the transformation of the Yenimahalle district of Ankara.

Spatial History of Yenimahalle

Among developing countries, Turkey has experienced rapid urbanization since the 1950s due to factors such as the modernization of agriculture, the liberalization of the economy, industrialization, the expansion of education, and rapid population growth. In 1927, the population of Turkey was 13,648,000, and in 2011, it reached

74,724,269. Of this population, 76.8% (57,385,706) resided in provincial and district centers, while the remainder resided in towns and villages (Kılınç & Bezici, 2011).

The designation of Ankara, the city experiencing the most rapid Westernization, as the capital was planned as the spatial equivalent of the new culture for the Republic (Aydın, et al. 2003). Urbanization in Türkiye accelerated between 1950 and 1980. Local governments began to be elected by the citizens' votes, and the content of the Modernization Project changed (Altay, 2009). After the 1950 elections, the majority of the deputies in the parliament changed. The housing shortage in Ankara escalated (Belli & Boyacıoğlu, 2007). After this year, the zoning system envisioned by the Jansen Plan began to deteriorate (Altay, 2009).

In 1959, the zoning regulations allowed Bahçelievler to be converted into garden apartment buildings. In 1971, Mebusevler was transformed into garden apartment buildings. With the frequent changes in zoning plans, Ankara lost its status as the first planned city of the Republic. The demolition-rebuild process accelerated, and it entered a period of unplanned and dense construction (Geray, 2000).

Despite projects such as Yenimahalle, implemented between 1963 and 1978 to provide housing for low-income families, the housing problem remained unsolved. Garden residences began to transform into multi-story residences (Dikmen, 2012). It's important to remember how the first settlements existed before the demolition-rebuild process in Yenimahalle.

On June 14, 1948, a law numbered 5218, which stipulated that "land shall be allocated to the Ankara Municipality to those who will develop a certain portion of its land into residences," imposed a construction obligation on those who would be granted land. To encourage construction, measures such as a 10-year tax exemption, transportation discounts, the removal of sand and stone from the surrounding areas, and encouragement of the establishment of construction cooperatives were implemented (Küçük, 1995). The lands cost the Ankara Municipality 98 pennies. They were offered to the public for 1 lira under the name "cheap lots," provided that the housing would be completed within two years (Kaba, 1995). Housing projects and subdivisions were obtained through competitions. Four different housing types were designed based on the number of floors and rooms (Küçük, 1995). Since the first-place winner was not selected, the second and third-place projects were used by the Ankara Municipality Zoning Directorate (Kaba, 1995).

Housing projects and loans were provided by Emlak Kredi Bank. Loans were provided piecemeal to those wishing to build housing. The plan included a primary school every 500 meters. All residences have gardens. Plot depths reach up to 25 meters. There can be up to 25 meters of space between the front and back yards and between two residences (Vimeo, 2025). The financial difficulties experienced by the owners during the construction of their homes led them to convert the storage and shelter areas in the basements into residences. For the same reason, the owners arranged the floors as apartments, positioning the stairs outside in the two-story houses (Küçük, 1995).

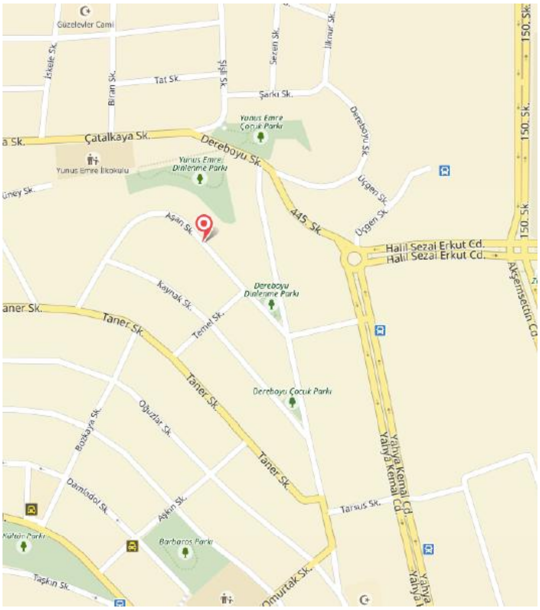
Yenimahalle, a unique settlement in Türkiye's urbanization history, had its first buildings demolished and rebuilt using a build-and-sell approach. In 1965, the first floor increase was made in Yenimahalle. The 1968 Zoning Regulations led to a second-floor increase. Yenimahalle's recent history, subjected to floor increases due to constantly changing laws, has significantly increased its population (Kaba, 1995).

Yenimahalle's transformation did not end with the completion of the apartmentization process. While factors such as the development of living conditions, needs, and technology, as well as the increase in the number of automobiles, have not sustained the transformation spatially in recent times, they have sustained it in terms of user profile. The population that has increased due to the apartmentization process has recently been leaving Yenimahalle, opting for gated communities and new residential areas. Vacant properties in Yenimahalle have also found new occupants. To facilitate discussion of these observations, a field study was conducted on Aşan Street in the Yunus Emre neighborhood of Yenimahalle, focusing on neighborhoods.

The spaces, streets, and open spaces that have changed with the apartmentization in Yenimahalle have also affected neighborly relations. The basic assumption of this study is that the transformation of the individual's lifestyle affects the neighborly relations and that the structure of Yenimahalle that causes the transformation is insufficient in space with new sociological layers and carries the neighborly relations to a different point.

In the immediate vicinity of Aşan Street are military housing and educational buildings. The shopping mall and the commercial units on Ragıp Tüzün Street are similarly distanced from the street. Taner Street and Dereboyu Street meet on the south of Aşan Street. Aşan Street joins these two streets in an arc to the north. The triangular area formed at the intersection of Dereboyu Street and Aşan Street has also been utilized as a recreational area. It is called "Dereboyu Recreation Park." Another recreational area in the immediate vicinity is Yunus Emre Park. Aşan Street is also close to Yunus Emre Vocational and Technical Anatolian High School and Yunus Emre Primary School. The street consists of apartments on parcels 14-39 of island number 8164, apartments on parcels 8012/1-2-3-5, 8013/23-32, 8014/24, and 8014/1 of island number 8012/4, and the first residential house (two-storey) made of masonry on parcel 8012/4.

Figure 1. Aşan Sokak and its Immediate Surroundings Map View

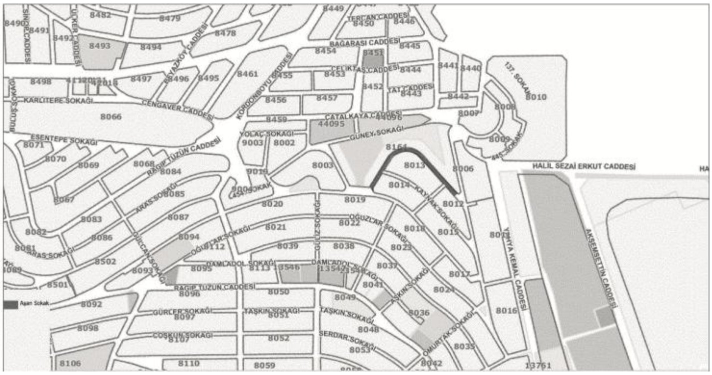


Source: Yandex Map, 2025

Figure 2. Master Plan in 1/1000 Technique

Source: TKGM, 2020

Figure 3. Master Plan in 1/1000 Technique



Source: TKGM, 2020

Figure 4.View of Aşan Street

Source: Author's Archive

According to information obtained from Yenimahalle Municipality, there is only one land map for the islands on Aşan Street, dated 1965. The only changes in the area were increased floor counts and road widths. According to the plan drawn in 1965, Yunus Emre Park has direct access from Aşan Street. Access between the park and the street is easily maintained. Block 8164/14 housed a grocery store until the 2000s. The last commercial unit on the street has since disappeared. A 3-meter elevation difference has emerged between Yunus Emre Park and the street, which has been transformed into apartments, and a retaining wall has been built as a result. Access to the park from the street has been completely eliminated. Access is now gained via Dereboyu Street or Taner Street.

Method

This study is a qualitative field study conducted to reveal the impact of this transformation on neighborly relations through a comparative spatial analysis of the old and new conditions of the examined street. The qualitative method of the study is an oral history research on residents of residences on Aşan Street in Yenimahalle. The data collection technique used was an interview guide approach and observations. Residents were randomly selected based on age, gender, and occupation. The sample comprised two participants living in the Doğan Apartment building on Aşan Street in Yenimahalle, Ankara; one participant who had moved from the same apartment building; one participant who had moved from the Şurgun Apartment building; one participant each living in the Bozkurt Apartment building, Başak Apartment building, Cerit Apartment building, Söylemez Apartment building, and Çiçek Apartment building; and one resident from the original Yenimahalle settlement. Data are published anonymously but are coded.

Some of the field study participants lived in the original residences, some moved into apartments without living in the original residences, and some moved from existing apartments. A single original settlement pattern exists on the street. There are two participants associated with the residence above. The interview questions were prepared separately based on the participants' differences in residence.

Participants 1 and 2, who reside in the Doğan Apartment Building; Participant 3, who lived in the residence on block 8012/4 (still existing) and later in the Doğan Apartment Building, but then moved out of town; Participant 4, who resided in the Cerit Apartment Building and then moved there; Participant 5, who lives in the

Bozkurt Apartment Building; Participant 6, who lives in the Başak Apartment Building; Participant 7, who lives in the Çiçek Apartment Building; Participant 8, who lives in the Söylemez Apartment Building; Participant 9, who lived in the demolished Şurgun Apartment Building; and Participant 10, the owner and resident of the residence on block 8012/4, contributed to the fieldwork. There were 10 participants in total. Summary information about the current status of the participants is shown in Table 1.

Figure 5. Residences Where Participants Reside

Table 1. Participants' Information

Partic. Code	Age / Gender	Family Status	Education - Occupation	Housing History / Status	Question Group Included
P1	40, female	Married, 2 children,	High school graduate, unemployed	Had never lived in first residence, but moved directly to Doğan Apartments.	Group-2 (new apartment)
P2	65, female	Lives with his father	University graduate, teacher	Did not live in the first residential building, lives in Doğan Apartment.	Group-2
P3	56, female	Married, 2 children	High school graduate, unemployed	After 1988, in military housing, after 1992, in block 8012/4 (first residential housing), then again in military housing, and in the Doğan Apartments in the 2000s, outside Ankara in 2024.	Group 1 & 3 (first residence + moved out)
P4	28, female	Single, living with his family	Bank officer	Lived in Cerit Apartments, then moved out	Group-3 (moved out)
P5	66, female	Married, 3 children, 6 grandchildren	Unemployed	Owner of first residence, later built an apartment building (Bozkurt Apt.)	Group 4 (currently first residence)
P6	50, female	Married, 2 children,	Unemployed	The first owner of the first residence building, later converted it into an apartment building (Başak Apt.)	Group-4
P7	40, male	Single	International Relations graduate, theater actor	Resident of Çiçek Apt.	Group-2
P8	35, male	Married, 2 children	University graduate, laboratory technician,	Söylemez Apartment resident	Group-2
P9	21, male	Uni. student	Student	Lived in a family apartment building, sold it; currently lives in a detached house in Koru	Group-3
P10	70, male	Married	İlkokul mezunu	Owner of the 8012/4 parcel residence.	Group-4 (currently first residence)

The questions for the fieldwork participants were designed into three different groups. The first group of interview guide questions was for those who lived in their first residence and currently live in an apartment building; the second group was for those who had never lived in their first residence and were living directly in a new apartment building; and the third group was for those who currently live in their first residence.

Table 2. Question themes

Participant Profile	*Question*	*Theme / Purpose of Research*
Group-1: Those who lived in the first residence and currently live in an apartment.	*1*	*Migration and timeline – reason for moving, duration*
	2	*Neighborhood spaces – meeting places*
	3	*Child relationships – play, friendship networks*
	4	*Neighborhood density – community size*
	5	*Social activity – shared activities*
	6	*Rituals – holiday/special day practices*
	7	*Assistance – mutual support*
	8	*Conflict – reasons for disagreement*
	9	*Continuity – connection with old neighbors*
	10-11-12	*Neighborhood in the new residence – places of encounter, frequency, activity*
	13	*Comparison – difference between old and new activity*
	14	*Rituals (new) – holiday/special days*
	15	*Child relationships (new)*
	16	*Neighborhood density (new)*
	17	*Assistance (new)*
	18	*Conflict (new)*
	19-20-21	*Social network width – apartment/off-street neighborhood*
	22	*Consumption habits – shopping mall/street*
	23-24-25	*Public/green space use – park, garden*
	26	*Perception of change over time*
	27	*Longing/nostalgia*
	28	*Difference between old and new*
	29	*Preference – desire to live in the old order*
	30	*Neighborhood score – old*
	31	*Neighborhood score – New*
Group-2: Those who have never lived in the first residential residence and live directly in the new apartment building.	*1*	*Migration and Timeline*
	2–3	*Neighborhood spaces and activities*
	4	*Child relationships*
	5	*Neighborhood density*
	6	*Rituals – holidays/special days*
	7	*Social cooperation*
	8	*Conflict*
	9–11	*Social network width*
	12	*Consumption habits*
	13–15	*Use of public/green spaces*
	16	*Perception of change over time*
	17	*Neighborhood score – new*
Group-2 (additional questions): Those who lived in Aşan Sokak and then moved	*1*	*Reason for moving*
	2	*New location choice/neighborhood attachment*
	3-4	*Neighborhood spaces and frequency in the new residence*
	5	*Use of public spaces in the new location*
	6	*Consumption habits*
	7	*Longing/nostalgia*
	8	*New neighborhood score*
Group-3: Those currently living in the first residential residence	*1*	*Migration and Timeline*
	2	*Motivation to maintain the residence – resistance to transformation*
	3	*Apartment preference evaluation*
	4	*Housing-specific habits/activities*
	5	*Changes in neighborly relations*
	6	*Meeting frequency and spaces*
	7	*Garden use*
	8-9	*Relationship with the tenant*
	10	*Consumption habits*
	11	*Neighborhood score – old*
	12	*Neighborhood score – new*

Findings

As previously mentioned, the residential status of the participants in the field study varied. Therefore, participants who lived in first residence and those currently living in an apartment building were asked questions to compare the two situations. Participants who had not previously lived in first residence were asked to evaluate the neighborhood in their current apartment building. Participants who had moved from Aşan Street were asked questions to determine their reasons for moving. An informational speech was held before the interviews with the participants. The presentation text for the participants is as follows:

Yenimahalle Aşan Street has undergone a rapid process of apartment development since the zoning law was passed in 1965, which mandated additional floors. The number of vehicles has increased, and spatial changes have occurred within the residences. This study, anticipating that this transformation is still ongoing, explores how this transformation has impacted the neighborhood. If you have resided in Yenimahalle's first residence, you are expected to contribute to the study by comparing the current and past neighborhoods. If you have not, you are expected to contribute by evaluating the current situation.

In this context, the group questions were analyzed, and findings regarding spatial neighborhoods were obtained based on themes. Table 2 summarizes the responses to the grouped questions, while Table 3 analyzes all participants' responses regarding spatial neighborhoods.

Table 3. Analysis of the responses related to the question themes

Theme (Question area)	G-1: First residence estate experience, now in the apartment (Exp.P3)	G-2: Those who moved directly into the apartment (P1, P2, P7, P8)	G-3: Those who experienced transition (housing estate, then apartment) (P4, P9, P3)	G-4: Still living in the first housing estate (converted into an apartment) (P5, P6, P10)
Reason for moving / relocation (Q1 etc.)	Leaving military housing, proximity to work/service; rent/opportunity (P3)	Proximity to work/metro/city center (P8); family order (P1, P2)	Lack of garden, crowding, need for garden (P4, P9); quality of life has decreased (P3)	Aging, maintenance needs (P10); property ownership (P5); nostalgia for the past (P6)
Neighbourhood spaces & frequency (Q2, Q10–12)	In the garden of the military house in the old period & interior courtyard; rare encounters in the new apartment (P3)	Indoor encounters; monthly meetings in the building (P8); limited due to workload (P2)	In new site or environment, some say "never" (P4), others say weekly (P9)	Regular weekly or daily visits continue (P5); more official/organized (P5)
Children's friendship networks (Q3, Q15)	Age peers; taking child to estate (P3)	School/parents' network; reduced outdoor play (P1); traffic concern (P2)	Military house/relatives' network (P4, P9)	Street or "square"-centered social network (P5)
Group size of gatherings (Q4, Q16)	4–5 people (in the military house) (P3)	3–6 people (day/game) (P8, P1)	0–2 people or small weekly home groups (P4, P9)	10+ person gatherings (P5)
Type of activities (Q5, Q12)	Tea, meal, "day" (P3)	Home gatherings, chats; nearby cafés (P8, P2, P1)	Family/relatives or garden gatherings (P4, P9)	Samovar, coffee, garden meetings (P5)
Festivals/rituals (Q6, Q14, Q15)	Spent holidays outside the city (P3)	Some went on holiday (P8), some continued (P5)	Generally family-oriented (P4, P9)	Accepted within the neighborhood (P5)
Mutual help (Q7, Q17)	Mutual support with the landlord in the first residential housing; sharing of wells in case of water outages (P3)	Key exchange, child pick-up (P1, P4); some say "none" (P2)	Limited to family (P4, P9); mutual childcare (P7)	Strong solidarity in daily life (P5)
Conflicts (Q8, Q18, Q19)	Parking, playground use, noise; partial isolation (P3)	Parking (P8); common expense issues (P4); some say "none" (P7)	Not stated (P5); "none" (P6)	Rare and short-term (P5)
Neighbourhood continuity (Q9)	Continuing with the host & military house environment (P3)	Weak neighbour ties (P2)	Relatives/neighbours continued relationship (P4, P9)	"Everyone was here" > even though they moved to the apartment, the

				bond was preserved (P5, P6)
Park/green space use (Q11, Q13, Q22, Q24, Q25)	Military housing gardens are busy; Doğan Apartments have low parking usage (P3)	Mostly low; individual/home garden (P7); some not at all (P2, P8)	Own gardens/site area at new location (P9); no parking required (P9)	Yunus Emre Park is used from time to time, in the past the garden was dominant (P5)
Garden use (Q27, Q23)	Inactive in Doğan Apartment (P3)	Mostly limited/inactive (P1, P2, P8)	Their own gardens are dense (P9)	Still active (P5); limited satisfaction due to restrictions in the apartment
Shopping practice (Q22, Q12)	Continuing traditional shopping (P3)	Shopping mall-based or mixed (P8, P7, P1)	Mixed; some are shopping malls (P4), some are street/markets (P9)	Street/wholesaling tradition is strong (P5)
Perception of change over time (Q26, Q28–29)	Low familiarity, coefficient↑ → belonging ↓ (P3)	Neighborhood decline; trust/parking/parking issues (P8, P1)	Some say it is "the same" compared to the past (P4) and some say it is "better" (P9)	Transition from appointment-free to appointment-based relationships (P5); belonging continues
Longing/preferen Ce (Q27, Q29)	Preference for a house with a garden; longing for the old order (P3)	Most tend to stay in apartments (P2)	Feelings from the old neighborhood: some miss it (P4), some don't (P9)	"Home on its own" is more peaceful (P5); some regret the transformation (P6)
Neighborhood scores (Q30–31, 18, 27)	Old: 8; New: 4 (P3)	Wide range of 1–7 (P1≈7; P8=5; P7=7; P9 in the previous session 2–1)	New region points: 5 (P4), 8 (P9), P3 in the new region "1 (on-site)–8 (off-site)"	Old: 10 (P5,P6); New: 8 (P5), 5 (P6); P10: social contact is weak due to age

Table 4. Analysis of spatial adjacency in participants' responses

Partic. Code	Housing Type / Location	Primary Meeting Space(s)	Frequency (approx.)	Spatial Scale	Public Space Use (park/street)	Verticality & Structural Impact*	Spatial–Neighborhood Density (1-5)
P1	New apartment (Doğan)	In front of the door; rarely inside; "daily/Friday gatherings" in other apartments	Low (once every 2 months; occasional gatherings in the meantime)	Outside the apartment / neighborhood	Other streets, none currently	Very multi-storey → familiarity decreases	2

P2	New apartment (Doğan)	Café/patisserie (Ragıp Tüzün); jamboree-like visits	Low–Medium (once a month)	Neighborhood / main street	No park use; strong street café	Very multi-storey; job density dominant	2–3
P3	Old: two-storey annex – Doğan Apt., now site (outside Ankara)	Formerly: building forecourt / inside the house → In Doğan Apt.: limited and inside → Now: site garden, walking	Formerly/ Now: high → In Doğan: low	Formerly street + annex; In Doğan: building interior → Now: site surroundings	Yunus Emre rare; Dereboyu short visits	As buildings get taller, familiarity decreases	3 (formerly 4–5, in Doğan 2)
P4	(Old) Cedit Apt. – new site	Corridor / entrance encounters	Very low (“almost none”)	Inside the building	Previously Dereboyu; now none	Gated site structure; secure	1-2
P5	First home – Apartment (Bozkurt)	Strong visual contact from inside the house to coffeehouse and street (ground floor/front façade)	Medium–High (almost daily)	Street + neighboring apartments	Occasionally Yunus Emre; formerly street–garden oriented	In apartment buildings, transitioning to formality; also ground floor advantage	4
P6	First home – Apartment (Başak)	Inside the house; formerly garden	Medium	Street	No park	Transition to apartment weakens contact	3
P7	New apartment (Çiçek)	Private backyard, inside the house	Medium (once every 2–3 weeks)	Building + nearby street	Dereboyu (dog walking), occasionally Yunus Emre	Low-rise; access to backyard	3–4
P8	New apartment (Söylemez)	Inside the house (match watching, home gatherings)	Once a month	Building + immediate surroundings	No park use; shopping mall oriented	Very high-rise; parking conflict visible	2–3
P9	Family apartment – detached house (Koru)	House / garden (weekday outdoor space)	Medium (weekly)	House + neighboring gardens	Previously park (with grandmother); now not required	Detached house → horizontal relationship / environment	4
P10	First home (8012/4 lot)	— (limited mobility)	Very low	Parcel	Park/garden no longer available	Stair access / accessibility problem	1

Figure 8. Participant 10 Housing Units

Among the older participants, neighbourhood relations were observed to be more frequent, and these relations also had clear spatial counterparts. Residents of the few remaining first-settlement houses demonstrated stronger neighbourly habits compared to those living in apartment buildings. In these original settlements, mutual assistance was higher, and conflicts were not spatial in nature but rather stemmed from social relations. Participants who moved out of the neighbourhood into new detached houses did not maintain the close-knit neighbourly relations characteristic of their initial homes. It is noteworthy that social housing types with shared gardens—such as lodgings—exhibited neighbourly relations as strong as those found in first-settlement houses.

It can also be said that the concentration of military personnel residing on Aşan Street is striking. Users who left military lodgings and settled on this street were observed not to detach from the communities they formed in the lodgings. This can be attributed to both the residents' shared socio-cultural background and the active use of open spaces. The military institution provides its members with a common sense of purpose and a shared way of life, which, in addition to socio-cultural uniformity, places all families on similar ground in terms of past experiences and lifestyle. For this reason, individuals who leave the lodgings continue to reside nearby and maintain their ties with the lodgings. When considering the military families on Aşan Street, it is evident that their social interactions and neighbourly relations outside the lodgings are rather limited. Their military community is sufficient for their needs, and they do not feel the need to establish new relationships. The fact that two military personnel lived in an upstairs–downstairs arrangement in Participant 5’s first settlement house in the 1980s also demonstrates that this pattern extends far back in time.

Another important criterion in neighbourly relations was age. Participants’ ages influenced how they interacted with one another. Older individuals were mostly associated with peers, while younger individuals interacted primarily with peers. Although there was interaction between different age groups, mutual complaints were observed. The presence of children of similar ages also facilitated the formation of neighbourhood ties.

In the old Yenimahalle settlement, conflicts between landlords and tenants living together often emerged around garden use. These problems persisted among apartment residents as well. The very small gardens—no larger than 15 square metres—were frequently referred to as “ornamental gardens” (Figure 9), and it was observed that they could not be used collectively or as actively as older gardens. The complete severance of the relationship between Yunus Emre Park and Aşan Street due to apartment development (Figure 10), along with the construction of a roughly 3-metre-high wall around the park, directly affected the use of green space. The open space behind the apartment blocks became idle and, in some cases, was used by apartment residents as a dumping ground. When the park and the street were still directly connected, neighbourhood relations extended into the park, which was used both for recreation and as a route to school. The park also maintained a relationship with the private gardens of nearby houses. Dereboyu Park, located at the intersection of streets, was a park used more frequently by former Yenimahalle residents compared with today. The severing of the connection between Yunus Emre Park and the street, along with the ornamental nature of the front gardens of apartment buildings, also led to a decline in the use of Dereboyu Park (Figure 11).

As neighbourly activities in open spaces declined, green areas came to be used primarily for walking pets. It was also observed that green spaces were sometimes used by individuals who were not known to residents and were socially perceived as outsiders. Overall, green areas were not used to maintain neighbourly relations but rather as places for young children to spend time. There were even users who completely abandoned approaching parks through daily-life routines and instead adopted a stance that supported the dominance of visual outlook—treating green spaces merely as scenery rather than lived spaces.

Figure 9. Bozkurt Apartment and Its Garden

Figure 10. Yunus Emre Park Wall at the Rear Facades of the Apartment Buildings

Figure 11. Dereboyu Park

Children’s use of the street and gardens was quite extensive in the old Yenimahalle settlement. Interactions among children also strengthened the neighbourly relations between their families. The street form was already quite narrow in the past. It is noteworthy that the residents defined the widened area at the end of the street as a "square" (Figure 12). The presence of commercial functions such as a grocery store, a haberdashery, and a hardware shop in this so-called "square" during that period suggests that this designation was not based solely on formal spatial characteristics. The area perceived as a square was animated through children's use of it.

However, today, children's use of the street and gardens has gradually decreased. Due to high vehicle density and the narrow street layout, children's play areas have shifted into homes.

Figure 12."The Area Referred to as the 'Square' Where the Street Meets Taner Street

In the past, everyone on the street knew one another, and neighbourly relations were at a very high level. The fact that the majority of the female residents were housewives was also one of the reasons for the intensity of neighbourhood activities. Today, however, the increase in residential density along the street has negatively affected neighbourly relations. The decrease in intimacy as the number of residents increases may be attributed to the fact that people no longer know each other. While some participants stated that they still feel a sense of trust with their neighbours, others reported feelings of insecurity due to the increase in the number of storeys and the changing user profile following the departure of long-term Yenimahalle residents. Efforts by residents to live in harmony with one another have gradually introduced a more formalised social atmosphere between neighbours. In addition, the increase in women's participation in working life compared to the past has further weakened neighbourhood relations, making it more common to encounter apartment residents who do not know each other at all.

Homeowners of the old Yenimahalle settlement continue to maintain their neighbourly relations at the same frequency. This relationship can be described as a form of "preserved neighbourhood environment," as it is based on a shared past and common cultural background. With working families, their relationships are instead built on a level of familiarity. It can also be said that a similar "preserved neighbourhood environment" exists in relations with local shopkeepers.

While the old settlement pattern is generally rejected by younger generations today, it should be emphasised that it remains the preferred living environment for older residents.

In the past, there was no significant vehicle density in old Yenimahalle, and most houses also had their own parking spaces. Today, however, parking problems have increased considerably and have become another factor negatively affecting neighbourhood relations. Although the street remains equally narrow, the increase in the number of housing units and the fact that almost every household now requires parking space for nearly two vehicles were not adequately addressed during the apartmentization process. Parking solutions remain insufficient. The provision of only single-lane vehicle access beneath buildings at street level (Figure 13) and the lack of adequate parking capacity represent major design deficiencies. As a result, parking spaces have become a frequent source of conflict among neighbours.

Figure 13. Single-Lane Parking Entrances of the Apartment Buildings

In both periods, it can be said that neighbourhood relations were not limited solely to the apartment buildings or even to the street itself, but were also established with the surrounding environment. While the narrowness of the street has been preserved, the vertical growth of the apartment buildings has caused ground-floor residents to be exposed to darkness and cold. In addition, the construction of a wall along the side of the street facing Yunus Emre Park has resulted in the loss of one of the façades of the ground-floor dwellings (Figure 14). For ground-floor residents who maintain a visual relationship with the street through only a single façade, the garden has gained increased importance. However, front gardens could not be used effectively; moreover, some apartment residents have completely eliminated these gardens and converted them into parking spaces.

Figure 14. Example of the Garden Being Used as a Parking Space

In recent years, abandonment of Yenimahalle has become increasingly common. It is also observed that those who continue to reside in Yenimahalle tend to prefer gated residential site living. The main reasons for moving out of Yenimahalle are generally parking problems, excessive concretion, the inability to use green areas, the ageing of buildings, and the weakening of neighbourhood relations.

The study is structured around a three-stage system: the distant past, the recent past, and the present. As a result of the field study, the sharp spatial separation between the distant past and the recent past has been found to affect neighbourhood relations. Negative concepts such as insecurity, formality, parking problems, and incompatibility with collective living have emerged. Users who have reached a level of exhaustion with these negative conditions tend to leave Yenimahalle whenever an opportunity arises. It is noteworthy that those who relocate generally prefer gardened, detached houses. Among some of the users who still reside in the area, a longing for detached houses with gardens is also observed.

The architectural attributes of old Yenimahalle directly shaped everyday life practices. An architectural solution was presented in which spatial life was carefully constructed. However, the process of apartmentization carried out without changing parcelization and planning left this spatial life configuration incomplete. While this situation negatively affected neighbourhood relations, it also caused residents to seek new spaces where they could reproduce their former daily practices.

Within the system structured as distant past–recent past–present, the urban element that reinforces neighbourhood relations is the street. The fact that open spaces functioned as places of neighbourhood interaction increased the street–neighbourhood relationship in housing designs connected to the street. The sharp separation of the street from housing has affected both everyday life practices and neighbourhood relations.

Conclusion

This study reveals that the user profile, the relationship between housing and street, and the spatial organisation are key parameters in shaping spatial neighbourhood relations. The strong relationship between the street, garden, and housing in first-settlement dwellings was directly reflected in neighbourhood relations. Shared production, spending the day together, and urban–spatial relations that enabled strong socialisation fostered the formation of a neighbourhood culture. Social housing types, such as lodgings, similarly offer a culture of neighbourhood and communal living.

In apartment buildings, however, spatial and technical problems have contributed to the emergence of conflicts in social relations. The loss of shared spaces has reduced socialisation and brought individualism to the fore. It is striking that users who internalise such a culture in contemporary detached houses exhibit inward-oriented socialisation behind garden walls. It is clear that this new form of socialisation does not include the traditional characteristics of "neighbourhood."

According to critics, the modern world appears as a product of an environment that has become enslaved to global capital and driven by profit. It cannot be said that the interpretation of the modern has been successful in transforming life and history. Architects have forgotten the importance of the design idea and have turned into technical experts producing automatically (Maden & Şengel, 2009).

In today's architectural environment in Ankara, examples can be found in which perceptions of the modern have diversified. While transforming life and architecture, the modern does not separate these two concepts, since it also constructs spatial experience. However, what society and profit-oriented actors overlook in their interpretation of the modern is the decline in the qualitative level of the new. If new architectural and urban outputs were able to enhance the qualities of what they replace, rather than weaken them, spatial relations would be strengthened instead of diminished.

Considering any design independently of the characteristics of the place, its history, and its context may affect the success of the resulting outcome. In the transformation of Yenimahalle, the prioritisation of profit over a thorough understanding of local life has led to one of the negative outcomes of this transformation. Neighbourhood is not merely an abstract concept between people. Space gives rise to these relations, and if it is not well designed, these relations are transformed. In a city that is increasingly becoming concreted, where the relationship with the street is severed, and the use of open spaces is reduced, it has been observed that neighbourhood relations are transforming by incorporating new meanings within the rapid flow of modern times. Preserving the familiar spirit of a place may not be possible when space undergoes negative transformation.

This study demonstrates that in today's transformations, changing the architectural product without altering the planning, or completely changing both the plan and the architectural product while ignoring the notion of place, increases the potential to create nothing more than clusters of concrete blocks. Architecture is not a discipline that should merely produce visual masses; it designs lives that incorporate the senses and emotions. Therefore, space directly affects the relationships of its users. When neither the garden functions as a true garden nor the dwelling offers genuine living practices as a true home, architecture fails to achieve its goal. Neighbourhood is a concept inseparable from space and is shaped by all of these interrelated elements.

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BÖLÜM 4

CIRCADIAN-RESPONSIVE URBAN DESIGN: INTEGRATING URBAN LIGHTING, HEALTH AND PLANNING

GİZEM İZMİR TUNAHAN[1]

Introduction

Urbanisation produces light to make the night 'visible and functional'; yet this production also creates the city's own artificial photic regime. The naturally low illuminance levels of the night have been replaced by a 24-hour lighting environment sustained by street lighting, architectural accent lighting, billboards, facade lighting, vehicle headlights and light leaking from indoors. This transformation does not simply mean 'brighter nights'; it also generates a new form of environmental exposure in terms of spectrum (wavelength distribution), timing (when and for how long) and spatial spread (where, at what intensity): artificial light at night (ALAN). When ALAN is not managed at the urban scale, it emerges as a multi-factor environmental risk that can affect both human health and ecosystems through skyglow, glare, light trespass and

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ecological light pollution (Falchi et al., 2016; Gaston et al., 2013; Zielinska-Dabkowska et al., 2023).

This chapter aims to bring the core mechanisms of circadian biology into dialogue with the language of urban lighting planning; to summarise measurement and mapping approaches; to discuss the health evidence using a cautious causal framing; and to present actionable design and policy tools as a holistic model under the framework of 'Circadian-Responsive Urban Design' (CRUD). This framework considers the spectral, temporal and spatial components of light together and emphasises that health- and environment-aligned lighting decisions are not merely a matter of selecting individual luminaires, but an issue of governance at the planning scale (Zielinska-Dabkowska et al., 2023).

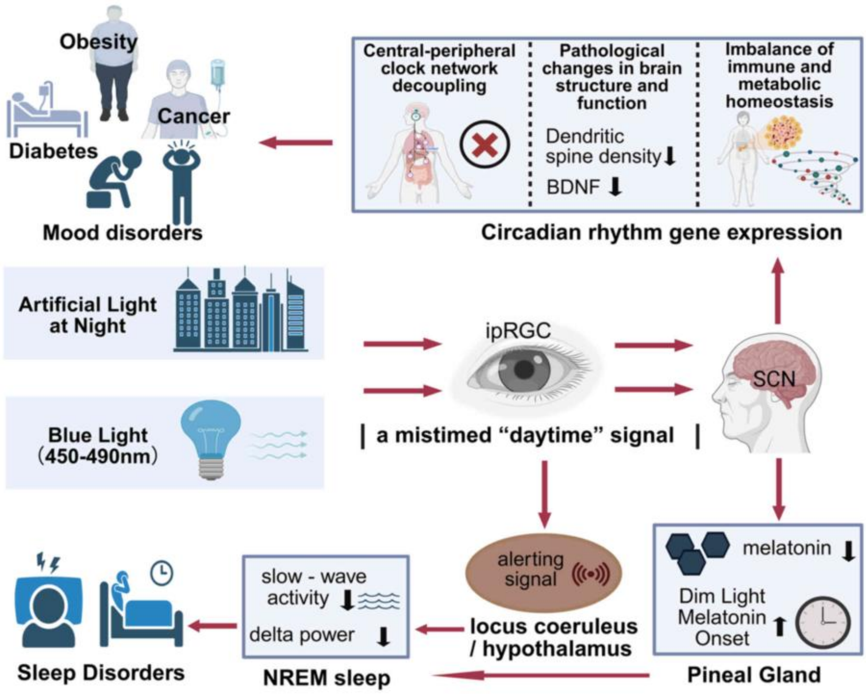
The circadian system and the biological effects of light

The ipRGC-melanopsin pathway and spectral sensitivity. Beyond visual perception, the human eye contains a dedicated retinal pathway that conveys the effects of light on biological timing (Figure 1). Cells known as intrinsically photosensitive retinal ganglion cells (ipRGCs), which contain melanopsin, are susceptible to short wavelengths (around 480 nm) and connect to the circadian clock via the suprachiasmatic nucleus (SCN) in the hypothalamus (Gooley et al., 2010). Therefore, two lighting arrangements with the same 'lux' level may not be biologically equivalent if their spectral content differs. A foundational principle of circadian-friendly design is that the quality (spectrum) and timing of light matter as much as its quantity.

Melatonin suppression, sleep and systemic regulation. Melatonin is a hormone that increases in darkness and is one of the biochemical markers of the sleep-wake cycle. Exposure to light at night can suppress melatonin secretion, delay circadian phase and postpone sleep onset (Zeitzer et al., 2000; Reiter et al., 2007).

Because these mechanisms are linked to metabolic regulation, immune responses and cellular repair processes, chronic exposure to 'light at the wrong time' is considered plausibly associated with long-term health risks (Bass & Takahashi, 2010; Blask, 2009; Zielinska-Dabkowska et al., 2023).

Figure 1 Retinal light input coordinates circadian rhythms and systematic health.



Source: (Yuan et al., 2025)

Measuring and mapping light exposure at the urban scale

Definitions: ALAN, skyglow and light trespass. Urban light exposure arises through multiple pathways: (i) light sources directly entering the visual field (e.g., a street lamp or billboard), (ii) light leaking from indoors to outdoors, (iii) light reflected from surfaces and (iv) skyglow produced by atmospheric scattering at the city scale. From a planning perspective, the critical distinction is that exposure is not only an 'outdoor' issue but also a risk transferred indoors through windows in dwellings and bedrooms (Zielinska-Dabkowska et al., 2023).

Satellite data and ground-level measurements. The most common approaches to monitoring light pollution at the urban scale include satellite-based nighttime lights data (e.g., VIIRS/DNB) and ground-level measurements of illuminance, irradiance and luminance. Satellite data are powerful for revealing spatial hotspots and temporal trends across large areas; however, they do not directly provide biologically critical variables such as spectral detail, vertical illuminance (eye-plane) and personal exposure. Accordingly, satellite data help answer the planning-scale question 'where is the problem?', whereas ground measurements provide detail on 'which light, under which conditions, and how influential?' (Cinzano et al., 2001).

Atmospheric modulators: clouds, aerosols and seasonality. Atmospheric conditions can amplify the impacts of urban lighting. Cloud cover can substantially increase sky brightness within cities and thus 'amplify' light pollution. In Berlin, sky brightness under cloudy conditions was reported to increase by a factor of 10.1 within the urban area (Kyba et al., 2011). This finding shows that light-management strategies should be evaluated not only for clear-sky 'ideal' conditions but also for cloudy and rainy night scenarios.

Artificial Light at Night and Public Health: Assessing Risk Levels and Evidence-Based Associations

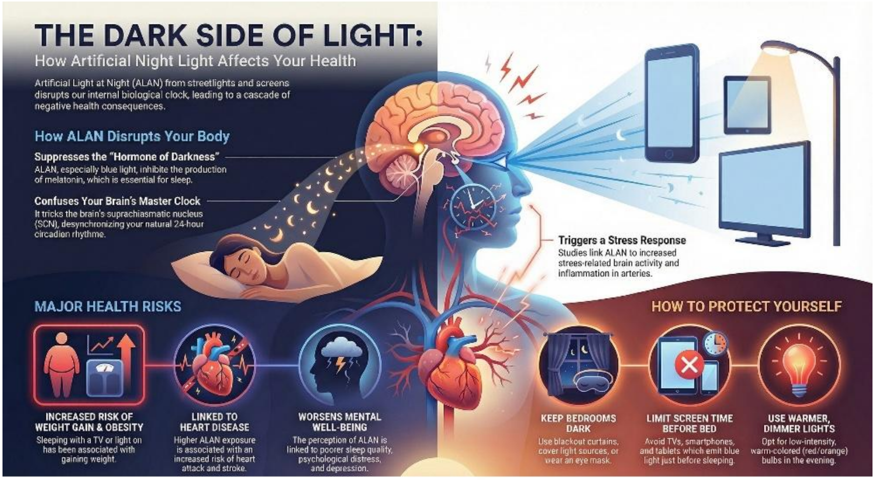
Findings associated with metabolic outcomes. Population-based studies have reported associations between nighttime light exposure and weight gain, as well as obesity and metabolic risks. For example, in a large cohort of women, having a light or television on in the room during sleep was reported to be associated with weight gain and a higher risk of obesity (Park et al., 2019). Similarly, evidence has been presented suggesting that nighttime light exposure may be associated with an increased risk of type 2 diabetes (Salomon et al., 2025).

Cancer-related findings and biological plausibility. The melatonin-suppression and chronodisruption pathway is discussed in relation to cancer biology through plausible mechanisms. Reviews in this area indicate that the 'nighttime light-melatonin suppression-hormonal/immune regulation' chain offers a biologically plausible framework, while emphasising the difficulty of establishing causality in human studies (Reiter et al., 2007; Blask, 2009). In prospective cohort data, higher exposure to artificial light at night has been reported to be positively associated with specific cancer types (e.g., thyroid cancer) (Zhang et al., 2021).

Mental health, sleep and adolescence. ALAN is discussed not only in relation to adult metabolism but also through pathways involving sleep patterns and mental health. In a national sample of US adolescents, satellite-based outdoor ALAN levels were reported to be associated with more adverse sleep patterns and mood/anxiety disorders (Paksarian et al., 2020). Such findings suggest that urban planning decisions may generate inequities for sensitive groups (children, adolescents, older adults and those with chronic conditions).

Causal language and limitations. The existing epidemiological literature essentially produces evidence at the level of association; that is, most study designs cannot definitively claim that ALAN alone has a direct causal effect (Figure 2). Exposure measurement error, socioeconomic differences, noise, air pollution, shift work and other confounders can influence outcomes. For this reason, this chapter adopts a cautious framing, using phrases such as 'is associated with risk' and 'is plausible via mechanisms' rather than definitive statements like 'causes' (Zielinska-Dabkowska et al., 2023).

Figure 2 The effect of artificial light on human health conditions



Source: developed by the author

Circadian-friendly urban lighting strategies

Spectral management: not CCT alone, but melanopic metrics. In practice, correlated colour temperature (CCT) is often used as a rough proxy for the 'blue component'; however, it is insufficient on its own to determine the biological impact. The CIE S 026 standard proposes alpha-opic metrics that quantify the ability of light to stimulate different photoreceptors and measures such as melanopic equivalent daylight illuminance (melanopic EDI) (CIE, 2018). Expert consensus recommendations developed for indoor environments suggest targeting higher melanopic EDI at the eye plane during daytime and applying the lowest feasible melanopic EDI limits in the pre-sleep period (at least 3 hours) and during sleep (Brown et al., 2022). From an urban planning perspective, this approach provides a strong technical justification for reducing outdoor nighttime lighting to the 'necessary minimum' and minimising short-wavelength content.

Intensity and timing management: dimming, curfew and adaptive control. Among the most effective risk-reduction tools in urban lighting are reducing light levels (dimming), partial shut-down or reduction at certain hours (curfew) and adaptive control systems based on usage intensity. The critical principle is to move from 'fixed high illuminance' to a lighting infrastructure that varies with need. This approach reduces both energy consumption and unnecessary exposure, and may also help limit the skyglow amplification observed on cloudy nights (Kyba et al., 2011; Zielinska-Dabkowska et al., 2023).

Optical control: directing light to the ground and reducing glare. Luminaire optics determine where light will be adequate. Full-cut-off luminaires reduce upward light output, thereby limiting the formation of skyglow. Glare and light trespass are not only matters of visual comfort but also of indoor exposure, because light that directly reaches a bedroom window can create a biologically relevant exposure even at low lux levels (Zielinska-Dabkowska et al., 2023).

Zoning: sensitive receptors and the urban hierarchy. Within the CRUD approach, not all parts of the city share the same lighting objectives. Hospitals, care homes, residential areas, school surroundings, dark corridors, ecologically sensitive areas and cultural heritage zones carry different risk profiles. Therefore, 'lighting zoning' is a planning instrument that can be aligned with health and ecology goals. GIS-based approaches enable the production of lighting priority maps by jointly considering land use, population density, sensitive sites, and cultural values (Soydan & Tekinalp, 2025). The core photometric and epidemiological evidence discussed thus far, which justifies the proposed circadian-responsive urban lighting framework, is synthesised in Table 1.

Table 1 Synthesis of Circadian Evidence and Urban Lighting Design Implications

Finding	Importance	Reasons/ Mechanisms	Conclusions/ Design Implications
ipRGC-melanopsin pathway and spectral sensitivity	Identifies biological sensitivity to specific light wavelengths beyond visual perception.	Retinal cells (ipRGCs) are sensitive to short wavelengths (~480 nm) and connect to the circadian clock via the SCN.	Quality (spectrum) matters as much as quantity; use melanopic metrics instead of just CCT; minimise short-wavelength content at night.
Melatonin suppression and systemic regulation	Linked to metabolic regulation, immune responses, and cellular repair processes.	Exposure to light at night suppresses melatonin secretion and delays the phase of the circadian rhythm.	Temporal planning: establish evening-night profiles and adaptive systems to limit suppression.
ALAN and Metabolic Risks (Obesity/Diabetes)	Associated with weight gain and increased risk of type 2 diabetes.	Light or TV presence during sleep disrupts metabolic regulation and sleep-wake cycles.	Control light trespass and advertising light; improve shielding and blackout measures for dwellings.
Cancer-related findings (Thyroid Cancer)	Higher ALAN exposure is positively associated with certain types of cancer.	Biologically plausible 'nighttime light-melatonin suppression-hormonal/immune regulation' chain.	Mitigation in chronically exposed zones; implement zoning for sensitive groups.

Adolescent Mental Health and Sleep	Outdoor ALAN is linked to adverse sleep patterns and mood/anxiety disorders.	Disruption of circadian rhythms and sleep during a critical developmental stage.	Enact low-level and early-reduction policies around schools and residential areas.
Skyglow amplification by clouds	Significantly increases light pollution levels in urban environments.	Cloud cover causes atmospheric scattering, increasing sky brightness by a factor of 10.1 in some cities.	Design dimming and curfew profiles specifically for cloudy-night scenarios; use adaptive control.
Optical control and Light Trespass	Reduces biologically relevant exposure inside bedrooms and limits skyglow.	Full-cut-off luminaires direct light to the ground; preventing light from reaching windows reduces the risk of indoor light pollution.	Use full-cut-off optics; transition from fixed high illuminance to varying infrastructure as needed.
Urban Lighting Zoning	Addresses varying risk profiles across different urban land uses.	Hospitals, residential areas, and dark corridors require distinct photic regimes for optimal health and ecological balance.	CRUD framework: Use GIS-based lighting priority maps to align with health and ecology goals.

Planning and policy integration

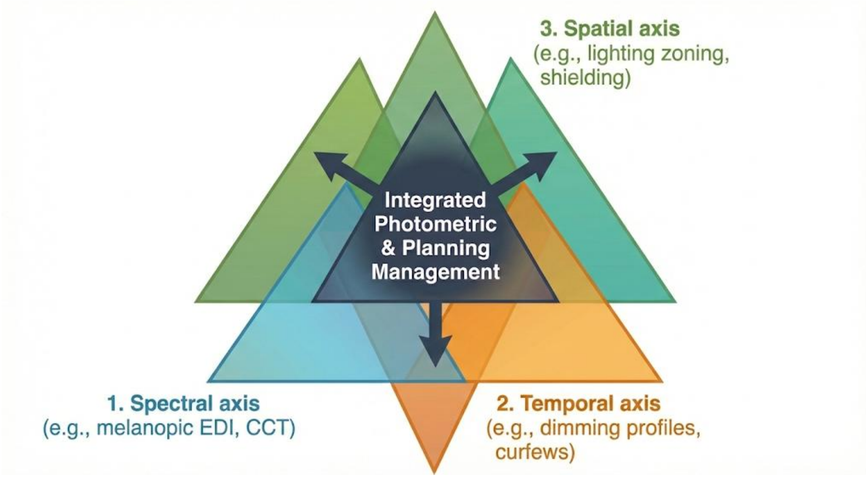
Lighting master plans: health-based performance targets. Engineering and aesthetic priorities often drive urban lighting decisions; however, a circadian health perspective requires linking decisions to measurable performance targets. A lighting master plan should include: (i) target light levels, (ii) spectral characteristics, (iii) temporal profiles (evening, night, morning), (iv) zoning and (v) monitoring indicators (KPIs). Integrating this plan with urban design guidelines, land-use planning decisions, environmental impact assessment and energy-climate strategies increases implementation success (Zielinska-Dabkowska et al., 2023).

Monitoring and governance. Urban light management cannot be sustained with a 'install once and forget' approach. Luminaire ageing, maintenance, new developments, billboards and changing use patterns continuously reshape the photic regime. Therefore, a monitoring loop should be established using satellite data, ground sensors, and field audits, and corrective-action mechanisms (e.g., PDCA cycles) should be implemented when targets are missed (Zielinska-Dabkowska et al., 2023; Soydan & Tekinalp, 2025).

Original framework: the Circadian-Responsive Urban Design (CRUD) model

Three components: spectral, temporal and spatial. CRUD addresses the urban photic regime along three axes: (i) the spectral axis - short-wavelength content and melanopic stimulation; (ii) the temporal axis -evening-night-morning profiles and dimming/curfew; (iii) the spatial axis - zoning, sensitive receptors and light trespass. Managing these axes together is based on the idea that 'single technical fixes' (e.g., reducing CCT alone) are insufficient if timing and spatial spread problems persist, because biological risk may remain (Zielinska-Dabkowska et al., 2023). Figure 3 illustrates the interconnected axes of the CRUD framework, emphasising the necessity of integrating spectral, temporal, and spatial controls to manage urban ALAN exposure effectively.

Figure 3 The CRUD framework integrates spectral, temporal and spatial control of urban ALAN exposure.



Source: developed by the author

Measurement metrics: melanopic EDI and eye-plane illuminance. To make the model operational, defining metrics is critical. CIE S 026 provides a metrology framework that enables the calculation of metrics such as melanopic EDI (CIE, 2018). Indoor expert consensus recommendations suggest practical thresholds, such as maintaining daytime exposure greater than 250 melanopic EDI, limiting pre-sleep exposure to less than 10 melanopic EDI, and ensuring a sleep environment of less than 1 melanopic EDI (Brown et al., 2022). These thresholds should not be copied directly to outdoor contexts at the urban scale; however, the focus on 'eye-plane/vertical illuminance' and 'melanopic content' makes the health dimension of outdoor lighting design technically visible (CIE, 2018; Brown et al., 2022).

Implementation roadmap. The implementation of CRUD can be summarised in four steps: (1) Situation analysis - ALAN maps and an inventory of sensitive receptors using satellite and field measurements; (2) Target definition - zone-specific targets for light level, spectrum and temporal profile; (3) Intervention design - optical control, dimming/curfew, adaptive control, and governance of advertising and architectural lighting; (4) Monitoring and improvement - periodic measurements, complaint data, linking with health indicators where feasible, and policy updates (Soydan & Tekinalp, 2025).

The following actionable strategies are recommended to integrate the CRUD framework into urban planning and lighting policies:

- **Spectral Management and Metric Transformation:** Move beyond Correlated Colour Temperature (CCT) and adopt alpha-opic metrics, such as melanopic equivalent daylight illuminance (melanopic EDI), as defined by the CIE S 026 standard. Lighting designs should prioritise minimising short-wavelength (blue) content during the pre-sleep and sleep periods to minimise circadian disruption.
- **Dynamic and Adaptive Lighting Control:** Transition from fixed, high-intensity illuminance to adaptive lighting systems that utilise dimming and curfew profiles based on real-time usage and necessity. These strategies must specifically account for atmospheric modulators, such as cloud cover, which can significantly amplify urban skyglow.
- **Health-Oriented Lighting Zoning:** Implement "lighting zoning" as a planning instrument, using GIS-based priority maps to establish distinct photic regimes for sensitive areas, including residential zones, hospital surroundings, schools, and ecological corridors.
- **Optical Control and Mitigation of Light Trespass:** Mandate the use of full-cut-off luminaires to ensure light is directed strictly to the ground, thereby preventing biologically relevant light trespass into bedroom windows and reducing overall skyglow.

- **Integrated Lighting Master Plans (LMP):** Develop LMPs that include measurable Key Performance Indicators (KPIs) for spectral content, temporal profiles, and spatial distribution. These plans should be legally integrated with urban design guidelines, land-use planning, and environmental impact assessments.
- **Continuous Monitoring and Governance:** Establish a permanent monitoring loop utilising satellite data, ground-level sensors, and field audits. Implement corrective-action mechanisms, such as PDCA (Plan-Do-Check-Act) cycles, to ensure that lighting environments remain aligned with health-based performance targets over time.

Conclusion

How cities light the night is not merely a matter of visual comfort or aesthetics; it is an environmental exposure regime that may be associated with biological timing, sleep health and long-term chronic disease risks. This chapter has brought together the core mechanisms of circadian biology (the ipRGC-melanopsin pathway and melatonin suppression), urban-scale measurement and mapping tools, and the health evidence to propose a planning-translatable framework. The proposed CRUD model integrates spectral, temporal and spatial management to support urban lighting that is implemented in the right place, at the right time, with the right spectrum and level. Ultimately, strengthening lighting master plans with health-based performance indicators, mainstreaming tools such as adaptive control, optical improvement, and zoning, and institutionalising monitoring loops are critical priorities for circadian-friendly cities (Zielinska-Dabkowska et al., 2023).

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BÖLÜM 5

ANALYSIS OF THE CHANGE IN TRADITIONAL CITY CENTERS USING THE SPACE SYNTAX METHOD: THE CASE OF AKSARAY CITY

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ZAFER KUYRUKÇU[2]

INTRODUCTION

Cities, one of the most important spatial formations of the contemporary world, express the way an era is shaped. The word city is defined as "a settlement, usually without agricultural activities, with a population of over twenty thousand, and where the majority of the population works in fields such as trade, industry, services, or administration; a town or city" (TDK, 2025). Cities undergo a series of changes and transformations over time. This change continues with the increase in spaces designed to facilitate the easy movement of the population within the city and to meet many of its needs. This change in the shape and structural characteristics of cities is analyzed through research in urban morphology. As a branch of science that examines the dynamic

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structure of cities, urban morphology enables the identification of the changing character of cities in the context of time, space, and physical environment (Sakar & Ünlü, 2019).

Cities have always held strategic importance due to their location within their geographical area (Boz & Kubat, 2018). As a result of the local and universal values that societies have created over centuries, cities have been open to development and change. Aksaray, a city that has been a settlement area for many civilizations throughout history and is located on important trade routes, is constantly undergoing a process of transformation due to these characteristics. Throughout history, Aksaray has undergone significant changes in its social, economic, and physical development. This study aims to morphologically analyze the change and development of Aksaray, which gained provincial status in 1989. The study area selected is the Merkez-1 region, which was determined within the scope of the urban planning studies carried out in 2012 and includes Aksaray's traditional city center and central business districts. The Merkez-1 region is bordered by Cumhuriyet Boulevard to the north, Atatürk Boulevard to the south, and the E90 Highway to the west, and encompasses the areas on both banks of the Uluırmak River. The urban morphology of the region, defined between 1989 (when Aksaray became a province) and 2024, a period of significant historical and geographical importance, has been analyzed using the Space Syntax method, focusing on connectivity, integration, intelligibility, and choice values.

Cities, due to the natural, cultural, and social layers they contain throughout history, are extremely important and valuable living spaces. Aksaray city center, in addition to having a rich history, is situated at a crossroads connecting the river passing through the study area and important trade routes, resulting in the region bearing traces of many civilizations. Aksaray, a Seljuk city, was founded on fertile lands for agriculture, watered by Uluırmak. Therefore, for many years, a large part of the economy of Aksaray has been based on agriculture (Kuyrukçu & Akbaş, 2024). Having been under the dominion of various cultures and administrations over time, Aksaray exhibits the characteristics of a single-centered city. The traditional city center, which emerged within the city walls, has survived to the present day.

Accurate perception of the city's current situation and the implementation of appropriate projects are important considerations. Because historical cities carry traditional values that are difficult to reclaim, basing studies on a mathematical foundation is of particular importance (Kepenek, 2011). This study examines the historical city center of Aksaray and its immediate surroundings using the space syntax method, analyzing the changes Aksaray underwent during its transition to provincial status from a historical perspective. The aim is to make predictions about how the city might develop in the future.

MATERIAL AND METHOD

Urban morphology is considered an important analytical tool in determining the processes of change and transformation that urban fabrics have undergone over time, understanding the historical origins of spatial and functional structures, and transferring this accumulated knowledge to the present day. A detailed analysis of urban morphology is necessary to understand the development processes of cities and to carry out effective planning in response to these processes. In this study, the urban morphology of the area located in the city center of Aksaray, defined as the Center-1 region in the 2012 Zoning Plan Notes, both before Aksaray gained provincial status and in the present day, was examined using the Space Syntax method. The basic parameters of this numerical method were Connectivity, Integration, Intelligibility, and Choice values.

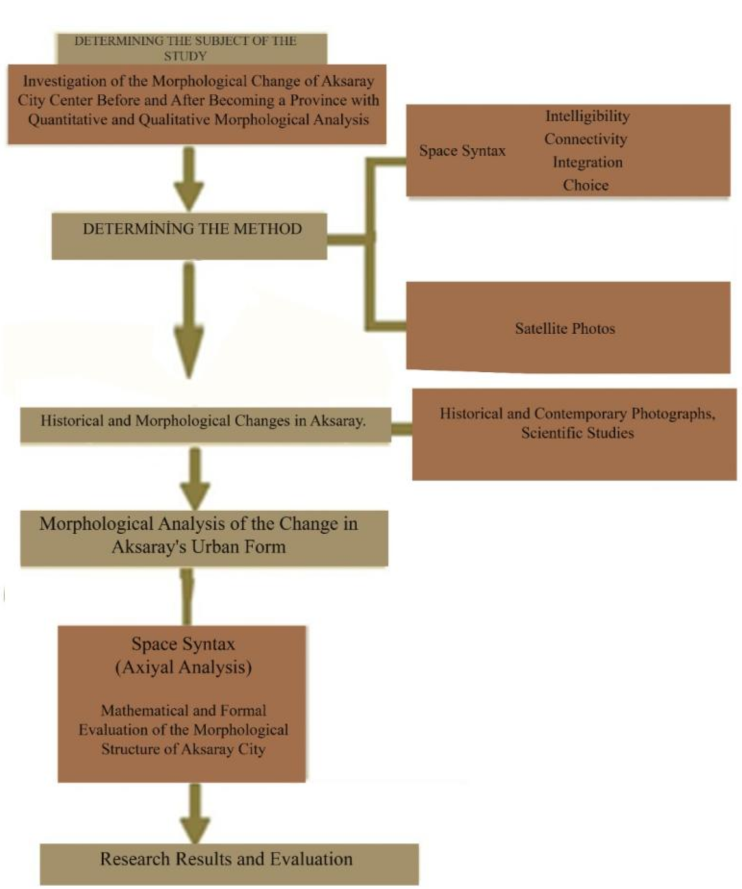
Connectivity is a concept that addresses the relationships between spaces within the framework of accessibility (Hillier & Hanson, 1984). It is considered one of the fundamental indicators in the analysis of spatial structure. In this context, the connectivity value expresses the quantitative equivalent of the direct relationships that any axis in a spatial system establishes with other axes. An increase in the value indicates that the system has integrated and strong relationships, that pedestrian use has increased, and that the spatial network has formed a tight network of relationships within itself (Ünlü, 1999).

Integration is a criterion that reveals the level of relationships each axis of movement in a spatial system establishes with other axes. Directions with a high number of intersections are considered to be strong axes with the highest integration value within the system, while directions with fewer intersections are defined as axes that are disconnected or separated from the system (Yıldırım & Çağdaş, 2018).

Intelligibility is a criterion that reveals the harmony between interconnectedness and integration values in a spatial system. This indicator reflects the capacity of a space user to mentally comprehend their entire environment. Increased intelligibility allows individuals to navigate more easily within a space and provides a more comprehensive visual understanding of their location (Hillier et al., 1987).

Choice value refers to the extent to which a particular axis or location within a spatial network is preferred over the shortest paths between different points. It is a criterion that shows. In other words, the choice value indicates the transition potential of an axis within the system and its importance in the flow of motion. This is revealed by Hillier & Hanson (1984). Axes with high choice value are considered to be more frequently used routes in movements between different starting and ending points in the system. Therefore, choice analysis is considered an important indicator, especially in understanding pedestrian and vehicular mobility, commercial activity, and public use intensity. In Space Syntax theory, choice value is one of the fundamental analyses that reveals the functional performance and flow orientations of a spatial network (Hillier, 1998).

Figure 1. Method Diagram



Kaynak: Created by the authors.

Spatial syntax is a comprehensive methodological framework developed to analyze the spatial organization of buildings and urban environments. By addressing the relationships between space and social structures within a holistic theoretical framework, it is one of the leading scientific approaches widely accepted in both architecture and urban design disciplines (Hillier, 1998). This method examines the connection between the morphological structure of space and the practices of users in experiencing and using that space within that morphological order. Within this framework, the aim is to produce findings that quantitatively reveal user behaviors and spatial usage patterns based on spatial forms and morphological characteristics.

Hillier and Hanson (1984) argued that the fundamental determinant in defining urban space is the relational arrangement between open and closed spaces within the urban fabric. Hillier (1983) argues that circulation dynamics at the urban scale are determined by the syntactic organization of spaces, the level of connection between spaces, and the grid-like morphology of the urban plan. Within this theoretical framework, the urban system that forms the flow of movement is conceptualized and expressed through axial lines. It is stated that in urban environments, grid structure directly affects movement flows, accessibility, and density distribution, but these variables do not have a decisive effect on grid structure itself. Therefore, in analyses conducted within the scope of spatial syntax, the grid level has been accepted as one of the fundamental components of analytical evaluations.

In the analyses, Google Earth satellite images from different years, historical photographs obtained from the Directorate General for Mapping archives, and zoning plans provided by Aksaray Municipality were used as data sources. This study attempts to visualize the morphological changes of the city over different years through marking and coloring performed on satellite images and zoning plans. The data obtained at the end of the analysis process were compared morphologically, and findings regarding the formal transformation of the city were revealed (Figure 1). The analysis results revealed the direction and dynamics of the change in Aksaray's urban form; based on these findings, suggestions were developed to contribute to the positive development of interaction between urban space and users.

HISTORICAL DEVELOPMENT OF AKSARAY

Aksaray province is geographically located in the Tuz Gölü basin of Central Anatolia. The region also holds a significant historical position, situated at the intersection of north-south and east-west routes. The city came under Ottoman rule in the last quarter of the 15th century and remained under the Karaman Province for a long time (Konyalı, 1974). The earliest information regarding Aksaray's administrative status dates back to 1476. In the first endowment register of the Karaman Province from that date, Aksaray is mentioned as a province, but it is thought to have been a district or sanjak at that time. In the second endowment register of the Karaman Province from 1483, Aksaray is referred to as a district, which strengthens the possibility that its administrative status in 1476 was a district. The designation of Aksaray as a sanjak is first recorded in the fiefdom dated 1516 (Yörük, 2005). Archaeological excavations conducted around Aşıklı Höyük and Acem Höyük reveal that Aksaray has been home to settled life since prehistoric times (Gülçur, 1999). With a history spanning ten thousand years, Aksaray was under the influence of Hittite, Persian, Hellenistic, Roman, and Byzantine civilizations before coming under Turkish rule (Doğanay & Eskin, 2018). Following the Battle of Malazgirt in 1071, Aksaray and its surroundings came under Turkish control with the conquest of Cappadocia by Danişmend Ahmet Gazi. Incorporated into the Seljuk territory during the reign of I. Sultan Mesut of the Anatolian Seljuks, Aksaray experienced a significant rise in cultural and economic terms during this period. After Konya became the capital, it emerged as a strategic settlement and military center on the route to the east. Aksaray, which was ruled by the Anatolian Seljuks, then the Eretna and the Karaman, entered Ottoman rule under Mehmet the Conqueror. During the Ottoman period, the city's inhabitants were forced to migrate to Istanbul; as a result of this process, the city was largely emptied and lost its former importance (Erdal, 2014). Today, the Aksaray district in Istanbul was historically founded by families who came from Aksaray as a result of these migrations (Baylak & Taş, 2021).

The Historical and Urban Development Process of Aksaray City

Aksaray stands out as a region that has hosted many civilizations throughout history, and there is mention of an ancient castle forming the city center. Located at the intersection of trade, military, and religious routes, the city is estimated to have been surrounded by walls. Only a small part of the castle has survived to the present day. Although definitive information about the castle is limited, historical sources reveal that its origins date back to ancient times (Gürel Ağır, 2021). Although Aksaray Castle has largely disappeared today, it continued to function as the city center, and the city's form was shaped around this castle (Table 1).

Table 1. Historical Development of Aksaray City Center

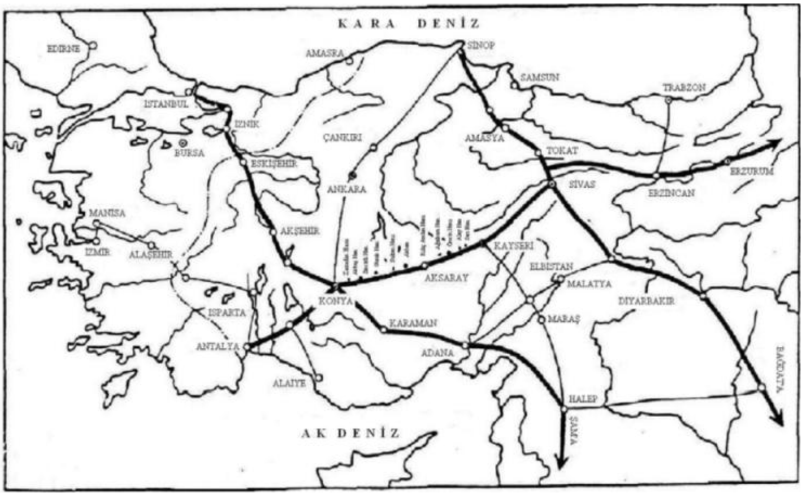
Aerial view of Aksaray, 1954	*Aerial view of Aksaray, 2023*

Kaynak: Gürel Ağır, 2021

Aksaray is situated on fertile lands irrigated by the Melendiz River (Uluırmak) and has gained significant development opportunities thanks to its strategic location on historical trade routes. However, its geographical lack of access to the sea has limited the city's growth potential to a certain extent (Aytekin, 2018). The Seljuk period stands out as a time when Aksaray made significant progress in social and cultural terms. During this period, the city experienced a significant development process, especially in terms of construction activities.

During the Seljuk period, Aksaray was largely used as a military base, and trade activities were significantly supported by the construction of caravanserais on important trade routes (Özer, 2017). In this context, Aksaray, with both its strategic location and its urban and architectural development, holds a special place historically and culturally as one of the important cities of Anatolia during the Seljuk period. The Seljuk period significantly supported regional economic development in Central Anatolia by ensuring the security and stability of trade, and the fact that the shortest route of the Konya-Kayseri-Sivas line passed through Aksaray stands out as one of the distinctive features of this period (Figure 2).

Figure 2. Historical Trade Routes



Kaynak: Topal, 2006

Aksaray, which was a district (sanjak) under Konya before the Republican era, gained municipality status in 1886. From 1920 to 1933, it was a province, but in 1933, a law was passed connecting it to Niğde, considering its population and level of development, and it gained district status. Aksaray regained its provincial status on June 15, 1989, with Law No. 3578. From the second half of the 20th century onwards, the city entered a significant development phase. During this period, the city experienced rapid growth, and administrative structures, industry, and trade activities quickly took shape. Among the administrative buildings constructed during the Republican era, the governor's mansion in the city center became an important landmark for both the city and its center (Güner, 2013). By 2025, Aksaray had demonstrated significant development in agriculture, trade, and industry. During this process, types of structures other than military structures came to the forefront, and at the same time, the effectiveness of civil society movements in social life increased (Özer, 2017).

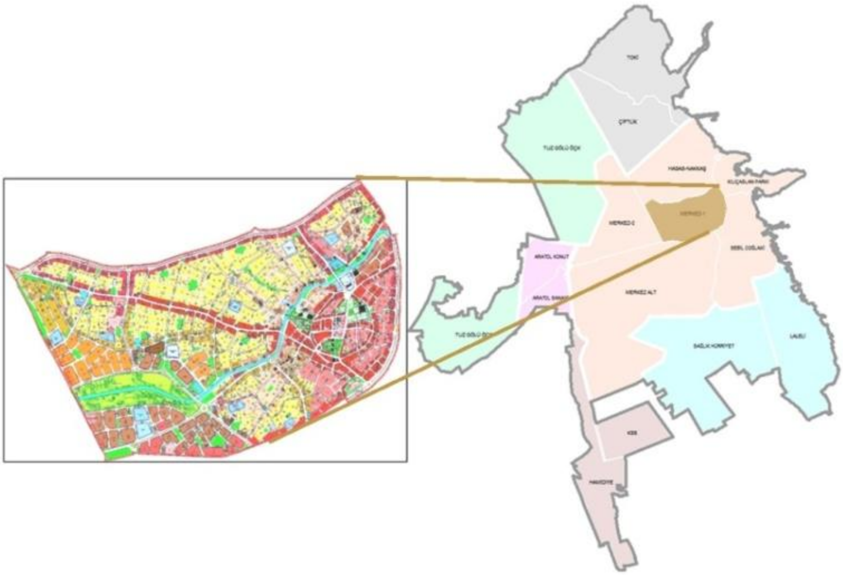
MORPHOLOGICAL ANALYSIS OF THE CHANGES IN THE TRADITIONAL CITY CENTER OF AKSARAY

Aksaray city center is an important settlement area that has carried traces of different civilizations throughout history. Located at the intersection of historical trade routes, the city has gained strategic importance. The city’s settlement structure has largely taken shape around the Uluırmak River, ensuring continuity within the city. The city center, located east of the Uluırmak, was originally situated on a slightly elevated hill. However, due to the dense urbanization today, this natural topographical feature is not fully understood. Studies on Aksaray city and its city center show that the current city center is a part and continuation of the city center from previous civilizations. A study aimed at understanding the morphology of the city in such an area provides an important analytical framework for analyzing Aksaray's urban identity and character.

Study Area

Data regarding the Aksaray city center, which was determined as the study area, was obtained from the Aksaray Revision Zoning Plan Research Report provided by the Aksaray Municipality. In addition, a 1/1000 scale cadastral map was also obtained from the Aksaray Municipality to serve as a basis for the analyses to be conducted in the study. In the Aksaray Municipality's revision zoning plan (2012), the city was evaluated in stages to facilitate the interpretation of problems in the areas, to make interventions easier by working in smaller urban areas, and to allow residents to participate more easily in the planning process. Accordingly, the zoning plans were examined in a total of 15 regions, including 6 main regions. The entire planning area is 10,466 hectares. The Central Planning Regions encompass the traditional city center and neighborhoods in its immediate vicinity, where rapid urban development is observed. Six sub-regions were included within the Central Planning Region, and from these six regions, the approximately 334-hectare Central-1 region, bordered by 30 and 40-meter-wide roads, was selected (Figure 3).

Figure 3. Planning Zones and Center-1 Area defined in the 2012 Zoning Plan Notes.



Kaynak: Akbaş, 2025

The study area is bordered by Cumhuriyet Boulevard to the north, Atatürk Boulevard to the south, and the E-90 Highway to the west, encompassing the city center and the areas on both banks of the Uluırmak River. The planning region is considered to be approximately 90-95% built-up. Nearly half of the area has been developed in accordance with the 2003 zoning plans, while the remaining areas consist of regularly plotted parcels created within the framework of previous planning decisions. The topography of the region, including the city center located immediately south of the Uluırmak River, exhibits a slightly elevated and flat hilly structure. This morphological feature is not easily perceived today due to the existing dense construction. Apart from this, the remaining planning area consists of plains with a slope varying between 0-5%.

The study area encompasses 13 neighborhoods: Büyük Bölcek, Küçük Bölcek, Pamucak, Muhsin Çelebi, Meydan, Çerdiğin, Sofular, Dere, Zincirli, Hacı Hasanlı, Hamidiye, and Taşpazar (Figure 4). The Central Business District, being a traditional city center, holds a significant position in understanding the changes in urban morphology.

Figure 4. Neighborhoods and Existing Boundaries in the Study Area.

Kaynak: Akbaş, 2025

The traditional city center was considered an area reflecting the spatial manifestations of the city’s commercial, social, and administrative functions, as well as its socio-cultural life, and was therefore selected as the study area due to its high user density (Figure 5). In this area, administrative, social, and religious buildings built by civilizations from different periods are widely present, these buildings revealing the historical and functional continuity of the city.

Figure 5. The Study Area and Focal Points in Its Immediate Surroundings.

Kaynak: Akbaş, 2025

Analysis of the Study Area Using the Spatial Syntax Method According to the Years 1989 and 2024

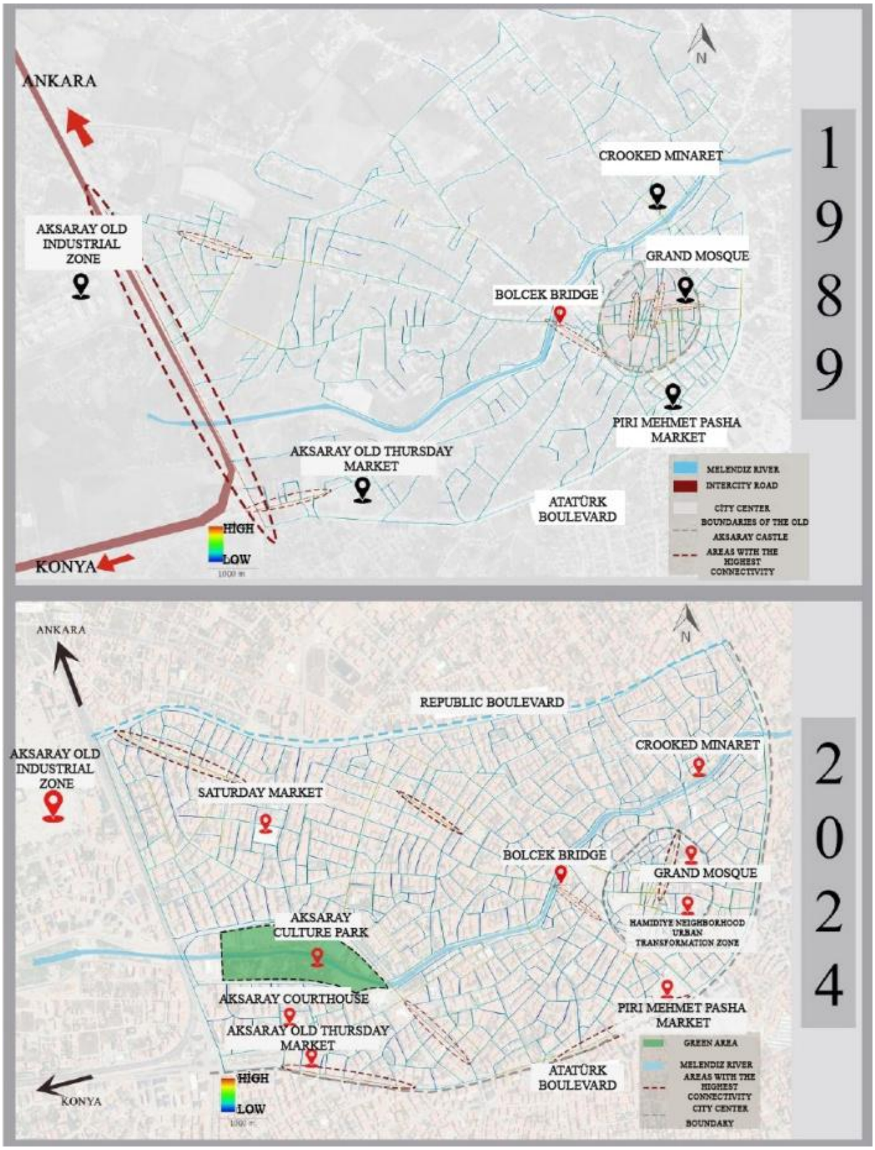
The study primarily examined the degree of **connectivity** between each line and other spaces using axis maps. Analysis of two different time periods revealed that the lowest connectivity value was 1 in both periods, while the highest was 10 for 1989 and 9 for 2024. Before Aksaray gained provincial status, the average connectivity value was 2.73, while in the 25 years since then, this value has increased to 3.03 (Table 2).

Table 2. Connectivity Values Data for the Years 1989 and 2024.

	Connectivity Values	
	Aksaray in1989	**Aksaray in 2024**
LOWEST	1	1
AVERAGE	2.73369	3.03479
HIGHEST	10	9

1989 connectivity map reveals high values in the western part of the city, around the city core, also known as the old castle boundaries. The Aksaray-Ankara road, the area opposite the courthouse near the old Thursday market, the vicinity of the Bölcek Bridge, and where this road connects to the Ankara road, and finally, the area opposite and around the Aksaray Grand Mosque, all exhibit the highest levels of connectivity. This strengthens the likelihood that these areas will form the main backbone of the city in the coming years. Examining the reasons for these high connectivity values, it is thought that the newly established industry in the city at that time played a significant role. Additionally, the old Thursday market and the area within the old castle boundaries also have high connectivity values due to being the most frequently visited places in the daily lives of city residents. From 1989 to 2024, the city has grown, transportation connections have increased, and there has been a noticeable change in informal settlements and morphology on the city's outskirts. Today, the average expression of connectivity value has increased and has been analyzed as high in the central points located on Atatürk Boulevard, also known as the 40-meter road, which is the historical backbone of the city. During this period, the street connecting Aksaray Culture Park to Atatürk Boulevard showed a high connectivity value, while the connectivity values were observed to weaken as one moved north from the city’s periphery (Figure 6).

Figure 6. Connectivity Map of the Study Area in 1989 and 2024.



Kaynak: Akbaş, 2025

Another measurement analyzed for the Aksaray city center is the **integration** value. In global integration (Rn) analysis, a high value indicates high accessibility, while in local measurement, accessibility values based on walking distances are obtained (Al_Sayed, 2014). While the average value was 0.45 in 1989, it increased to 0.58 after 25 years and with significant morphological changes. In 2024, the lowest integration value increased compared to 1989, while a decrease was observed in the highest integration value (Table 3).

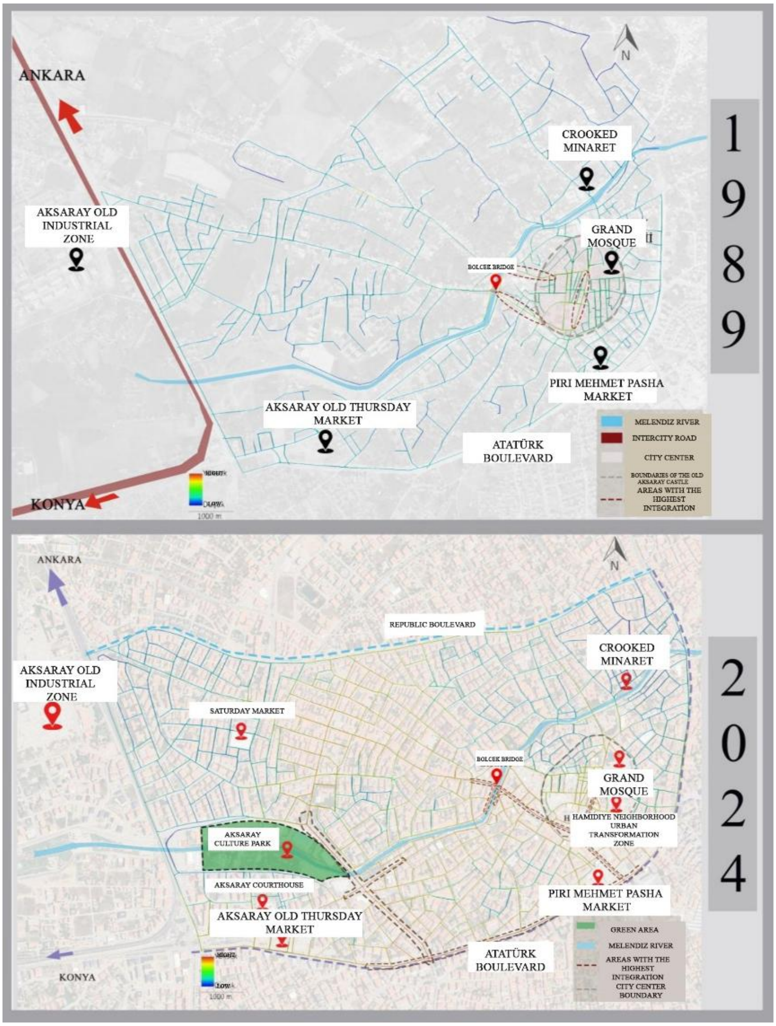
Table 3. Integration Values for the Years 1989 and 2024.

	INTEGRATION VALUES	
	Aksaray in 1989	**Aksaray in 2024**
LOWEST	0.21242	0.396141
AVERAGE	0.451026	0.58685
HIGHEST	1	0.813905

In the 1989 integration map of the study area, the highest integration values were found in the city center and its immediate surroundings. This value decreases as one moves away from the city center and into side streets. The 2024 integration map, however, reflects an increase in the areas where the highest values were observed (Figure 7). The 2024 data reveal that integration values have further increased, particularly in the Taşpazar and Büyükbölcek neighborhoods. Atatürk Boulevard (40-meter road), which forms the backbone of the city center, and the wide streets connecting to it, are among the areas with the highest integration values. It was also determined that Atatürk Boulevard formed a strong urban axis during this period. It is observed that the strong integration value in and around the Citadel spread to many areas in the period up to 2024, and the area from the city square, representing the old city, to the Grand Mosque maintained high integration values during this period as well. The urban axis extending from the present-day Piri Mehmet Pasha Bazaar to the

Bölcek Bridge, and the street connecting this axis to the Ankara road, as well as the street extending from Aksaray Culture Park and its surroundings to the 40-meter road, have been determined to have high integration values. The fact that urban vibrancy, reflecting active street life, is more intense in these areas compared to other regions supports this finding.

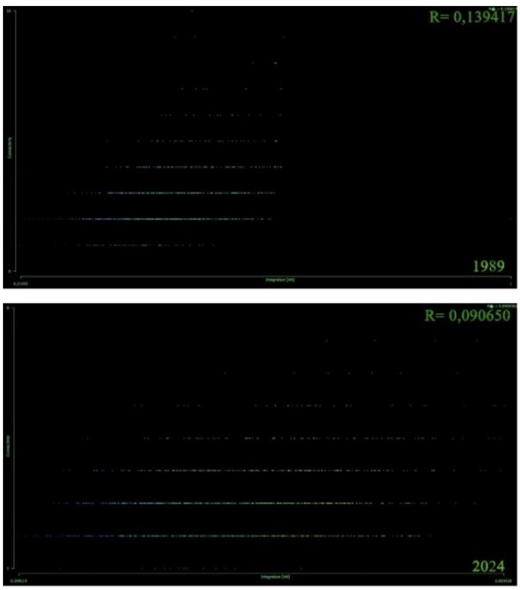
Figure 7. Integration Map of the Study Area in 1989 and 2024.



Kaynak: Akbaş, 2025

Intelligibility is expressed as a correlation between connectivity and integration values. This value is related to the level at which the user of the space perceives the entire system. Systems with high intelligibility provide the user with ease of navigation and a wide visual perspective from their location (Peponis et al., 1989). Looking at the intelligibility data for the study area from 1989 and 2024, the value, which was 0.1394 in 1989, decreased to 0.0906 in 2024 (Figure 8). This change can be attributed to the increasing urbanization and the increasingly complex morphological structure of Aksaray. Therefore, it indicates that the current (new) urban structure has a less readable and more difficult-to-understand plan layout compared to the (old) urban structure before it became a province. This situation can be understood from zoning plans, satellite images, and historical photographs.

Figure 8. Intelligibility Analyses for 1989 and 2024.



Kaynak: Akbaş, 2025

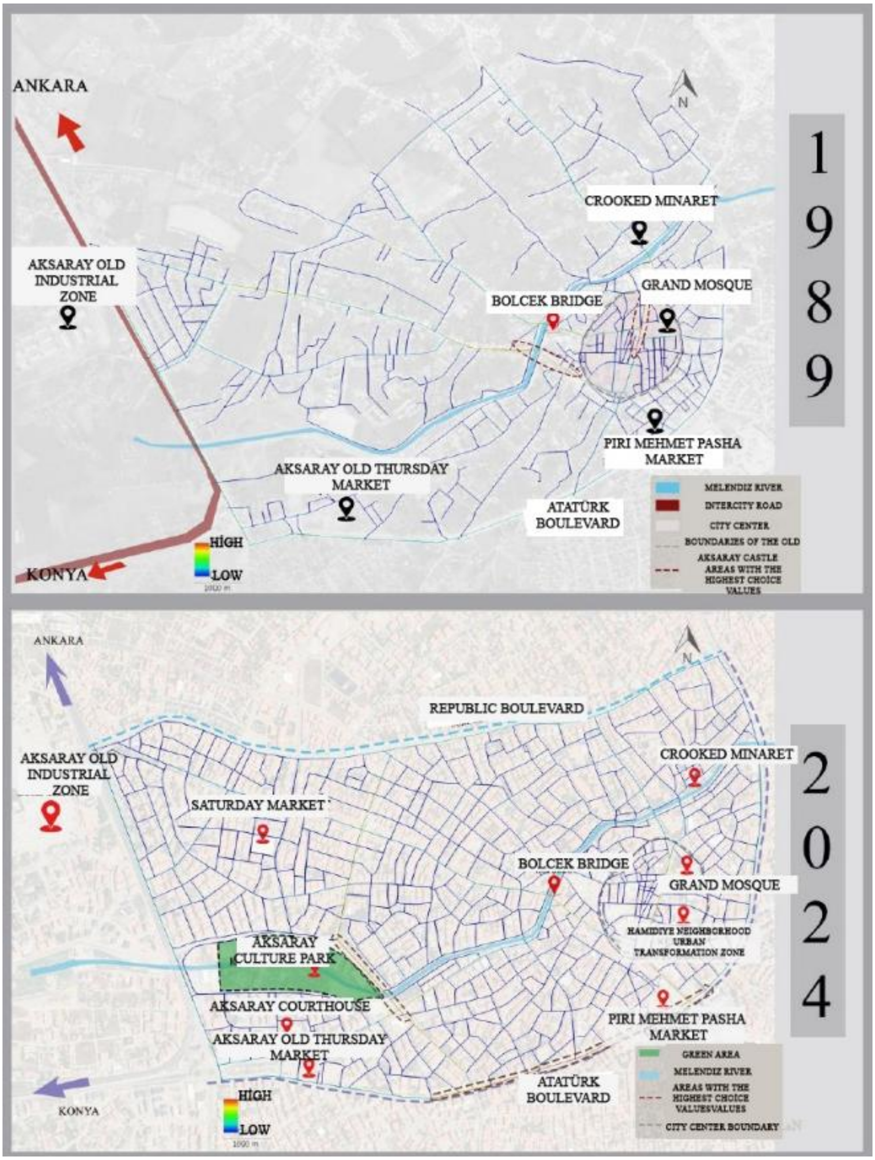
The study examined the preferences of street networks in the city during two different time periods. Researching accessibility levels and the use of points providing intra-city connectivity. The **choice** parameter, which allows for evaluation, has also been analyzed. The data obtained show that there is no significant change over time in the lowest and highest levels of the choice value. While the average value was 15.272 in 1989, it increased to 18.564 25 years later and with the attainment of provincial status (Table 4).

Table 4. Choice Values for the Years 1989 and 2024.

	CHOICE VALUES	
	Aksaray in 1989	**Aksaray in 2024**
LOWEST	1	1
AVERAGE	15272.6	18564.7
HIGHEST	251569	415142

In the 1989 study area map (Figure 9), the highest global choice value was observed in the vicinity of Bölcek Bridge, opposite and around the Ulu Mosque. During this period, Ankara Street and Bankalar Street, designed as the main axis of the city and representing an administrative axis for the city center, had the highest choice values in the preference analysis. Examining the 2024 choice map, Atatürk Boulevard (a 40 m wide road) and the wide streets connecting to it were found to have a high level of preference. However, the western corridor axis, designed as an alternative urban corridor, has created a center of attraction in the region, which is reflected in the choice values. The fact that the Melendiz River passes through Aksaray Culture Park also led to high choice values in the area and other streets connected to it. The areas north of Uluırmak and the Taşpazar neighborhood showed a lower level of choice.

Figure 9. Choice Map of the Study Area in 1989 and 2024.



Kaynak: Akbaş, 2025

CONCLUSION

The concept of urban morphology examines the formal evolution of cities over time, investigating the physical, sociological, economic, and other factors influencing this change, thus offering a perspective on the past and future of cities. Morphological analyses can be conducted on the city or a part of the city, and sometimes at the parcel and building level. This study analyzes the traditional city center of Aksaray, a city that has hosted many civilizations from the past to the present, from a morphological perspective. The area selected as the study area, located between Cumhuriyet and Atatürk Boulevards and designated as Center-1 according to the 2012 Zoning Plan, is situated within the historical city center of Aksaray and offers a rich resource for morphological analysis with its physical and sociological layers. To examine the morphological structure of the historical city center before and after it became a province, within the framework of two defined historical periods, the integration, connectivity, intelligibility, and choice values provided by the spatial syntax method were examined. The mathematical data provided by the method were used to attempt a morphological assessment of the changes in the traditional city center, which consists of 13 neighborhoods. The conclusions drawn from the analyses are summarized as follows:

- The study concluded that the city core, encompassing the Aksaray Castle, a monumental and administrative landmark of the city, has maintained its existence from historical periods to the present day, but its urban potential has decreased in some areas. In particular, the roads leading to the city square and the area around the Grand Mosque were observed to be areas with strong analytical value both in the present day and in the 1990s.

- The streets leading to Atatürk Boulevard, one of the busiest arteries in the city center today, showed high values for preference, connectivity, and integration. While the Kalealtı and Belediye Street areas, historical central points of Aksaray, were analyzed to have high connectivity, integration, and choice values in the 1990s, and these values are not observed in this region today, it has been determined that the cultural heritage is being preserved.
- Analyses have revealed that the historical city axes, designed as the backbone of the city, have failed to maintain their strong characteristic influence today, giving way to the newly developing western and northern axes that are changing the direction of the city's growth. While the Ankara road had a high level of connectivity in the 1900s, it has been concluded that those strong values have been transferred to the 40-meter-wide road (Atatürk Boulevard) by the present day.

Based on the analyses conducted for the study area, it would not be wrong to say that when the city is evaluated holistically, the focal points of the city located in and around the historical city center still hold potential for Aksaray. However, as the city grew and developed, its direction of growth changed, and new spatial configurations emerged in the westward direction. This result necessitates a close-scale analysis of the morphological changes, resulting spaces, and differentiated areas occurring in the historical backbone of Aksaray and the newly developing western and northern axes. Such an analysis is important for Aksaray, which became a province approximately a quarter of a century ago, as it will provide a basis for future implementation plans by identifying the types of changes that have occurred in the areas that are representative of the city and play an active role in planning decisions. In addition, researching the spatial characteristics in the newly developing and developing growth axis of the city is critical for understanding the future of Aksaray.

This study makes it possible to draw various conclusions about how Aksaray's provincial identity has transformed throughout history and what direction it might take in the future. By employing a verifiable morphological method at the urban scale, the study offers a unique perspective and emphasizes the importance of evaluating the evolving structure of Aksaray, which recently gained provincial status, from a morphological standpoint.

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BÖLÜM 6

DIGITAL FABRICATION PATHWAYS IN OFF-SITE CONSTRUCTION: FROM INDUSTRY 4.0 TO 3D PRINTING

DAMLANUR İLİPINAR[1]
SEMAHAT MERVE TOP[2]

Introduction

Manufacturing and construction are long-established sectors that, over time, developed along separate but parallel trajectories, ultimately becoming distinct industries. The manufacturing sector has made great strides so far, but the construction industry has not kept up (Lou et al., 2021). This is because the construction industry has distinct problems than the manufacturing industry when it comes to boosting productivity. There are a lot of problems in the sector, such as interrelated processes, sub-processes, and a lot of stakeholders at different stages at different building locations. This makes things very unclear (Dallasega et al., 2018). Also, the construction industry must employ a great number of workers due to

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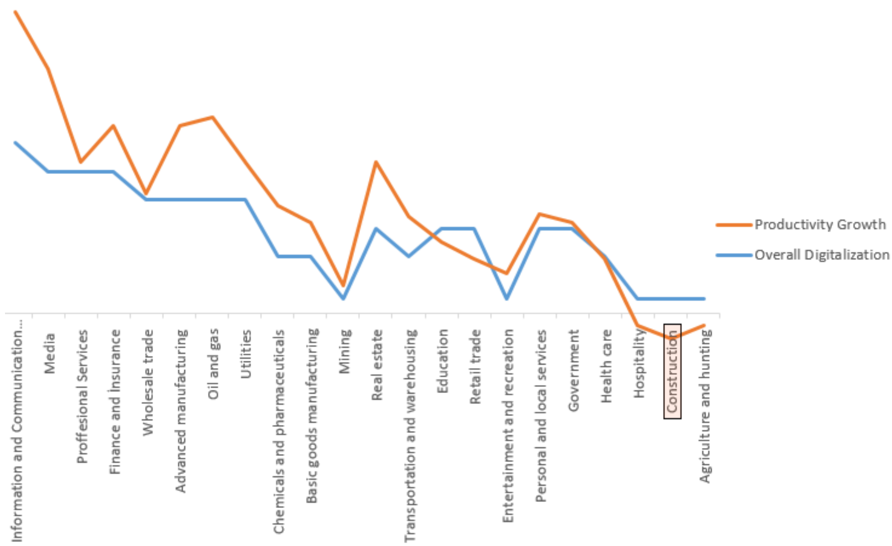
the nature of the industry, unlike other manufacturing industries, thereby the productivity of the construction sector is mainly predicated on human effort and performance. As a result of this, many construction projects face time delays and cost overruns on account of poor productivity rates (Hasan et al., 2018). Conversely, the manufacturing industry has proceeded with a more efficient production process and met client needs by going entirely digital (Osunsanmi et al., 2018). This digitalization approach is a part of the Industry 4.0 principles, which are expected to positively affect today's production processes (Demirkesen & Tezel, 2021). Industry 4.0 describes the digital transformation of industry in which physical and informational domains are merged through cyber-physical system technologies (Maskuriy et al., 2019). The main goal of Industry 4.0 is to establish a manufacturing process that is integrated, customized, optimized, service-oriented, and interoperable, in conjunction with algorithms, big data, and advanced technologies (Lu, 2017). It changed the direction of the present tendencies toward digitalization, automation, and the extensive use of information and communication technology (ICT) (Kozlovska et al., 2021). It is also talked about using words like "smart manufacturing," "the industrial internet," and "integrated industry" (Maskuriy et al., 2019). The concept was introduced by the German government in 2011. The next version 5.0 is expected in the near future (Kozlovska et al., 2021). The reviewed literature regarding Industry 4.0 application showed that there are a number of publications concentrating on almost the whole manufacturing industries like the computer science, engineering sector, business management, decision science, material science, electronic, industrial, manufacturing, and mechanical industries, and more (Lu et al., 2017; Zabidin et al., 2020; Kozlovska et al., 2021). In the construction industry, however, Industry 4.0 principles are only used in a limited way. This shows that Industry 4.0 is still being formed and needs more research (Oesterreich & Teuteberg, 2016). Construction projects necessitate a significant level of customization and standardized specifications for processes, materials, labor, and teams, owing to their distinctive and time-sensitive characteristics, in contrast to other sectors such as business services, manufacturing, finance, transportation, and utilities (Dallasega, Rauch & Linder, 2018; Schoemaker, 2022). In today's world, companies are more interested in using automation systems to connect all of the systems used in manufacturing with the systems that will be used in the future. To illustrate, the old way of delivering goods by truck is being replaced by unmanned aircraft delivery. Amazon has launched a rapid last-mile delivery option that brings eligible orders to customers' doors in about 30 minutes, provided the package weighs less than 5 kg (Naseem & Yang, 2021). Similarly, many different technologies and innovations provided by Industry 4.0 are being implemented in many different sectors like healthcare and medical, education, logistics, agriculture, energy, media, textile and clothing, computer science, engineering sector, business management, decision science, material science, mathematics, social science, electrical, electronic, industrial, and mechanical, etc. Construction has also gained from these advancements; however, the sector's inherent complexity has contributed to a comparatively slower pace of industrial development (Kozlovska, Klosova, & Strukova, 2021). In other words, as Faltinsky & Tokunova (2018) remarked, over the last few decades, most industrial sectors have undergone immense alterations with digital and process innovations. However, the practical application of the potential of these transformations cannot be observed in the construction industry. As seen in Figure 1, the construction business has a low level of penetration of digital technology or a low digitalization ratio compared to other industries. Besides, the productivity growth between the years 2005-2014 of the sectors is also visible in Figure 1.

Figure 1 Penetration of digitalization ratio and productivity growth of different sectors



Source: Generated from McKinsey Global Institute (MGI)'s digitization index, Manyika et al., 2015

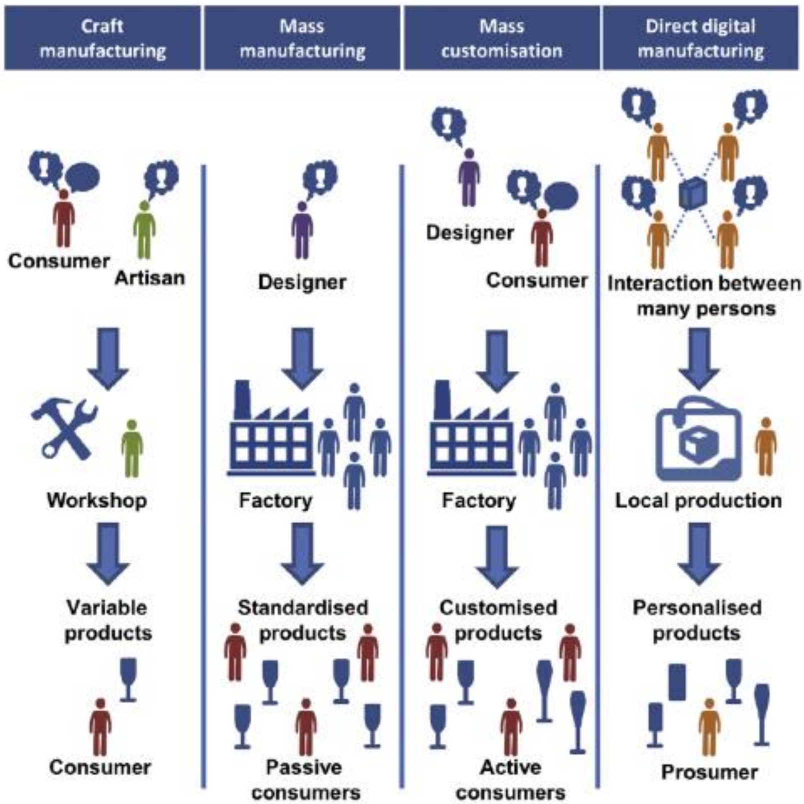
One observation from the figure is that the productivity growth line for the industries is generally parallel to the digitalization ratio of the industries. Another and more specific observation from Figure 1 is that one of the lowest digitalization rates is in the construction industry, and its productivity growth goes down when the value is less than zero.

Wang et al. (2020) explored benefitting digital technologies and their ratio in off-site construction to overcome industry problems by reviewing the literature. These studies on digital technology utilization in off-site construction started in 2016, and it has been maintained to increase steadily to 2020. The results showed that only 12.8% of total papers on off-site construction from 2010- 2020 generated published papers on digital technology utilization in off-site construction. This ratio shows that not enough research has been done on how digital technology is used in off-site construction, and that the amount of digital technology use is low. For these reasons, off-site manufacturing is promising to be an alternative means of improving construction productivity. As a result, there is a necessity for comprehensive examinations of the factors influencing individuals, processes, and technology within the context of off-site construction (Bendi et al., 2021).

Manufacturing Logic for Off-site Construction

People have long criticized the building sector for not adopting new technologies and innovative methods as quickly as other industries (Bendi et al., 2021). When investigating the manufacturing industry development (observed from Figure 2), it starts with manual crafting at a very slow pace and reaches the 20th-century industrial revolution and mass production. With increasing technological developments, manufacturing systems have evolved to lean manufacturing, which allows highly standardized products with high quality and produces economically smaller batch sizes, and so the premises of customization are offered. In this direction, consumers wanted low-cost products with high quality, and that's why mass customization was initiated through fragmented demand and homogeneous niches. Mass customization is comparable to mass manufacturing in many ways, but customers have a say in how the items are made. But digital manufacturing is a new thing. This trend is quite similar to mass customization. Products are made in the spirit of mass customization, but each one has a unique trait that is linked to the customer. In this sense, the niches are not the same; they are different in terms of mass personalization. So, the system's flexibility needs to be able to meet this need (Chen, 2015). Technological developments entice several industries and individuals, subsequently resulting in direct digital production, characterized by the integration of dispersed additive manufacturing equipment with contemporary information and communication technology (ICT) (Trollman et al., 2019). Figure 2 shows that many different persons are needed to design the digital design manufacturing process.

Figure 2 The evolution of the manufacturing paradigms and their main actors



Source: Chen et al., 2015

Thanks to adopting technology into the industries with various benefits, the prosumer manufactures personalized products for local demand. Digital design manufacturing can make tailored, high-quality items with a batch size of one by combining the best parts of several manufacturing methods. As a way of making things in the 20th century, it has a lot of promise to revolutionize the world of manufacturing. In addition, digital manufacturing can reshape production workflows, improve material efficiency within product-oriented business models, and even transform how products relate to end users (Chen et al., 2015).

Additionally, the features of manufacturing paradigms for design and production differ based on their classification. To understand the organizational structure of the manufacturing paradigms, some questions have been asked and summarized in the following table in Chen et al.'s study (2015).

Table 1 Characteristics paradigms for design and manufacturing

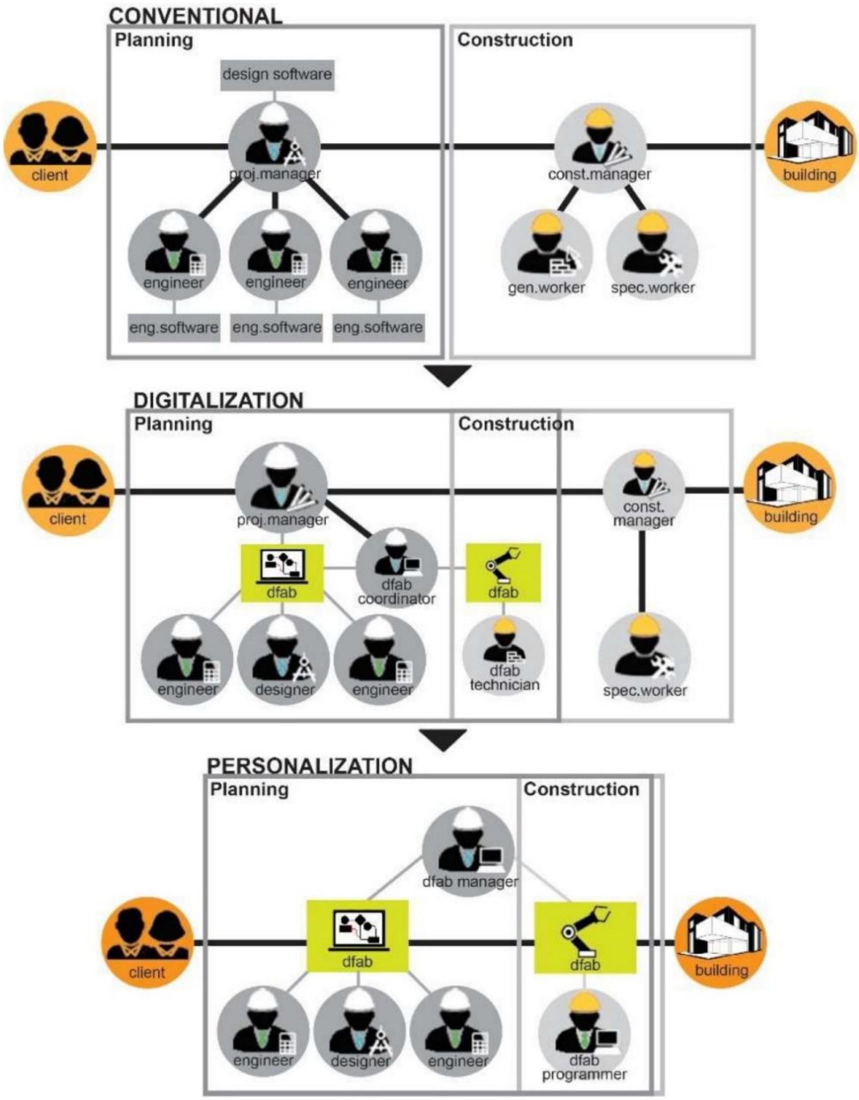
	Craft Production	Mass Production	Mass Customization	Direct Digital Manufacturing
Who	Craftsmen	Designer and Specialists	Designer and Specialists	Network of different people
How	Experience based	Receive design	Receive design	Create and/or download design
Where	In a workshop	In a factory	In a factory	On an Additive Manufacturing machine
What	Variable products	Standardized, high quality products	Standardized, high quality products with predetermined variants	Personalized and variable, high quality products
How many	Lot size of one	In large batches	In small batches	Lot size of one
For whom	Consumer (few to few)	Passive consumers (few to a large group)	Active consumers (few to many small groups)	Prosumer (Network to individuals)

Source: Chen et al., 2015

Digital Manufacturing and Its Implications for Off-site Construction

Digital technologies—enabling innovative, computer-controlled production processes—have transformed many sectors, including automotive, aerospace, and shipbuilding. In construction, however, adoption has progressed more slowly than in these industries, even though digitalization is widely viewed as essential for improving productivity. In order to cope with the construction sector's problems, digital fabrication (dfab) procedures and emerging technologies represent promising avenues for automation and digitization (García De Soto et al., 2019). In other words, the use of digital technology in the Architectural Engineering Construction and Operation (AEC/O) field, especially in construction., improves operating and sharing data, eliminates human intervention, and increases efficiencies by mechanized automation (Axelsson et al., 2019). In this context, Figure 3 shows how the construction organizational structure could change if digital technologies were used. This diagram includes three phases: traditional, digitalization (short-term), and personalization (long-term). To relate these three phases to the construction industry: The traditional phase represents the existing traditional, fragmented organizations of the construction sector. The second phase, the digitalization scenario (short-term phase), provides digital platforms for planning and automated processes in construction. In the digitalization phase, all data from engineers in the planning phase is placed on a central digital platform, and the architect uses this shared information to finalize the building's design. In the construction phase, the digital manufacturing specialist takes control of robotic production on-site. This is an attempt to create a link between traditional projects and new digital technologies, and it is expected that project timelines will be shortened through digitalization and the use of robotics on-site (De Schutter *et al*., 2018).

Figure 3 Representation of the evolution of the construction structure resulting from the digitalization of the construction industry



Source: De Schutter et al., 2018

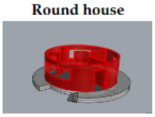
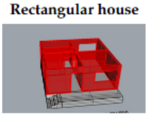
The final step—the personalization scenario (long-term phase)—positions the owner as an active participant in the building process, taking on responsibilities related to coordination and management. However, owners usually lack specialized technical knowledge. This shift, therefore, requires a new role for the owner's representative, while the traditional roles of designers and project managers evolve into consultancy and co-creation to stay accessible to owners and end users. In practice, construction experts would design and put up the digital fabrication solutions that are part of the online platform and help owners or users through the customisation process. Consequently, these service providers may emerge as essential stakeholders in the construction sector (De Schutter et al., 2018; García De Soto et al., 2019). Other industries also advance personalization enabled by digital technologies. For example, 3D printers allow users to create physical versions of self-designed objects, promoting the rise of personalized products (Chen et al., 2015). In the construction field, additive manufacturing provides a clear way to turn personalization into off-site delivery by changing where fabrication occurs and how components move through the supply chain. Therefore, the next section focuses on 3D Printing and Off-site Construction.

3D Printing and Off-site Construction

Three-dimensional (3D) printing, which is sometimes called additive manufacturing, helps the manufacturing industry change to digital. Additive manufacturing uses a digital design file to make parts by adding material one layer at a time (Khajavi et al., 2021). In recent years, the construction industry has increasingly explored this approach because it can accelerate the transition from design to fabrication and enable rapid production of customized elements (Ituarte et al., 2016). Additive manufacturing can also shorten building supply chains by making parts from a digital model with little help from people (Khajavi et al., 2021).

In concrete 3D printing, material is pumped to a printing head and deposited at a controlled rate to form the desired geometry. This technology can be used in both industrialized prefabrication and work done on site. To print on-site, the robotic printer and concrete pump are brought to the site, set up, and utilized to print right there. Alternatively, printing can be performed in a factory; in that case, printed components are transported to the site for assembly. From a supply-chain perspective, on-site printing typically reflects a decentralized configuration, as production resources and inputs are delivered to the site where fabrication occurs. In contrast, a centralized configuration represents factory-based production, followed by transportation and on-site assembly of fabricated components. These alternative configurations are feasible; however, they lead to different time and cost outcomes (Khajavi et al., 2021). In this context, Khajavi et al. (2021) conducted a case study using two design options and seven scenarios; the scenario details are presented in Figure 4.

Figure 4 Seven scenarios for the time and cost analysis and comparison

		Technologies	
	Supply chain configuration	3DCP	Conventional construction
Round house 	On-site	**Scenario 1** (On-site printing of round house: **ONP-RND**)	**Scenario 3** (On-site conventional construction of round house: **ONC-RND**)
	Off-site	**Scenario 2** (Off-site printing of round house: **OFP-RND**)	-
Rectangular house 	On-site	**Scenario 4** (On-site printing of rectangular house: **ONP-RECT**)	**Scenario 6** (On-site conventional construction of rectangular house: **ONC-RECT**)
	Off-site	**Scenario 5** (Off-site printing of rectangular house: **OFP-RECT**)	**Scenario 7** [1] (Off-site conventional construction of rectangular house: **OFC-RECT**)

[1] Scenario is not fully comparable to others, since the numbers include the profit margin of the prefabrication company.

Source: Khajavi et al., 2021

Two design options were compared to assess how geometry affects the feasibility and performance of alternative construction scenarios. The round house represents a more flexible and geometrically demanding option, whereas the rectangular design reflects a conventional layout typically associated with cast-in-place concrete work using formwork. Seven scenarios were then defined by combining supply chain configuration (on-site vs off-site) with construction method (3D concrete printing vs conventional on-site construction). One scenario was excluded because producing the round house through an off-site workflow was considered impractical due to clear limitations in execution.

Cost and completion-time analyses were conducted for the construction of both exterior and interior concrete walls under each scenario. The cost model included construction machinery and equipment, raw materials, transportation, and labor. The pre-construction stage was omitted on the assumption of a completed architectural design, except for Scenario S7 (prefabrication), which requires assembling wall components and carrying out joint concrete works. For conventional on-site scenarios, the scope covered formwork installation, reinforcement placement, concrete casting, demolding, and mold cleaning. For 3D printing scenarios, the construction stage included wall printing as well as reinforcement activities up to the completion of printing. The post-construction stage for 3D printing accounted for printer disassembly and relocation, and, where printing was performed off-site, the drying of printed walls, transportation to the site, and assembly of wall modules. Using these inputs, total project costs (transportation, labor, material, and machinery) and durations across the pre-construction, construction, and post-construction stages were calculated and summarized in Table 2.

Table 2 Schedule and Cost Analysis Results

Scenarios	Total Duration	Total Cost (EUR)
S1 (ONP-RND)	4 days 8.5 h	3477.5

S2 (OFP-RND)	15 days 13.16 h	5112.77
S3 (ONC-RND)	29 days 12.4 h	8197.16
S4 (ONP-RECT)	4 days 14.3 h	4410.31
S5 (OFP-RECT)	15 days 16.96 h	5960.99
S6 (ONC-RECT)	29 days 13.8 h	7943.25
S7 (OFC-RECT)	6 months 2 days 7 h	12,865.51

Source: Generated from Khajavi et al., 2021

The comparison shows that 3D printing is cheaper than traditional building and takes less time than traditional methods. When comparing on-site versus off-site options, off-site 3D printing definitely takes longer to finish the whole project, mostly because the post-construction process is lengthier. In addition, 3D printing remains more economical for both the round and rectangular designs, while on-site printing is cheaper than off-site printing because it avoids the additional transportation and assembly costs associated with moving printed components. Overall, the findings suggest that 3D printing can reduce both project cost and completion time compared to conventional construction. Importantly, it also enables the delivery of complex geometries at lower cost: the round-house option produced by 3D printing is less expensive than its conventional counterpart. This supports the broader literature suggesting that 3D-printed solutions may offer cost advantages over traditional construction methods for geometrically complex designs.

Khajavi et al. (2021) also note that concrete printing still requires substantial labor for operating and managing the system, including robot movement, calibration, alignment, and the coordination of supporting subsystems. The on-site monitoring of printing operations—typically performed by a trained operator—remains a critical, technology-intensive task. These data suggest that increased automation may diminish labor intensity and enhance the competitiveness of 3D printing within the construction sector.

Conclusion

Digital manufacturing is making it easier for the construction business to get a lot of information about new trends, approaches, and procedures. For practitioners, identifying which approaches are both suitable and beneficial for real projects remains challenging, and innovation therefore becomes difficult to implement in practice. For this reason, a clear roadmap is needed to guide the adoption of digital technologies and digital manufacturing methods in construction.

As a key outcome of this broader transformation, off-site construction is closely linked to the digital evolution of the sector. Successful implementation depends heavily on effective technology use; however, transportation and assembly remain critical determinants of both cost and project duration in off-site delivery. Accordingly, the impacts of supply chain configurations—particularly off-site versus on-site alternatives—need to be clarified when evaluating and adopting digital manufacturing technologies.

Another major barrier to adoption is the limited availability of experienced labor. Compared with traditional project phases, digitalized workflows introduce substantial changes, especially in planning and execution. At present, digital manufacturing still requires considerable human input for managing and operating systems, and human–machine interaction can hinder full process and technology integration. Further automation, therefore, offers potential to reduce labor intensity and increase competitiveness. Nevertheless, not all construction tasks can be fully automated. As digitalization levels increase, workforce size may decrease while roles evolve toward monitoring, supervision, and control of automated processes, with construction know-how progressively transferred into robotic and digital systems.

Finally, improving automation in off-site construction will likely require tighter integration between complementary technologies, particularly robotics and 3D printing. Despite growing interest, the literature still shows limited evidence on how different digital technologies can be effectively bridged and integrated within off-site construction processes.

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BÖLÜM 7

OFF-SITE PRODUCTION IN THE CONSTRUCTION INDUSTRY: A CRITICAL REVIEW

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Introduction

The construction sector is a critical area of the global economy and one of the largest sectors in the world. Each year, almost $10 trillion is spent on goods and services connected to building (Barbosa et al., 2017). It is also seen as one of the most important areas that directly helps countries grow and build their economies (Maskuriy et al., 2019). In industrialized countries, the construction industry is estimated to contribute an average of 10% annually to gross domestic product (Azimi et al., 2011). However, despite this high economic volume, the sector faces long-standing problems of low productivity and predictability compared to manufacturing industries (Barbosa et al., 2017). The construction industry has a lot of problems, such as broken structures and management, no leadership, bad education, financing, and implementation models, a small and low-quality workforce, no

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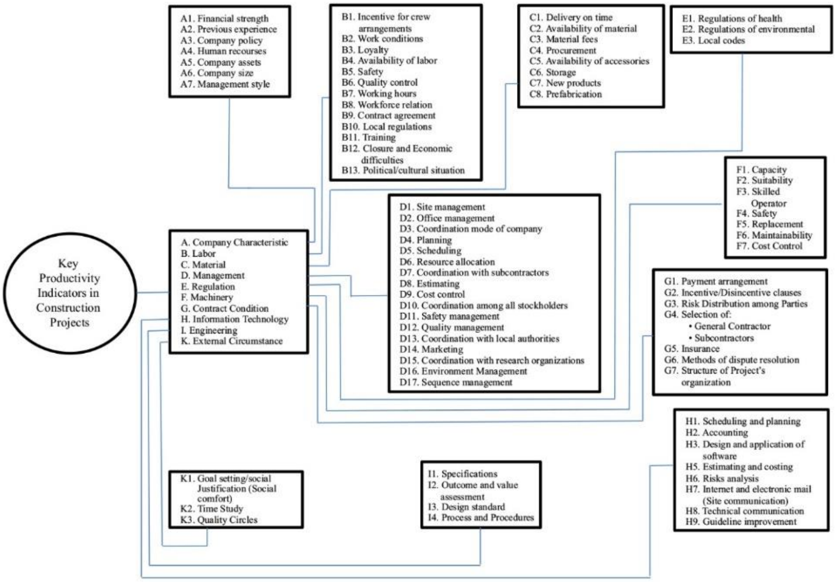
cooperation among stakeholders, and not enough money spent on new ideas (Farmer, 2016). These structural problems clearly demonstrate that conventinal construction techniques have attained their limitations, making it imperative to utilize mechanization and industrial production approaches more effectively in the sector (Bock, 2015). Complex and fragmented activities, difficulties in identifying professions with the right skills, insufficient coordination, lack of cooperation and safety between contractors and suppliers, and inadequate data flow are some of the reasons why the engineering and construction sector cannot keep pace with the manufacturing industry (Maskuriy et al., 2019). One of the biggest problems that people in the construction industry have always had to deal with is low productivity on construction sites (Ghasemi Poor Sabet, P & Chong, 2019). Under current socio-economic conditions, a broad range of factors can be identified that influence productivity in both developing and developed countries. Systematically defining and analyzing these indicators is critical for achieving lasting improvements in construction productivity. Figure 1 gives a summary of the key groups and subgroups of indicators that measure productivity in building projects (Hasan et al., 2018). Within this conceptual framework, factors like the workforce, company characteristics, materials, management, regulations, machinery, contract terms, information technologies, engineering, and external environmental conditions show how many different things can affect productivity on construction projects. A thorough and comprehensive understanding of these factors makes it possible to identify areas for intervention to increase productivity in the sector and maximize improvement potentials (Hasan et al., 2018).

Figure 1 Conceptual framework illustrating the key productivity factors influencing project success



Source: Ghasemi Poor Sabet & Chong, 2019

According to a survey carried out in 2017, 90% of respondents representing diverse professional backgrounds—such as construction contractors, designers, manufacturers, and academic researchers—anticipated a future increase in the number of off-site construction projects (Fenner et al., 2017).

Off-site Construction

In recent decades, the construction sector has endeavored for higher productivity (Zhang et al., 2020). In 1998, the Rethinking Construction Report of Egan remarked on the need for performance improvements, and for this, supply chain partnerships, standardization, and off-site production have an important role (Blismas, Pasquire & Gibb, 2006). Shifting works from on-site to off-site with innovations and improvements, including methods, tools, and machines, provides higher productivity and quality (Zhang et al., 2020).

Off-site construction refers to an approach in which activities traditionally performed on site are relocated to climate-controlled production facilities, enabling the efficient use of advanced machinery and manufacturing technologies (Liu et al., 2017). It is a mix of manufacturing and construction that happens in regulated industrial settings without outside interference, as opposed to at a construction site (Goulding et al., 2015). Off-site construction is a new approach for the building industry to work. It involves making and putting together parts, elements, and/or modules in a place other than the site where they will be installed (Hu et al., 2019). Off-site fabrication or off-site construction is recognized as both prefabrication (the process of making and combining parts) and pre-assembly (the process of putting parts together) at a factory (Killingsworth et al., 2021). When the off-site construction is compared with the conventional stick-built construction, it has three main construction steps: (i) making building parts (panels or modules) in a controlled setting, (ii) moving the parts to the site, and (iii) putting the modules together on-site (Zhang et al., 2020).

The idea of off-site construction has been around since the 1800s, when it was known by names like manufactured construction, off-site production (OSP), off-site construction (OSC), off-site manufacturing (OSM), modern methods of construction, modular construction, and construction prefabrication. However, only a small percentage of construction activities in both developed and developing countries use off-site construction (Goulding et al., 2015). However, off-site construction has become more popular in the last 20 years. The popularity of off-site construction is widely observed in China, Hong Kong, Australia, Germany, and the Netherlands (Ferdous et al., 2019; Kamali et al., 2016; Lawson et al., 2014). Off-site manufacturing is thought to be a different way to boost construction productivity (Durdyev & Ismail, 2019). But most construction sectors only use off-site construction a small amount of the time (Goulding et al., 2015), and off-site construction still makes up a small part of the national and international construction industry (Suliman & Rankin, 2021).

On the other hand, advanced technologies used in off-site construction projects can provide effective solutions to the sector (Hou et al., 2020). To illustrate, information and communication technology regulates the ways of collecting, analyzing, and communicating on project data, providing for effective supply chain management and quality control in off-site construction workmanship (Zhang et al.2017). Nonetheless, if the construction manufacturing domain follows the traditional on-site construction process approach, it may not take full advantage of modular construction and lean implementation (Zhang et al., 2020).

Mapping the Literature Knowledge for Off-site Construction

The construction industry has long suffered from poor productivity or inefficiencies (Hu et al., 2019). Wang, Li, Zhang, and Li (2016) say that the main reason people feel inadequate in the construction business is because the work is done outside and requires a lot of physical labour. Because of the nature of the construction activity, the weather can alter the work conditions. Workers can change the quality of the products, and there are usually a lot of people working at the same time on the site (Jang et al., 2021). Therefore, off-site construction has evolved from advancements in the traditional construction process. Off-site construction, an industrialized construction method, is different from traditional construction in terms of project goals, design, permits, supply chain configuration, stakeholder composition, and delivery chains. This includes new processes, techniques, technologies, and methods (Wuni et al., 2021).

Off-site construction encompasses multiple levels of production, ranging from non-volumetric preassembled elements, such as exterior and interior wall panels, to fully preassembled volumetric units and even complete finished modules. Gibb and Pendlebury (2006) identify several categories of off-site construction, including component sub-assembly, non-volumetric and volumetric pre-assembly, hybrid configurations, panel-based systems, and fully modular construction. Because off-site construction is closely associated with manufacturing-oriented building processes, a range of terms—such as panelized, manufactured, prefabricated, preassembled, industrialized, and standardized—are frequently used interchangeably in the literature to describe these approaches (Killingsworth, Mehany, & Ladhari, 2021).

Off-site fabrication, thought of as the future of the construction industry by many researchers (Bendi et al., 2021), achieves greater productivity and quality of both design and construction while reducing construction cost, time, and resource waste (Suliman & Rankin, 2021). Industrialized construction has its benefits, but there are still problems that need to be solved. These include poor communication between stakeholders, a lack of strong quality inspection systems for manufacturing and installation, low efficiency throughout the supply chain (Qi et al., 2021), and a slow uptake of new technologies (Suliman & Rankin, 2021). One reason why off-site construction isn't spreading or being accepted more is that it's still a new area for comparing new ideas (Suliman & Rankin, 2021). The construction industry is still behind other industries when it comes to using new technologies (Oesterreich & Teuteberg, 2016). You and Feng (2020) said that new technologies are only being used in certain areas, and there aren't many big studies on how to combine construction and technology. Another big problem with off-site construction projects is that they can cause problems with the supply chain and make it hard to coordinate. The off-site construction supply chain includes a long and complicated value chain that includes things like bidding, design, engineering, manufacturing, transportation, storage, and assembly on site. Clients, main contractors, designers, manufacturers, transport providers, and assembly subcontractors all need to work together and coordinate their efforts at a high level for these processes to work. Because these stakeholders are spread out and their management is becoming more complicated, they need strong communication tools and good ways to share data (Wuni, Shen, & Mahmud, 2019). Also, off-site construction brings in more people with different goals, values, and operational needs, especially when it comes to moving big parts of the building and putting them together on site. In this situation, industrialized construction has many benefits, but it also has its own set of problems. This shows how important it is to set best practices to help everyone involved in the project reach the goals they set for themselves (Wuni et al., 2021).

A Framework for Off-site Construction Projects

Adopting a workflow-oriented perspective is essential for understanding the logic of industrialized construction projects, as it enables a structured and comprehensive analysis of their processes (Wuni et al., 2021). Project workflow frameworks provide valuable insights into both the nature and the inherent complexity of off-site construction operations. In developing an effective workflow framework for industrialized construction, Wuni, Shen, and Darko (2021) examined nine representative case studies encompassing a wide range of project types—including housing, hotels, educational facilities, transportation infrastructure, and stadiums—across Australia, Hong Kong, and Singapore. For each case, the researchers documented key project considerations, principal stakeholders, typical deliverables, and best practices, including challenges encountered, lessons learned, and performance indicators.

The synthesized findings are presented in Figure 2, which illustrates the life cycle phases of industrialized construction projects, the critical decision points within each phase, and the key project participants involved at different stages. A notable observation from this framework is the strong interconnection between work packages and stakeholders throughout the project phases, resulting in a complex, multidisciplinary network of actors, each with distinct objectives, value systems, and roles (Luo et al., 2019). As a result, successful project delivery depends on using collaborative procurement strategies that let stakeholders with different interests work together, communicate, and coordinate their efforts (Wuni et al., 2021).

Furthermore, robust monitoring and control systems are essential to manage the wide range of interdependent and complex activities involved in off-site construction processes (Azimi et al., 2011). As depicted in Figure 2, multiple inputs and contextual factors influence the workflow of off-site construction projects, underscoring the importance of developing decision-support frameworks that enable multidisciplinary evaluation and informed selection of appropriate off-site construction systems (Amer, Mustafa, & Attia, 2019). These projects are particularly challenging because of many of interrelated processes and sub-processes, the involvement of numerous actors across different project phases and locations, and the significant levels of uncertainty—especially during early project stages. Moreover, the increasing demand for customization adds another layer of diversity and complexity to industrialized construction projects (Perrier et al., 2020).

Figure 2 Project phases of the industrialization constructions with key consideration, key project stakeholders, and typical outputs from each phase

Stage	Key Considerations	Relevant Stakeholders	Deliverables
Conceptualization Stage	-Identify the needs and specification of the client or owner; -Develop and evaluate project alternatives; -Develop business case; -Develop decision support	Clients/developer; Consultant; Project manager; Project engineers; Engineering managers	Needs assessment report; Project proposal/ concept paper; Construction method selection
Planing Stage	-Evaluate project feasibility; -Plan and address risk; -Develop project scope; -Estimate and mobilize required resources; -Mobilize support and commitment; -Commitment to the use of IC; -Decide structural systems; -Decide building materials; -Selection of procurement system; -Selection of suitable crane	Clients/developer; Consultant; IC planning specialist; Planning authorities; Project manager; Crane Specialist	Feasibility report; Risk management plan; Selection of structural system and building materials; Procurement system selection; Suitable cranes selected
Design Stage	-Formation of the design team; -Engage contractor, fabricator, suppliers, business partners, and logistics companies; -Engineering and design scope specification; -Detailed design with BIM and early design freeze; -Considering allowable tolerance	Client/developer; Designer; Architect; Engineer; Contractor; Manufacturer/supplier; Project manager	Detailed design freeze; Working drawings; BIM models; Prototypes
Factory Production Stage	-Selection of module supplier(s) or manufacturer(s); -Review of design; -Consideration of manufacturing tolerances; -Checking, mock-ups, trial assembly and prototyping; -Curing of concrete modules; -Concurrent execution of onsite work packages	Developer/Owner; Suppliers; Manufacturers; Building authorities/ Inspectors	Prototypes of modules; Production materials procured; Produced modules; Temporary storage of modules
Transportation/Storage Stage	-Considering Just-in-Time delivery arrangement; -Arranging temporary storage or buffer location, subject to the delivery and programme; -Special traf fic arr angement for transportation of modules exceeding allowable dimensions	Logistics company; Customs and highway authorities; Contractor	Transportation contract awarded; Required modules delivered; Modules buffered or stored
Onsite Assembly Stage	-Forming project management team and managing relationships; -Review and revise project plan and kick off project; -Carry out the project activities as planned; -Controling project budget and schedule; -Monitor, evaluate and report project progress and performance; -Final selection and configuration planning of suitable crane(s); -Review of assembly sequence; -Considering onsite assembly tolerance; -Coordinating onsite and offsite work packages	Crane operators; Crane specialist; Traffic controller; Assembly contractors; Project manager; Site operatives; Building authorities/Inspectors; Site managers; Project control managers; Operation managers	Resources mobilized; Modules installed ; MEP reports; Progress reports; Outputs produced and delivered; Inspection certifications; Environmental quality certification; Completion report
Completion/closure Stage	-Final test and inspection of the project; -Preparing completion report; -Settling all financial transactions; -Commissioning the project; -Contract termination	Owner/Client/developer; Project manager; Contractor; Building authorities/ Inspectors	Final project completion report; Settled financial claims; Deliverables transferred

Source: Adopted from Wuni et al. (2021)

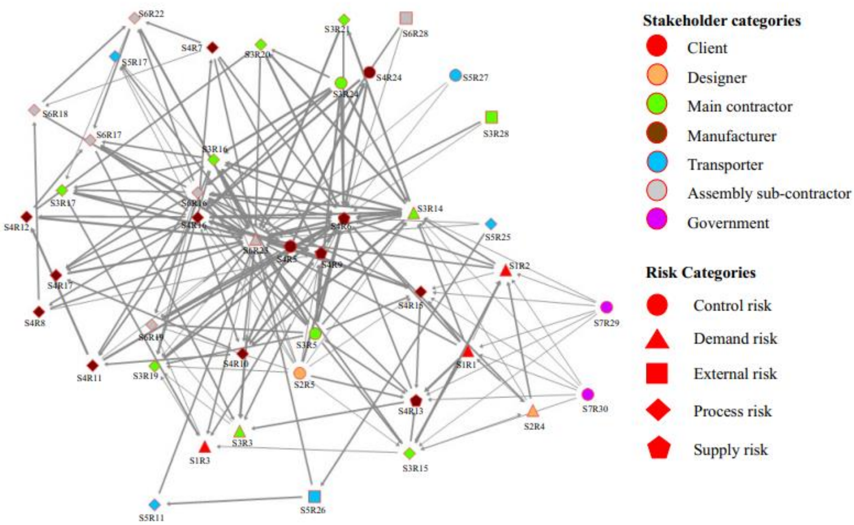
Actors in Off-site Construction

In construction projects, the number of stakeholders can vary considerably; however, it is generally large, and the interactions among them are highly complex (Karlsen, 2002). As a result, establishing collaborative relationships within this project-based industry is inherently challenging, often leading stakeholders to operate independently as separate organizational entities pursuing their own interests (Gan et al., 2018). This fragmented organizational structure hinders effective process management in off-site construction projects. Nevertheless, off-site construction requires a seamless transition of workflows between off-site manufacturing and on-site assembly environments. Consequently, addressing management-related challenges in construction projects necessitates a thorough examination and understanding of the digital capabilities offered by technological innovations (Hou et al., 2020).

A lot of people are involved in off-site construction projects, such as clients, end-users, contractors, consultants, labor unions, line groups, public authorities, financial institutions, and insurance firms, all of whom are closely interconnected (Karlsen, 2002). For instance, Xue et al. (2007) illustrated the relationships among stakeholders and the flows between them in prefabrication projects, identifying exchanges of information, materials, services or products, and financial resources. These interactions collectively form a complex supply chain network. During the design, manufacturing, transportation, and assembly stages, key project participants like clients, major contractors, designers, manufacturers, transport providers, and assembly subcontractors are involved in many processes that are connected to each other. It's important to remember that these actors are only a subset of the whole project team, as additional parties may be involved at different stages of the construction process.

Accordingly, supply chain risks in off-site construction are closely linked to how stakeholders interact with each other, showing a high level of interdependence (Luo et al., 2019). Luo et al. (2019) examined stakeholder-related risks and their interrelations through a case study of a prefabricated building project in Hong Kong. In their study, stakeholders were selected from full-time front-line employees and managerial staff who had been involved in the project from its inception and possessed a thorough understanding of its processes. This dual perspective enabled the identification of critical risks from both operational and managerial viewpoints. The ten most significant risks and their interconnections are seen in Figure 3.

Figure 3 Stakeholder-related risk network



Source: Luo et al., 2019

The case study interviews identified three primary risks: delays in the assembly schedule associated with assembly subcontractors, labor shortages on the manufacturer's side, and insufficient labor resources within assembly companies. These risks appear in nine of the most critical interconnections within the network, indicating that they require careful management in order to reduce overall network complexity. Furthermore, large-scale construction projects often involve hundreds of participants with diverse roles and responsibilities (Oesterreich & Teuteberg, 2016).

This highlights the necessity of adopting a systematic approach to effectively identify, prioritize, and engage stakeholders with high levels of salience (Bal et al., 2013).

Conclusion

This research concentrates on an automated and integrated construction system that bridges the construction and manufacturing sectors: off-site construction. The chapter has examined off-site construction from a comprehensive perspective, outlining its typologies, underlying principles, key processes, application sectors, and the actors involved across the project life cycle. By positioning off-site production within a broader industrial and organizational context, the chapter highlights how construction differs from, yet can learn from, more mature manufacturing industries in terms of productivity, process integration, and standardization.

The analysis indicates that although off-site construction has considerable potential to mitigate persistent problems in the construction industry—such as low productivity, fragmented processes, and coordination challenges—its effective application largely depends on the successful integration of diverse stakeholders and interconnected processes. The complexity of extended supply chains, the diversity of actors involved, and the need for seamless transitions between off-site and on-site environments underscore the importance of structured workflow frameworks and collaborative project delivery approaches. Furthermore, the analysis demonstrates that off-site construction should not be understood solely as a technical or production-oriented solution, but rather as a systemic transformation of construction practices. Its effectiveness relies on organizational alignment, early-stage decision-making, and the establishment of clear communication and coordination mechanisms across the project life cycle. In this sense, off-site construction represents a critical step toward the industrialization of construction, providing a foundational platform upon which more advanced digital and automated technologies can be built.

Overall, this chapter contributes a critical synthesis of the existing research on off-site production in the construction sector, clarifying its core concepts, structures, and challenges. By framing off-site construction as an integrated industrial approach rather than an isolated technique, the study provides a conceptual basis for both researchers and practitioners seeking to understand, evaluate, and implement off-site production strategies.

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BÖLÜM 8

SUSTAINABILITY ANALYSIS WITH FUZZY LOGIC METHOD ON SİVRİHİSAR TRADITIONAL HOUSES

MELTEM ERBAŞ ÖZİL[1]

INTRODUCTION

Recently, it has been recognized that the natural environment and energy resources are irreplaceable. consumption, artificial environments being alien to human beings and nature, architectural brings new approaches to designs. The negative effects of created artificial environments on the ecosystem over time force architects to take approaches that take into account how the environment will be designed and how buildings will be produced, and direct them to reconsider designs that cause the least harm to the natural cycle (Gezer 2013) Architects are developing sustainable design methods as solutions to the existing influences in the universe. However, before these methods, traditional architecture has already achieved harmony between the natural environment and buildings.

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Describing the essence of traditional architecture with a single word is challenging. However, with a general approach, it can be characterized as constructions built by ordinary individuals to meet their specific needs, cultural values, and to respond to their cultural lifestyles and economic conditions. In other words, traditional architecture is not only defined in terms of cultural elements and traditional building materials but also encompasses environmental sensitivity and the impact of climatic factors on architectural designs (Glassie 1990). Traditional architecture establishes a strong connection between the structures and environment built in a specific geography and the people living in that region, showcasing its unique architectural language. Also referred to as vernacular architecture, traditional architecture inherently assimilates the natural needs of individuals and the culture of the community, often in an unconscious manner (Glassie 1990). Architects strengthen and take a step towards a sustainable future by emphasizing the harmony between individuals, nature, and societal culture in their works. The fundamental source of sustainability lies in the preservation of local architectural heritage and its transmission to future generations. In this context, the local and authentic architectural construction culture should be thoroughly examined and embraced in a way that guides contemporary understanding (Özdemir 2023).

In this study, the focus has been on examining the traditional features of Sivrihisar Traditional Houses that reflect the traditional texture. The primary objective of this research is to determine the sustainability of the local traditional architecture by creating a model using the fuzzy logic method, which has not been applied in any previous study. The fuzzy logic method has been widely utilized in various fields such as control systems, artificial intelligence, robotics, medicine and healthcare, traffic management, financial analysis, home appliances and automation, environmental engineering, and computer games. However, when viewed from an architectural perspective, the evaluation of the sustainability of traditional architecture is a relatively recent area of study with limited sources available. This study aims to make significant contributions to interdisciplinary scientific fields beyond architecture. Furthermore, the findings derived from the traditional Sivrihisar Houses aim to reveal the sensitivity of traditional textures to the environment. The conducted research holds importance in showcasing traditional architecture as an example for modern architecture and emphasizing the role of traditional architecture as a reference in developing environmentally conscious sustainable architectural approaches in the present and future.

MATERIAL AND METHOD

In this section, information regarding the study area and methodology is provided.

Material

The discussion on the data obtained from the Traditional Sivrihisar Old Houses progresses in the next section with an explanation of the geopolitical position and historical context of the study to enhance better understanding.

Afterwards, details regarding the primary material of the study, pertaining to the designated area, are presented.

The Historical Evolution of Sivrihisar District

When examined in a historical context, Sivrihisar has a deep-rooted history dating back to the Hittite period. According to Doğru's findings, Sivrihisar served as a provincial center during the periods of Etiler, Phrygians, Romans, Byzantines, Seljuks, Bayezid, and Kanuni. While it belonged to the Bursa province until the 17th century, with the establishment of the Ottoman provincial organization in 1845, it became part of the Ankara province. In 1914, it joined the Eskişehir province, and during the Republican era, in 1925, it became the district center affiliated with the province of Eskişehir (Doğru 1999).

Sivrihisar is located 95 km from Eskişehir, and 135 km from Ankara, situated at the intersection of roads leading to Afyon in the south and Konya in the southeast (Figure 1).

(Where is Sivrihisar? How to get to Eskişehir Sivrihisar? 2021)

Figure 1: Sivrihisar's Location

Sivrihisar is defined by Ramsay (1960) as a city established at the intersection of military and postal roads within the Byzantine transportation system, designed to meet the secure accommodation needs of armies. Additionally, it can be said to serve functions related to the safe exploitation and marketing of internationally potential mineral resources. According to Ramsay (1960), it is possible to assert that, besides the Byzantines, other civilizations also utilized this region as a military and strategic center on a volcanic rock mass. To implement this strategy effectively, the Sivrihisar Castle was constructed on the Royal Road, controlling this route (Ramsay 1960). The Byzantines built this castle using cut stones, marble fragments, and rubble stones brought from the ancient city of Pessinus in the village of Ballıhisar in Sivrihisar.

Few remnants have survived to the present day, including the remains of the city walls, cisterns, grain warehouses, and some underground spaces within the castle. In addition to these remnants, findings from the Seljuk period indicate the military-strategic nature of the region, revealing structures such as cisterns, food warehouses, arsenals, and cellars within the city's spatial structure and elements (Özcan 2008).

Sivrihisar's Urban Settlement and Traditional Texture

According to the data describing the urban settlement of Sivrihisar, it is observed that the neighborhood structure has largely preserved its original form. Sivrihisar encompasses neighborhoods settled on the slopes of crescent-shaped rocks that block the northern winds, creating a natural amphitheater-like setting (Figure 2).

(What's Sivrihisar like? If you look at the painting 2016)

Figure 2: General view from Sivrihisar

Streets, merging from east to west at the same level, along with occasionally winding and dead-end alleys, form a distinctive neighborhood texture on the ground paved with cobblestones. In addition to small squares formed by a few streets converging around fountains between neighborhoods, there are squares at intersections where one or more streets intersect with avenues.

Similar to other Anatolian cities, the streets here are mostly narrow and winding; concurrently, the streets, bordered by house facades and high walls, signify the preservation of the urban fabric as a historical heritage transported into the present (Figure 3).

(Erbaş Özil, 2024)

Figure 3: The Traditional Texture of Sivrihisar

Information Regarding Examined Traditional Houses Within the Scope of the Study

The district has hosted many periods throughout history, and structures known as Sivrihisar houses, with different examples of architectural and civil architectural styles from various periods, sustain their existence in harmony. The historical richness embedded in the genetic codes of Sivrihisar district emerges as a significant factor in the creation of high-quality architectural spaces. The cultural accumulations specific to this district contribute to a rich urban fabric, influencing various areas such as architecture, agriculture, trade, tourism, and social life. The region-specific architecture takes shape in accordance with the specified criteria. Sivrihisar's traditional houses have been examined based on four selected residences within the study area, taking into consideration the scale of the settlement. Among these sample residences are Zaim Ağa Mansion, Fevzi Budak House, Metin Yurdanur, and Rahman Çakır House (Table 1).

Table 1: Sivrihisar Traditional Houses Examined within the Scope of the Study

Zaim Ağa Mansion	***Site Plan -Floor Plans***	***Building Materials***	
		***Ground Floor***	*Mud-Mortared Crushed Rubble Stone*
		First Floor	*Adobe-filled carcass and Wooden lintel with brick infill*
		Flooring	*Timber joists*
		Roof	*hipped roof covered with corrugated tiles*
		Plaster Material	*lime*
		Doors	*timber*
		Windows	*wooden guillotine window*
		Projections and Balconies	*Wooden beam/ wooden lining*
Fevzi Budak House	**Site Plan -Floor Plans**	***Building Materials***	
		***Ground Floor***	*Wooden-brick infilling*
		First Floor	*Wooden-brick infilling*
		Flooring	*Vernacular stone pavement*
		Roof	*Alaturka tiles*
		Plaster Material	*Filling plaster + paint*
		Doors	*timber*
		Windows	*wooden guillotine window*
		Projections and Balconies	*Wooden beam/ wooden lining*

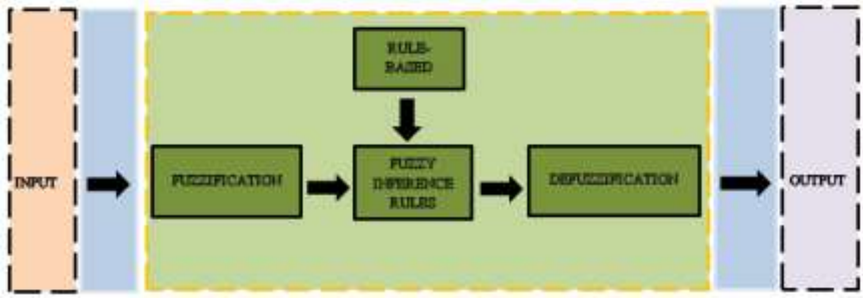
Continuation of Table 1

	Site Plan -Floor Plans	***Building Materials***	
Metin Yurdanur House		***Ground Floor***	*lime-based plaster + paint*
		First Floor	*lime-based plaster + paint*
		Flooring	*wooden pavement*
		Roof	*Alaturka tiles*
		Plaster Material	*Filling plaster + paint*
		Doors	*timber*
		Windows	*wooden guillotine window*
		Projections and Balconies	*Wooden beam/ wooden lining*
Rahman Çakır House	**Site Plan -Floor Plans**	***Building Materials***	
		***Ground Floor***	*lime-based plaster + paint*
		First Floor	*lime-based plaster + paint*
		Flooring	*wooden pavement*
		Roof	*Alaturka tiles*
		Plaster Material	*Filling plaster + paint*
		Doors	*timber*
		Windows	*wooden guillotine window*
		Projections and Balconies	*Wooden beam/ wooden lining*

Method

The study begins with a comprehensive literature review on the location, urban settlement, and traditional texture of Sivrihisar District. In the context of this subject, identity cards for the examined four traditional houses are created through on-site observation and photographic documentation methods. Subsequently, information is provided about the main focus of the study, which is the fuzzy logic method. Finally, membership degrees related to topography, temperature, wind parameters, and the stages of the fuzzy logic method concerning the examined houses are demonstrated.

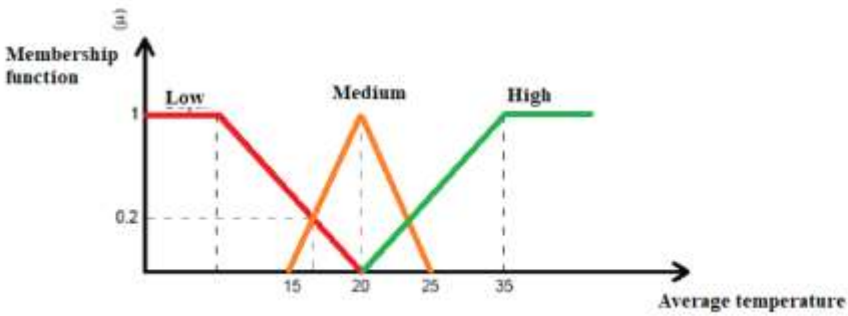
"The concept of fuzzy logic was first introduced by Zadeh in 1965 (Zadeh 1965). Fuzzy logic inherently possesses a non-statistical nature. In the fields of natural and social sciences, the fuzzy set method is commonly employed. As mentioned by Bala and Üstüntaş (2014), fuzzy logic variables have been extended to address the concept of partial truth, where values can vary between completely true and completely false (Alkan Bala, Üstüntaş 2014) This methodology encompasses the Mamdani fuzzy inference approach, capable of modeling complex systems under uncertain and/or imprecise conditions (Sun, Li, Gao and Xia 2018). The Mamdani method allows for a more intuitive and human-like definition of expertise (Kaur and Kaur 2012). Additionally, fuzzy logic operates on a rule-based structure to generate an output of information. These rules typically consist of "If…Then…" propositions (Figure 4). For instance, in a fuzzy conditional statement such as 'If the room temperature is low, then gradually increase the heat valve to a high level,' both X and Y convey a fuzzy meaning. The fuzzy logic method is eventually transformed into a crisp value.



(Fuzzy Logic 2021)

Figure 4: Fuzzy logic method process diagram

In Figure 5, the linguistic representation of the impact level of room temperature is depicted based on the rules of 'low,' 'medium,' and 'high' with respect to the average temperature in degrees Celsius. Returning to the example of a room temperature of 16 °C, it holds a membership degree of 0.2 in both 'low' and 'medium' categories, implying a mitigated effect of the room temperature." (Kaur and Kaur 2012).



(Fuzzy Logic Tutorial 2021)

Figure 5: Fuzzy logic system

RESULTS

In this section, general information about Sivrihisar traditional houses is initially provided, and then the focus is on environmental sustainability. Subsequently, under the title of environmental sustainability, membership degrees and fuzzy logic method stages are demonstrated based on topography, temperature, and wind parameters.

Sivrihisar Traditional Houses and Architectural Features

Traditional Sivrihisar houses are situated in one corner of naturally formed plots, leaning against the plot boundary, covering one end of the plot, or positioned in an L-shape. Courtyards and gardens are observed alongside or behind the buildings, and even in small plots where there might not be a garden, a courtyard is arranged with access from the street, hosting auxiliary spaces such as a tandoor house, cellar, storage, well, and fountain. Plans include layouts with internal courtyards, external courtyards, and mixed courtyards. Generally designed as two stories, the walls of Sivrihisar houses are constructed with rubble stone masonry from the foundation to the water basement or the second-floor level, while the upper portions are built in a frame structure with wooden framing filled with brick or adobe infill (Figure 6).

(Erbaş Özil, 2024)

Figure 6: Sivrihisar Traditional Houses

The ground floors of traditional Sivrihisar houses are designed to be harmonious with the plot and have fewer windows, while the upper floors are animated with projections. In the simple facade arrangements of traditional Sivrihisar houses, both horizontal and vertical lintels are entirely visible. In some structures, the intersections of the window sills and floor lintels with vertical lintels are adorned with wooden carved elements. In some examples, the external plastering is omitted in the entire building or only in the projections, and a brick adobe wall construction in geometric forms such as herringbone, with embossed joints between wooden posts, is stylized. Another significant decorative element is the lattice windows with railings.

Windows in Sivrihisar houses are typically 1/2 or 1/3 proportioned, with very few guillotine windows, where the lower half of 1/2 windows and the lower or upper thirds of 2/3 windows are operable. Projections are sometimes extensions of the flooring, sometimes extensions of the walls perpendicular to the facade, often profiled with cantilevered console beams, and sometimes covered with lath-covered wooden surfaces. Cantilevered projections are generally supported externally by wooden posts (Özmen 2018).

Roofs are generally four-sided, but if they lean on another building, they may be two or three-sided, with slopes given to the open outer walls. Traditionally, roofs are constructed by making a ceiling floor, covering it with soil, piling reeds, giving the roof a minimum of 25% slope with mud leveling, and placing tiles. As houses grow, and the area to be filled with reeds expands and rises, the edges of the roof are again filled with reeds, and a ridge or ridge support, connected to it by four sloping ridges, is placed in the middle. Rafters are nailed at wide intervals, and after leveling with reeds and mud, tiles are placed, forming what is locally known as "yarım çatılar" or half roofs. Eaves, usually uncovered, have ceiling beams and rafters visible. In some examples, the eaves are covered with lath-covered wood and are 50–70 cm wide. The chimneys of Sivrihisar houses are either square or rectangular, with three sides open and covered with brick mesh, or they can be closed with caps. There are two types: stove chimneys with triangular voids left open in four directions, constructed on a brick or rubble base, or tandır and furnace chimneys, which are built square or rectangular, lifted with brick feet from four sides, covered with Alaturka tiles in a cradle roof style (Özmen 2018).

The ongoing sections of the study address the environmental sustainability of traditional Sivrihisar Houses.

Environmental Sustainability of Traditional Sivrihisar Houses

Environmental sustainability is a phenomenon that strives to meet the current generation's needs without compromising the ability to meet the needs of future generations (Goodland 1995). While aiming to enhance human well-being and preserve raw material resources, it also seeks to increase environmental sensitivity by minimizing the negative impacts of humans on nature. In the scope of this study, the environmental sustainability of the selected Traditional Sivrihisar Houses is analyzed under three categories: temperature, wind, and adaptation to topography.

Topography

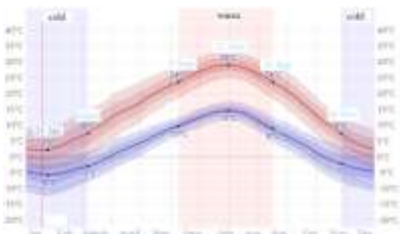
Topography is one of the crucial design inputs that influence the arrangement of structures, the shaping of cities, the formation of roads, and the relationships between buildings and roads. The neighborhoods formed around organically designed roads consist of residences that constitute the foundation of the traditional urban fabric. These residences are planned in harmony with the topography and positioned in a way that does not obstruct each other. Additionally, factors such as kinship relations, socio-cultural status, the concept of neighborhood, and the mass compatibility of structures have directly influenced the placement of residences (Figure 7).

(Erbaş Özil, 2024)

Figure 7: The Topographical Harmony of Traditional Houses in Sivrihisar

Temperature

Temperature plays a crucial role in achieving spatial comfort and preserving raw material resources. Figure 8 provides the average, minimum, and maximum temperature values for Sivrihisar by month, considering the importance of ensuring spatial comfort and conserving raw material resources.



(Weatherspark 2024)

Figure 8: Average High and Low Temperatures in the Sivrihisar Region

The mild season lasts approximately 3 months, starting on June 9th and continuing until September 16th, with daily average high temperatures exceeding 24°C. July is the hottest month in the Sivrihisar region, with an average high temperature of 28°C and a low temperature of 14°C. The cold season spans approximately 3,5 months, beginning on November 26th and lasting until March 6th, with daily average high temperatures below 8°C. The coldest month in the Sivrihisar region is January, with an average low temperature of -5°C and a high temperature of 2°C (Weatherspark 2024).

In Sivrihisar Traditional Houses, an attempt has been made to achieve a balance between internal and external climatic variables, which is influenced by temperature changes. To maximize sunlight utilization, the expansion of facades facing south, the use of stone on the ground and adobe material on external walls, and the entrance to the structure from a specific water basement level aim to provide spatial thermal comfort. In this context, vernacular architectural systems offer one of the most intriguing features for thermal regulation through thermal release tailored to climates. The ideal temperature is considered to be 20°C for both internal and external comfort. Below 10°C is categorized as "low," 15-25°C as "moderate," and above 20°C as "high."

Evaluation has been conducted based on 4 selected houses in the study area due to the size of the settlement area of Sivrihisar Traditional Houses. Zaim Aga Mansion, Fevzi Budak House, Metin Yurdanur House, and Rahman Cakir House were chosen as the sampling area from Sivrihisar Traditional Houses. In the winter months, the indoor temperature was measured as 26°C in Zaim Aga Mansion and Rahman Cakir House, 27°C in Fevzi Budak House, and 28°C in Metin Yurdanur House. In the summer months, the indoor temperature was measured as 23°C in Fevzi Budak and

Rahman Cakir houses, 22°C in Zaim Aga Mansion, and 21°C in Metin Yurdanur House.

Wind

Wind is another significant design input that affects the placement of doors, windows, walls, roofs, and the overall layout of structures. Therefore, wind is taken into consideration in directing the orientation of architectural structures. The prevailing wind in Sivrihisar blows from the north. Sivrihisar is situated on the surface of the hills, shaped like a natural amphitheater, where crescent-shaped rocks block the northern wind. Therefore, the northern facades of traditional houses are either closed or strategically buried, taking advantage of the topography.

Membership Degrees and Fuzzy Logic Method Stages According to Parameters

The historical town of Sivrihisar has developed in the east-west direction in a region where the slope decreases from north to south. The northern part of the town progresses towards the region with pointed rocks (Toprak 2020). Sivrihisar is situated like a natural amphitheater on the slopes of crescent-shaped rocks that block the north wind, forming neighborhoods that harmonize with the topography (İnceoğlu 2013).

Due to the hot and arid continental climate during the summer, specific materials like stone and adobe have been used to balance the interior-exterior temperatures (providing spatial comfort). Figure 9 illustrates membership degrees and fuzzy logic method stages according to topography, temperature, and wind parameters.

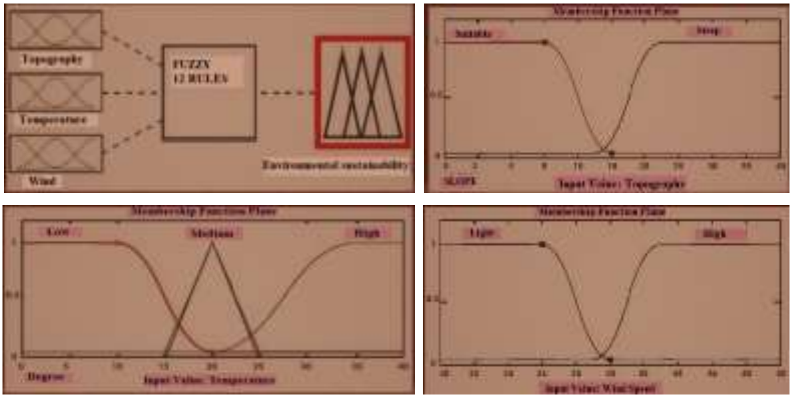


Figure 9: Membership degrees according to parameters

Sivrihisar Traditional Houses were evaluated based on 12 rules for environmental sustainability. These rules are as follows:

- ***1st Rule:*** If the topography is suitable, and the space temperature is low, and the dominant wind direction is closed, then the environmental sustainability coefficient is low.
- ***2nd Rule:*** If the topography is suitable, and the space temperature is low, and the dominant wind direction is open, then the environmental sustainability coefficient is low.
- ***3rd Rule:*** If the topography is suitable, and the space temperature is moderate, and the dominant wind direction is closed, then the environmental sustainability coefficient is moderate.
- ***4th Rule:*** If the topography is suitable, and the space temperature is moderate, and the dominant wind direction is open, then the environmental sustainability coefficient is moderate.

- ***5th Rule:*** If the topography is suitable, and the space temperature is high, and the dominant wind direction is closed, then the environmental sustainability coefficient is high.
- ***6th Rule:*** If the topography is suitable, and the space temperature is high, and the dominant wind direction is open, then the environmental sustainability coefficient is high.
- ***7th Rule:*** If the topography is unsuitable, and the space temperature is low, and the dominant wind direction is open, then the environmental sustainability coefficient is low.
- 8th Rule: If the topography is unsuitable, and the space temperature is low, and the dominant wind direction is closed, then the environmental sustainability coefficient is low.
- ***9th Rule:*** If the topography is unsuitable, and the space temperature is moderate, and the dominant wind direction is open, then the environmental sustainability coefficient is low.
- ***10th Rule:*** If the topography is unsuitable, and the space temperature is moderate, and the dominant wind direction is closed, then the environmental sustainability coefficient is moderate.
- ***11th Rule:*** If the topography is unsuitable, and the space temperature is high, and the dominant wind direction is open, then the environmental sustainability coefficient is moderate.
- ***12th Rule:*** If the topography is unsuitable, and the space temperature is high, and the dominant wind direction is

closed, then the environmental sustainability coefficient is high.

Based on these rules, the environmental sustainability coefficient was evaluated. Thus, the inputs of Sivrihisar Traditional Houses (topographical compatibility, positioning according to the dominant wind direction, and indoor-outdoor temperature) were examined within the scope of environmental sustainability. As a result of these examinations, the surface graphs in Figure 10, showing the interactions between the inputs, have emerged.

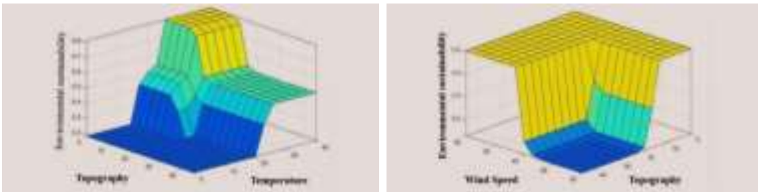


Figure 10. Interaction Among Inputs

CONCLUSIONS

Vernacular architecture is an architectural form that prioritizes climate and terrain data while aiming to sustain social and cultural characteristics. However, contemporary urbanization has reduced the use of regional architectural examples, highlighting new construction methods and material usage. This situation leads to an increase in energy consumption of buildings, contributing to environmental harm.

Maintaining the continuity of the natural balance of the universe is crucial for the sustainability of future generations. In this context, the environmental sustainability of nature is hidden in the harmony between humans and the universe. This harmony emerges as a possible balance between the climate and topography bestowed by nature and the living space created by humans. Over the years, the use of vernacular architecture has been recommended to establish this balance. Vernacular architecture is not only important for conscious material selection and effective use of natural resources but also plays a significant role in environmental awareness and the impact of climate factors on architecture.

While creating living spaces, small touches to nature make the land meaningful. Taking advantage of the possibilities offered by the terrain, it transforms into spaces where people can benefit more from the sun, pause to relax, and sometimes contemplate the scenery.

In this study, the concept of environmental sustainability, reflecting vernacular architectural features, was determined for Sivrihisar Traditional Houses using the fuzzy logic method. Within the scope of environmental sustainability, temperature, wind, and topography parameters were examined. These parameters reveal the impact on the settlement and orientation of buildings, the shaping of cities, and the selection of building plans and materials. Sivrihisar Traditional Houses are constructed in accordance with environmental sustainability based on temperature, wind, and topography parameters. The act of construction not only contributes to architectural environmental sustainability but also facilitates the establishment of neighborhood relations and the transmission of cultural values of the community to future generations without disruption. In this regard, traditional houses provide important clues about new constructions and information that can be transferred to architecture. These houses, adapted to climatic conditions, can be considered as a good model.

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BÖLÜM 9

NEUROARCHITECTURAL AND BIOPHILIC INTERIOR CONFIGURATIONS IN INPATIENT WARDS: VR-BASED NEUROPHYSIOLOGICAL MEASUREMENTS AND AI-SUPPORTED EVIDENCE-BASED DESIGN

ELİF SÖZER[1]

1. Introduction

Spatial qualities in healthcare facilities are related to external manifestations such as stress, anxiety, orientation, perception of privacy, and satisfaction. Inpatient wards, in particular, are environments where users (patients, companions, staff) spend extended periods and may be more sensitive to environmental stimuli. Findings demonstrating the relationship between environmental elements, such as natural landscapes, and healing processes are among the cornerstones of the evidence-based design approach (Ulrich, 1984). In this context, biophilic design, with its elements that bring nature into the space, provides an applicable framework to support healing processes in healthcare facilities (Kellert et al., 2008; Ryan et al., 2014).

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However, studies that address the impact of biophilic indoor parameters on the user through controlled scenario generation with VR, simultaneous data collection with neurophysiological measurements, and multivariate modeling with artificial intelligence are still limited (Bower et al., 2019; Taherysayah et al., 2024). This study proposes a holistic method and output set that targets this gap.

In this context, studies related to biophilic design, which is an approach that systematically integrates nature-based stimuli into design (Kellert et al., 2008), show that biophilic design is associated with psychophysiological and cognitive benefits (Ryan et al., 2014). Evidence showing that natural landscapes can contribute to the healing experience in healthcare facilities also strengthens this framework (Ulrich, 1984).

Furthermore, research examining the relationship between built environments and affect and stress emphasizes the importance of using Heart Rate Variable (HRV), which measures the balance of the autonomic nervous system, and Electroencephalography (EEG), which measures the electrical activity produced by the brain, together with self-report scales (Bower et al., 2019). Large-scale studies on the use of HRV as a stress indicator show that it is strongly associated with the sympathetic and parasympathetic nervous systems (Kim et al., 2018; Thayer et al., 2012). Therefore, monitoring the effect of biophilic design variations on physiological stress and arousal patterns with HRV can increase the measurement and evaluation capacity in the production of "evidence-based design" (Kim et al., 2018).

In this context, Sozer, in her book Neuroarchitecture Metamorphosis -Healing Spaces (2023), describes how a space modelled in three dimensions in computer programmes is experienced by users through virtual reality (VR), while their stress and emotional responses are measured simultaneously using neurophysiological measurements. Sozer establishes the conceptual framework of neuroarchitecture by emphasising that design can be optimised according to stimuli that elicit positive responses from individuals.

3. Method

3.1. VR scenario generation and experimental control

VR allows for the controlled generation, comparison, and repetition of different design variants of the same space. Studies using VR and EEG together in built environment assessment have aimed to capture the relationships between design decisions and emotional responses in a more “data-driven” way (Hu and Roberts, 2020). Studies that systematically compile the use of VR-EEG in the context of architecture draw attention to the diversity of methods and emphasize the need for transparency in measurement and analysis protocols (Taherysayah et al., 2024). In the approach proposed in this study, a typical hospital room is modeled in a VR environment, and scenarios with different biophilic levels and spatial elements (light, color, material, natural elements, landscape, openness-closedness, etc.) are generated.

3.2. Data Collection: EEG, HRV, and Self-Report Scales

Multi-channel EEG and HRV measurements are taken while participants experience scenarios with a VR headset. Mood, perceived stress, and spatial satisfaction-comfort scales are administered after each scenario. Collecting neurophysiological data together with subjective scales makes it possible to analyze the relationship between physiological response and conscious experience testing (Bower et al., 2019).

3.3. Artificial Intelligence Analysis and Closed-Loop Optimization

Biophilic-spatial parameters, EEG-HRV indicators, and self-report data are modeled together in the collected dataset. The aim is to reveal which parameter combinations are associated with lower physiological stress and higher perceived comfort using “learning” models. Such learning processes are suitable for producing “parameter-effect maps” that can be translated into design decisions (Bower et al., 2019; Hu & Roberts, 2020).

3.3.1. Closed-Loop Optimization Logic

The closed-loop approach aims to generate maximum information from a limited number of experiments through a "suggestion-experience-measurement-learning-re-suggestion-decision" cycle. Examples of closed-loop experimental design in neuroscience, which aims to be systematized within this framework, discuss how stimulus selection can be optimized with real-time feedback (Lorenz et al., 2016). This framework can be transformed into a decision support pipeline that replicates the improvement of biophilic parameter combinations in inpatient room design based on "measurable response".

4. Discussion and Conclusion

The proposed framework offers an interdisciplinary method that models subjective experience together with neurophysiological measurements such as EEG and HRV by testing biophilic indoor parameters in a VR environment in a controlled manner in inpatient rooms, and optimizes design decisions with artificial intelligence analytics. This approach aims to transform the literature on how biophilic design can support well-being in healthcare environments into a “design rule” through measurable biomarkers (Kellert et al., 2008; Ryan et al., 2014; Ulrich, 1984). It also responds to the methodological need highlighted in studies that address the affective effects of built environments together with neurophysiological and subjective indicators (Bower et al., 2019; Taherysayah et al., 2024).

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BÖLÜM 10

OPEN-SOURCE APPROACHES IN INTEGRATED BUILDING SCIENCE PROCESSES: IFC-BASED SEMANTIC DATA MANAGEMENT WITH BLENDERBIM

MUSTAFA HAKİ ERASLAN[1]

Introduction

Due to its inherently fragmented nature, the construction industry necessitates the continuous generation, revision, and interdisciplinary transmission of vast quantities of data throughout the entire project lifecycle, ranging from inception to decommissioning. Consequently, driven by this need for intensive and complex communication, data lifecycle management has assumed paramount importance (Bucher et al., 2024). In conjunction with the digitalization process that has gained momentum in recent years, Building Information Modeling (BIM) has positioned itself at the core of this transformation. The primary potential of BIM applications lies in their ability to establish a reliable, shared knowledge resource for all project stakeholders (Borrmann et al., 2018). However, the traditional structural fragmentation within the

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construction sector leads to the formation of "information silos" or "islands of automation," stemming from the use of specialized, proprietary software by different stakeholders (Bucher et al., 2024; Lai & Deng, 2018). The reliance of commercial software on proprietary formats creates a "black-box" problem that restricts data flow, thereby subjecting users to vendor lock-in and compelling them to engage in high-cost, complex data migration processes. This situation causes severe bottlenecks in data integration both across project phases and among interacting parties.As a remedy to these entrenched problems, the OpenBIM approach—based on open standards and independent of software vendors—and its fundamental data standard, Industry Foundation Classes (IFC), have been developed. The OpenBIM paradigm aims to reclaim data ownership from software firms, restoring it to project authors, while ensuring interoperability (Lai & Deng, 2018; Prikhodko, 2024). A review of the literature reveals that BIM applications predominantly focus on geometric modeling and visualization. However, within Building Science processes, the management of non-geometric "physical data" (such as thermal conductivity, specific heat, fire resistance, and acoustic transmission of materials) is of critical importance (Borrmann et al., 2018). Particularly for energy performance and comfort analyses, it is imperative that building elements evolve from mere geometric shells into "semantic objects" embedding physical properties (Van Treeck et al., 2018; Parekh & Trabucco, 2024). In current commercial software, the management of such data is often confined to closed libraries, precluding transparent data auditing.The objective of this study is to demonstrate the potential of open-source approaches in semantic data management, a fundamental requirement of building science. In this context, using BlenderBIM—a flexible and customizable open-source software tool—this study investigates how critical building physics parameters, such as thermal conductivity (λ), fire resistance, and material density (ρ), can be integrated into a geometric building model on an IFC basis. The implementation concretely demonstrates that a BIM model can transcend being a mere repository of geometry to become a rich source of semantic information supporting advanced engineering analyses.

Theoretical Framework

The discipline of Building Science encompasses not merely construction and fabrication processes, but rather the management process of rich semantic data required throughout the entire building lifecycle (Koch & Konig, 2018). The element that renders a BIM model "intelligent" is not the geometric data it contains, but rather the semantic information assigned to this geometry that defines the model's behavior. This information includes parameters critical for the operation and performance analyses of the structure, such as material layers, thermal properties, cost data, maintenance schedules, and logical relationships between components (Belsky et al., 2016).

In engineering calculations requiring expertise—particularly energy performance simulations, fire safety scenarios, and acoustic analyses—the consistency of this semantic data gains precedence over geometric accuracy (Mazzoli et al., 2021). Consequently, within the context of Building Science, the modeling process should be conceptualized not as drawing production, but as a process of "Database Management" and "Semantic Enrichment."

Open BIM and the Industry Foundation Classes (IFC) Standard

Developed by buildingSMART to overcome data sharing challenges in the sector, Industry Foundation Classes (IFC) is an object-oriented data model that has achieved international standardization under ISO 16739. IFC utilizes the EXPRESS data modeling language to define data and presents a hierarchical structure. Through this structure, a wall is defined not merely as a

3D box, but as a qualified object belonging to the IfcWall class, associated with sub-components such as IfcMaterial and IfcPropertySet (Yu et al., 2023).

The most significant technical advantage of IFC is its extensible nature. The requirements of various disciplines (static, mechanical, energy) can be met through custom property sets (Psets) added to the standard schema (Dai et al., 2024). This neutral and open data structure ensures that data is liberated from software vendor dependency (vendor-neutral) and guarantees sustainable digital archiving, ensuring data remains readable even decades later, considering the long economic lifespans of buildings (Noardo et al., 2021).

Data Management via Native IFC Authoring and BlenderBIM

Prevalent commercial BIM tools in the sector typically store models in their proprietary internal formats and employ complex mapping processes to transform data during export to IFC. This “translation” operation constitutes a fundamental problem causing data loss and data corruption, particularly regarding semantic relationships and parametric data (Gerbino et al., 2021).

To overcome this issue, the “Native IFC Authoring” approach has been developed, which allows reading and writing directly onto the IFC schema without converting data into an intermediate format. This approach eliminates the software’s dependency on proprietary internal schemas, thereby ensuring the preservation of the IFC file’s original data structure (Lai & Deng, 2018; Bucher et al., 2024). Open-source tools such as BlenderBIM act as pioneering platforms offering this native authoring capability. Based on the IfcOpenShell library, BlenderBIM enables geometric modeling and semantic data assignment processes to be performed directly on IFC entities (Diara, 2025). This technical superiority provides the necessary infrastructure for the lossless integration of building physics parameters (thermal conductivity, density, etc.) into a geometric model, thus maximizing data quality within the OpenBIM ecosystem (Zhu et al., 2023).

Material and Method

The methodology of this study is predicated on the premise that the “black-box” data structures of proprietary BIM software constrain the transparent and auditable management of physical parameters, which constitute the fundamental components of building science. Consequently, the study is constructed upon open-source platforms. The research is grounded in the principle of “Semantic Enrichment,” which refers to the transformation of a purely geometric model into information by enriching it with data regarding building physics, material science, and performance metrics.

In this context, the primary objective of the research is to experimentally demonstrate the implementation of physical and semantic data entry on a basic building element within an environment compliant with IFC standards.

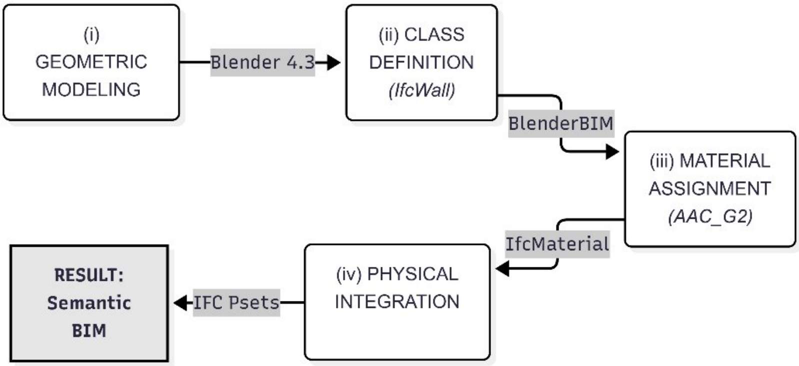
Tools and Software Infrastructure

The open-source 3D modeling software Blender (v4.3) and the integrated BlenderBIM add-on were utilized as the study environment. BlenderBIM was selected for its capability for “native authoring” directly onto the Industry Foundation Classes (IFC) schema, distinguishing it from commercial BIM software. This approach eliminates potential information loss during data conversion, thereby enabling the production of building information in a manner that is portable and compliant with international standards.

Workflow and Implementation Process

The experimental process was structured into four fundamental stages, ranging from the generation of raw geometry to the integration of numerical data related to building physics (Figure 1). These stages were configured as follows: (i) Geometric modeling, (ii) Class definition, (iii) Material assignment, and (iv) Integration of physical parameters.

Figure 1 The semantic enrichment workflow followed within the scope of the study.



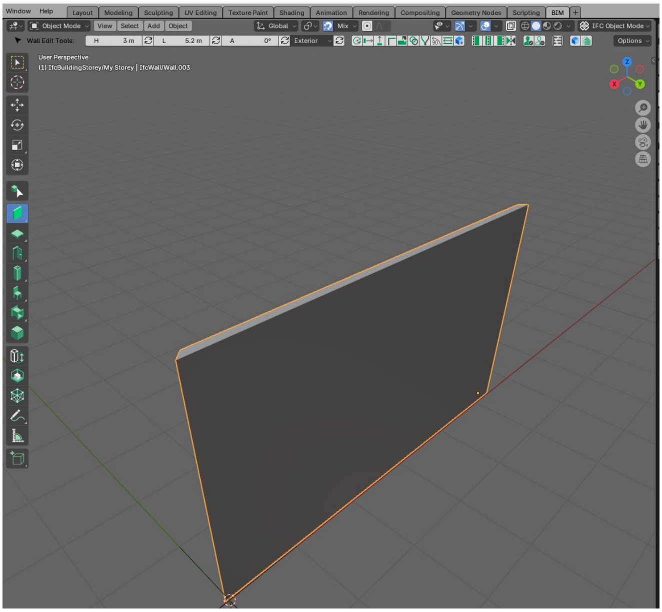
Data Entry Simulation

Within the scope of the implementation, a standard exterior wall element was modeled to represent IFC-based data entry. The geometric properties of the wall were determined based on typical dimensions widely used in architectural practice.

- Geometric Modeling and Classification

In the initial phase, a prismatic wall model with dimensions of 320 cm in width, 320 cm in height, and 20 cm in thickness was generated within the Blender environment. Using the BlenderBIM interface, this raw geometry was assigned to the IfcWall class, thereby acquiring a structural identity within the framework of IFC standards (Figure 2). Consequently, the model was transformed from a mere 3D object into a semantically defined building element.

Figure 2 Assignment of the wall element to the IfcWall class.



- Material Assignment and Semantic Association

Following the class definition, material information was assigned to the structural element. In this context, the nomenclature AAC_G2 was employed to represent Autoclaved Aerated Concrete (AAC), a material frequently cited in building physics literature due to its porous structure and thermal performance characteristics. Particular attention was paid to ensuring that material nomenclature complied with academic and technical standards.

- Integration of Physical Parameters

In this step, which constitutes the most critical phase of the study, numerical data related to building physics were integrated into the digital identity of the building element. For this purpose, the Pset_MaterialThermal and Pset_MaterialCommon (and/or Pset_WallCommon) property sets, defined within the scope of IFC standards, were utilized. The following physical parameters were embedded into the model (Figure 3, 4):

Fire Rating: F120

Acoustic Rating: 50dB

Thermal Conductivity (λ): 0.13 W/mK (For heat loss and energy performance calculations)

Specific Heat Capacity (c): 1000 J/kgK (For thermal inertia and phase shift calculations)

Mass Density (ρ): 600 kg/m³ (For static load, acoustic performance, and material behavior analyses)

Through these data, the generated wall model was transformed into a semantic building element capable of providing direct input for energy analysis, acoustic evaluation, and building physics-based simulations.

Figure 3 Entry of values within Pset_WallCommon for the wall element.

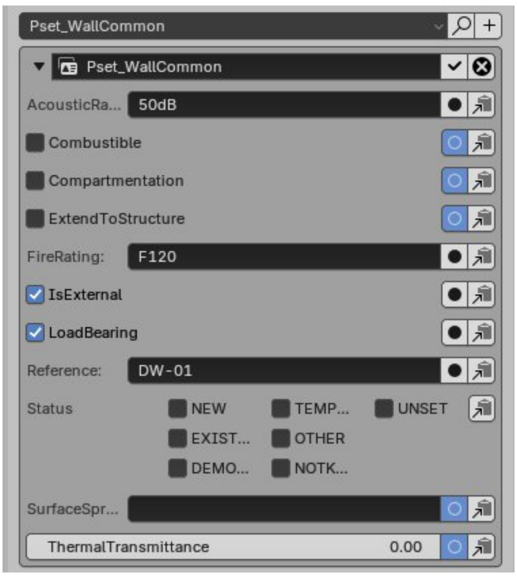


Figure 4 Entry of Material Property values for the wall element.

Findings and Discussion

The implementation carried out within the scope of this study has demonstrated, through concrete data, the potential of open-source software regarding the generation and management of building information. The findings obtained are evaluated under the headings of semantic data integrity and interoperability.

Semantic Data Integrity

As a result of the simulation conducted, it was determined that the physical parameters entered via the BlenderBIM interface were embedded into the model not merely as text tags, but as numerical and computable data types (Double, Real). Building physics data processed onto the IfcWall element via Pset_MaterialThermal and Pset_MaterialCommon sets—specifically Thermal Conductivity (λ =0.13) and Density (ρ =600)—were recorded in the Pset (Property Set) format in accordance with the international IFC schema.

Through this method, material, which consists of a mere "visual texture" in traditional modeling approaches, has been transformed into a structural component exhibiting "physical behavior." This substantiates that the architect can manage decisions regarding the building's energy performance during the design phase without any additional cost or requirement for proprietary licensed software.

OpenBIM and Interoperability

The findings indicate that the most significant advantage of open-source approaches is Interoperability. Since the entered data (e.g., ThermalConductivity) adhere to the IFC standard, when the model is transferred to energy analysis engines such as EnergyPlus or OpenStudio, these software tools automatically recognize and utilize these values. Contrary to data confined within the proprietary formats of commercial software, the data generated in this study possess the quality of being preservable throughout the building lifecycle, independent of any specific software vendor.

Evaluation and Conclusion

The discipline of Building Science has evolved from merely the physical assembly of building elements into a multi-layered structure encompassing the processes of generation, management, and dissemination of information pertaining to these elements. The case study conducted within the scope of this research, utilizing Blender and BlenderBIM tools, has demonstrated that open-source OpenBIM approaches present not merely an experimental but a professional and reliable alternative in the management of building information.

In light of the findings obtained, the primary outcomes of the study can be summarized as follows:

- Accessibility: The process of establishing the fundamental database required for building physics analyses can be comprehensively executed entirely through open-source tools, without reliance on commercial software necessitating high licensing costs.
- Data Auditing: Users are capable of directly manipulating material properties such as thermal conductivity, density,

and specific heat, without being confined to the default and closed parameter sets frequently encountered in commercial software; thereby, they can audit the source and accuracy of the generated data.

- Academic Freedom and Reproducibility: Particularly in graduate research and academic studies, the transparent generation of data and its storage within the framework of IFC standards enhances the reproducibility, verifiability, and reliability of scientific studies.

In this context, the role of the designer in future architectural practice is evolving from that of a modeler solely producing geometric forms to that of a "data curator" orchestrating the physical, digital, and semantic data of the structure. Open-source initiatives such as BlenderBIM occupy a critical position in this transformation process regarding the democratization of building science in both architectural education and professional practice.

In line with the findings of this study, the following research and application areas are recommended for future studies aimed at developing the open-source OpenBIM ecosystem:

- IFC-Based Open Material Libraries: The development of IFC-compliant open material libraries containing verified physical parameters suitable for different building types and climatic zones on open-source platforms would fill a significant gap for both academic and professional use.
- OpenBIM Approaches for Historic Structures: In the documentation and conservation of cultural heritage structures, it is proposed to develop HBIM (Historic Building Information Modeling) focused studies using open-source tools instead of the restrictive structure of commercial BIM software. In this regard, integrating original material and

deterioration parameters into the IFC schema will contribute to the creation of digital twins of historic structures.

- Integration of Artificial Intelligence and Open Source: Integrating open-source BIM environments with Large Language Models (LLMs) and machine learning-based tools may enable the development of automatic material identification, damage classification, and physical parameter recommendation systems. Such hybrid approaches have the potential to reduce human error while accelerating data generation processes.
- Education-Oriented Open BIM Platforms: To reduce dependency on commercial software in architectural and engineering education, it is recommended to develop building physics and performance-based learning scenarios constructed upon open-source BIM tools.

In conclusion, the open-source OpenBIM ecosystem offers not merely a software alternative, but an ethical, transparent, and sustainable approach to the generation and dissemination of building knowledge. The widespread adoption of this approach will both enhance the quality of academic research and guide the digital transformation of the architectural discipline.

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BÖLÜM 11

HISTORIC SPACES OF PHYSICAL AND MENTAL EXPERIENCE: ARCHITECTURAL MEANING IN THERMAL STRUCTURES

ÖZLEM ATALAN[1]
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Introduction

Historic thermal structures, as architectural spaces shaped around the healing properties of water, have played a significant role across different periods and cultures. From Antiquity to the present day, thermal buildings have not only served as the spatial counterparts of health-related practices but have also reflected the spatial formation of social, cultural, and religious practices (Yegül, 1992; Ward-Perkins, 1981). In each period, these structures developed distinctive typologies in terms of architectural order, spatial organization, and patterns of use. Therefore, thermal structures should be examined not merely as functional buildings serving physical healing, but as multilayered architectural environments that produce mental perception, sensory awareness, and cultural meaning (Rapoport, 1982; Blesser & Salter, 2007).

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Thermal structures provide an environment that integrates spatial and bodily experience. Users directly experience the space through their movement, posture, and the relationship they establish with the architectural environment (Yegül, 1992). Physical factors such as spatial scale, plan organization, material use, lighting conditions, and temperature play a decisive role in the formation of bodily awareness (Rapoport, 1982). For example, domed coverings and sequential temperature spaces guide the user's bodily rhythm, while material selection and surface texture enhance the tactile experience (Eyice, 1997). In this way, thermal spaces function as environments that distance users from the tempo of everyday life and offer an experience integrated with the architectural setting (Kuban, 2007).

The sensory experience of thermal structures is not limited to spatial organization alone; sound and acoustic characteristics also constitute fundamental components of this experience. The flow of water, dripping effects, echoes formed in domed and enclosed volumes, and moments of silence deepen spatial perception and support both physical and mental experience (Blesser & Salter, 2007). In this context, the auditory environment isolates the user from the external world, encouraging concentration and an inward-oriented perceptual process. Sound in thermal spaces emerges as a sensory layer that shapes the perception of architectural space and occupies a central position in both bodily and mental experience (Erzen, 2012).

Historic thermal structures can also be evaluated as buildings that materialize social and cultural norms at the spatial level. In Antiquity, particularly in Anatolian and Roman examples, the use by women and men was generally regulated through time-based separations, and the understanding of privacy was defined within a more collective framework (Yegül, 1992). During the Roman period, in large public baths, gender separation was implemented both spatially and temporally, and these structures became central elements of public life (Ward-Perkins, 1981). In the Ottoman period, privacy was ensured through strict spatial separations in accordance with Islamic cultural norms, with women's and men's sections organized through separate plans. In this period, dome openings, semi-dark interiors, and controlled acoustics exemplify the architectural production of privacy (Eyice, 1997; Kuban, 2007).

This study aims to examine historic thermal structures with a focus on physical and mental experience. In particular, the relationships between architectural space and meaning are addressed, and the sensory experiences produced through thermal structures in different periods are analyzed. The study seeks to contribute to the evaluation of thermal structures not merely as functional buildings, but as experiential environments in which the interaction between body, mind, and space is concretized. This approach enables a more comprehensive understanding of the cultural and experiential value of thermal structures within the fields of architectural history and conservation. Within the scope of the study, several significant buildings and building groups from Türkiye and Europe, dating to the Ancient, Roman, and Ottoman periods, have been selected. This study adopts a comparative architectural analysis to examine thermal structures from the Ancient, Roman, and Ottoman periods. The evaluation focuses on spatial configuration, functional hierarchy, sensory experience—particularly light and sound—and degrees of privacy within bathing spaces. By analyzing representative examples from each period, the study aims to reveal how architectural design mediated bodily comfort, social interaction, and mental experience across different cultural contexts.

Thermal Structures in Antiquity: Architectural Space, Spatial Configuration and Meaning *(Examples from Anatolia, the Aegean, and the Roman World)*

In Antiquity, thermal structures are defined as buildings that developed around natural hot springs and constituted the architectural counterparts of practices related to health, purification, and healing. Through their plan schemes, circulation patterns, and sensory conditions that guide the body's relationship with space, these structures reflect an experience-oriented architectural approach. In ancient thermal architecture, space was conceived not merely as a functional arrangement, but as an environment that shaped bodily perception, mental awareness, and cultural meaning (Yegül, 1992; Nielsen, 1990).

The fundamental definition of architectural space in ancient thermal structures was established through bodily movement and changes in temperature. The sequential arrangement of spaces with different temperature levels—such as the frigidarium, tepidarium, and caldarium—transformed bodily experience into a gradual process. This spatial configuration formed a systematic planning approach in Roman bath architecture and was applied according to similar principles across different geographies (Ward-Perkins, 1981). The Stabian and Forum Baths in Pompeii (Campania / Italy) are among the early and well-preserved examples of this planning scheme, where transitions between spaces were organized to allow the body to adapt to changes in temperature and spatial volume.

In Anatolia, the Pergamon (Bergama, İzmir / Türkiye) Asklepion and Allianoi (Bergama–Yortanlı, İzmir / Türkiye) reveal spatial arrangements in which thermal structures were integrated with therapeutic processes. In these centers, spaces were designed with consideration for long-term use and bodily comfort. The continuity established between water channels, pools, and enclosed spaces enabled the body to experience an uninterrupted spatial sequence (Rheidt, 2006; Özgür, 2010). Spatial organization was shaped through the succession of narrow and wide volumes that guided circulation.

The architectural meaning of thermal structures is directly associated with the concepts of health and purification. This layer of meaning becomes particularly evident in examples that establish strong connections with the natural environment. In Hierapolis (Pamukkale, Denizli / Türkiye), thermal structures were conceived together with travertine formations, ensuring visual and physical continuity between open and enclosed spaces. Space was designed as an environment in which the body engaged with the natural setting and experienced the healing qualities of water (D'Andria, 2003). Similarly, thermal structures on the island of Kos (Kos / Greece) were associated with the tradition of ancient medicine, and their spaces were designed in a calm, controlled manner integrated with the surrounding environment (Nutton, 2004).

In the Roman world, the public and collective dimension of thermal structures became particularly pronounced in monumental-scale examples. The Baths of Caracalla (Rome / Italy), with their axial plan organization, large domed volumes, and symmetrical spatial configuration, intensified the perception of scale between the body and architectural space. This structure represents an architectural approach that treated the thermal experience not as an individual practice but as a public activity (Yegül, 1992). Sound and acoustic characteristics emerge as significant components of experience in ancient thermal structures. Stone surfaces, vaults, and domed roofing systems determined the propagation of sound within space. The sound of flowing water, dripping effects, and the auditory environment generated by users' movements deepened spatial perception (Blesser & Salter, 2007). In more controlled-scale structures such as Allianoi and Pompeii, the acoustic environment provided a balanced setting that supported calmness and prolonged use, whereas in large volumes such as the Baths of Caracalla, reverberation became an element that emphasized the monumentality of space.

In terms of open-air thermal experience, Bath (Aquae Sulis, Bath / United Kingdom) constitutes an important example. The open thermal pool located in the city center allowed environmental perception to directly participate in the experience through the combined effects of water sound, steam, and natural light conditions. This demonstrates that thermal architecture was not limited to enclosed volumes alone, but was conceived in conjunction with environmental conditions (Cunliffe, 1984). When the examples of Pergamon, Hierapolis, Kos, Pompeii, the Baths of Caracalla, and Bath are evaluated together, it becomes evident that in Antiquity, thermal structures guided physical and mental experience through architectural space. Spatial configuration, meaning production, and acoustic characteristics enabled the holistic formation of experience in these buildings. Ancient thermal structures stand among the early examples that systematically employed the sensory and experiential potential of architectural space.

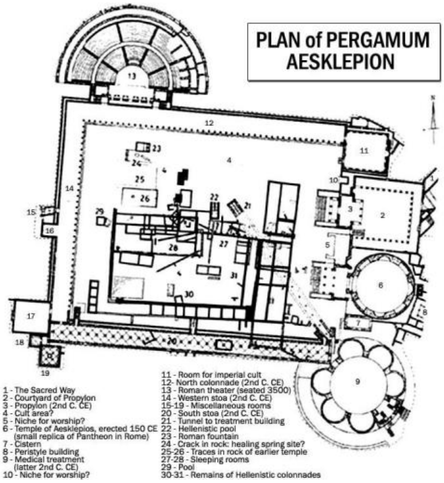


Figure 1 Bergama Asklepion (URL 1)

The bath at the Bergama (Pergamon) Asklepion, unlike the public thermae of classical Roman cities, is a balneum-type structure with a therapeutic and ritual purification function, forming an integral part of the Asklepion's holistic healing system (Yegül, 1992; Rheidt, 2006). Although the core of the Asklepion dates back to the 4th century BCE, the bath and water-related arrangements whose remains are visible today were largely shaped during the Roman Imperial period, particularly in the 2nd century CE, under the reign of Hadrian (CE 117–138) (Rheidt, 2006; D'Andria, 2003).

The operation of the bath expressed not cleanliness in the modern sense, but rather a medical and sacred process. Within the Asklepion, water was regarded as a medium of purification, bodily relaxation, and spiritual healing (Nutton, 2004). Ancient sources—most notably Aelius Aristides' Hieroi Logoi—indicate that patients were directed to bathe according to specific therapeutic regimens, with the sound of water, curative springs, and hot–cold applications accompanying the treatment (Aristides, Hieroi Logoi; Yegül, 1992). In this context, the bath was directly connected to incubation (sacred sleep) chambers, sacred water sources, and treatment buildings, functioning as a transitional space that prepared the body for the divine healing power of Asklepios (Burford, 1969; Nutton, 2004). From a semantic perspective, the Asklepion bath is both a sacred and a medical space. Water here represents not only cleansing from physical impurity, but also purification from the spiritual and bodily burdens of illness (Eliade, 1958). Consequently, the bath is defined not by social interaction and everyday life, as seen in Roman urban baths, but by ritual discipline, silence, and therapeutic order (Yegül, 1992). The architectural configuration of the Asklepion supports this meaning: the bath spaces were designed not on a monumental scale, but at a controlled scale integrated into the healing process (Rheidt, 2006).

With regard to the use by women and men, the determining factor is the Asklepion's function as a healing sanctuary. Unlike the large bath complexes of Roman cities, where strict gender segregation was common, evidence suggests that use in the Asklepion was regulated according to the therapeutic program rather than fixed architectural separation (Yegül, 1992). Ancient texts and spatial data indicate that both female and male patients were admitted to the Asklepion; however, bath use was most likely organized through time-based separation (different hours or treatment phases) or through controlled access directed by physicians (Nutton, 2004). This arrangement parallels practices observed at the Asklepia of Epidaurus and Kos (Burford, 1969; Nutton, 2004).

The bath at the Pergamon Asklepion, as part of a healing tradition rooted in the 4th century BCE and reaching maturity in the 2nd century CE, represents a health-oriented and sacred interpretation of Roman bath culture through its architecture, operation, and symbolic meaning (Yegül, 1992; Rheidt, 2006). Rather than a social public space, it functioned as a disciplined therapeutic environment aimed at healing both body and soul within the framework of the cult of Asklepios.

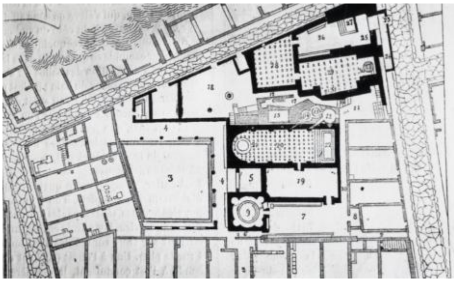


Figure 2 Pompei Site Plan (URL2)

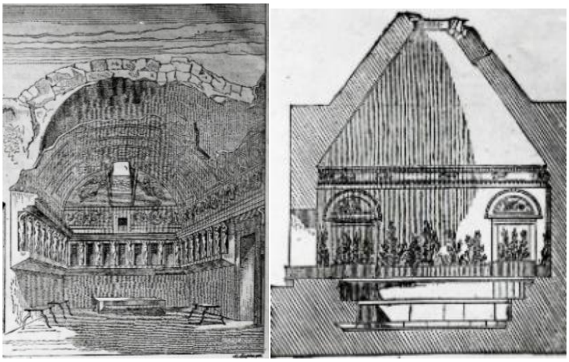
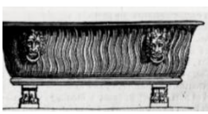
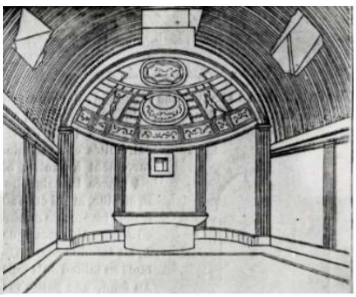


Figure 3   Tepidarium , Pompei and Frigidarium, Pompei(URL2)





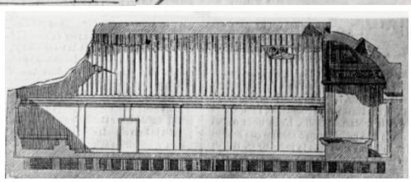


Figure 4. Bath tub Figure 5. Caldarium ancient baths, Pompei
Figure 6. Ancient baths Pompei (URL2)

The baths of Pompeii rank among the structures that emphasized public and social functions in the daily life of the Roman Empire. Built in the city of Pompeii in the 1st century CE, these bath complexes were designed both to ensure the bodily cleanliness of the city's inhabitants and to encourage social interaction (Cooley & Cooley, 2014). Although more modest in scale when compared to large imperial bath complexes such as the Baths of Caracalla, the Pompeii Baths constitute significant examples that reflect the social, aesthetic, and ritual dimensions of public space.

The planning of the baths was based on the principal functional spaces—frigidarium, tepidarium, and caldarium—which were organized in a hierarchical sequence of transition. This arrangement enabled visitors to experience not only physical cleansing but also a ritualized emotional and mental experience shaped by gradual changes in temperature (Yegül, 1992). In the Pompeii baths, floor and wall heating was provided through hypocaust systems, creating a controlled circulation between different thermal zones. This architectural and technical organization offered a sensory ritual experience accompanying bodily relaxation. The acoustic design of the space directly influenced both social interaction and the experience of ritual. In the Pompeii Baths, vaulted ceilings and marble and brick surfaces were designed to regulate both heat and sound. In this way, conversations, the sound of water, and spatial reverberations were balanced, creating an environment that supported both social communication and meditative silence (Yegül, 1992).

Interior spaces enriched with decorative elements, mosaics, and frescoes not only provided aesthetic satisfaction but also reinforced the social and ritual meaning of the space. Through the visual and auditory qualities of the environment, visitors experienced purification on both physical and mental levels. In this respect, the Pompeii Baths reveal the multidimensional function of Roman public architecture, functioning as structures that simultaneously organized bodily, social, and ritual experiences.

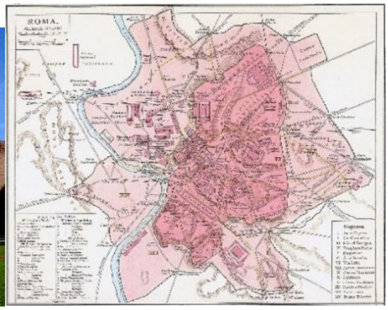


Figure 7. Baths of Caracalla   Figure 8. The location of the baths in Rome during Antiquity (URL3)

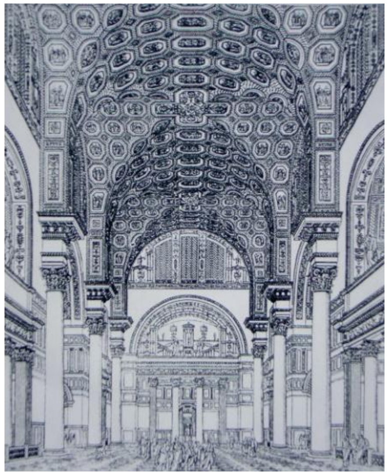


Figure 9. Fresco of Dionysus from triclinium ceiling of home incorporated into Baths of Caracalla (Rome)   Figure 10 . The Baths of Caracalla (reconstructive drawing from 1899) (URL3)

The Baths of Caracalla (Thermae Antoninianae) rank among the structures that most comprehensively reflect the Roman Empire's conception of public life. Initiated during the reign of Emperor Septimius Severus and completed and opened to use in 216 CE under Emperor Caracalla, this monumental complex is considered one of the largest and most impressive imperial bath complexes of ancient Rome. Covering an area of approximately 11 hectares, the complex was designed as a multifunctional space in which socialization, relaxation, physical exercise, and cultural and intellectual activities were experienced together, extending far beyond the function of public cleanliness (Britannica, 2025). The organization of the bath complex is distinguished by the hierarchical and symmetrical arrangement of its principal spaces, including the frigidarium (cold room), tepidarium (warm room), and caldarium (hot room). This layout offered visitors not only bodily cleansing but also a mental experiential process shaped through ritualized temperature transitions and spatial orientation (Britannica, 2025).

The hypocaust systems employed in the baths enabled the controlled heating of floors and walls, creating a comfortable flow between different thermal zones. In this way, visitors experienced a sensory transition alongside physical relaxation (UNRV, 2025) Interior spaces were enriched with large vaults, high domes, marble revetments, and sculptural programs. These aesthetic elements contributed to the formation of a sensory and visual atmosphere accompanying bodily comfort (Gensheimer, 2018). In conclusion, the Baths of Caracalla demonstrate that Roman architecture functioned not merely as a utilitarian framework, but as an instrument shaping daily life, strengthening social relations, and reinforcing public cohesion. Bringing together social, cultural, and political interactions within a spatial context, this complex has been regarded as a symbol of egalitarian public access and shared experience in Roman society (UNRV, 2025).

Table 1. Thermal Structures of the Ancient and Roman Periods

Thermal Structure (City / Country)	Construction Date	Architectural Space Description	Spatial Configuration	Operational System	Spatial Meaning	Sound and Acoustic Characteristics
Pergamon Asklepion (Bergama, İzmir / Türkiye)	4th–2nd century BC	Enclosed and semi-open thermal spaces focused on treatment and healing; therapy rooms and sacred structures	Controlled circulation and transitional spaces organized around a courtyard	Thermal water distributed through channels and small pools for therapeutic and ritual use	Healing, ritual, and bodily purification	Balanced reverberation in semi-open spaces; dominant sound of water
Hierapolis Thermal Structures (Pamukkale, Denizli / Türkiye)	2nd century BC – 3rd century AD	Environmentally integrated spaces consisting of open and enclosed thermal pools; travertine terraces	Continuity between open and enclosed spaces	Thermal water supplied directly from natural sources through stepped pool systems	Nature, sacredness, and healing	Water sounds in open spaces combined with environmental silence
Pompeii Baths (Pompeii, Campania / Italy)	1st century AD	Enclosed thermal volumes for public use, including frigidarium, tepidarium, caldarium, and exercise rooms	Sequential progression of frigidarium–tepidarium–caldarium	Hypocaust-based underfloor heating system; temperature-controlled circulation	Public purification and social interaction	Pronounced reverberation in vaulted spaces; interaction with water sounds
Baths of Caracalla (Rome / Italy)	AD 212–216	Monumental-scale public thermal spaces including frigidarium, tepidarium, caldarium, and areas for exercise and relaxation	Axial, symmetrical plan with large-scale spatial volumes	Hypocaust heating system; hierarchical thermal flow and ritualized circulation	Power, publicness, and collective experience	Strong reverberation emphasizing monumental scale; immersive acoustic environment

Thermal Structures in the Middle Ages and the Islamic World

During the Middle Ages, the Roman bath tradition was largely interrupted in Europe, and the public and architectural continuity of thermal structures weakened considerably. In contrast, within the Islamic world, architectural practices related to water continued in close association with concepts of cleanliness, health, and worship. In this context, bath buildings emerged as structures that reinterpreted the spatial principles of ancient thermal architecture and sustained this legacy (Yegül, 1992; Hillenbrand, 1994).

In the Islamic world, thermal structures were conceived on more controlled scales, and their spatial organization was shaped by a design approach that guided the user's bodily movement and experience. The Umayyad baths in Damascus (Syria), Fatimid-period baths in Cairo (Egypt), and Seljuk baths in Isfahan (Iran) are notable examples in which spaces were arranged sequentially, allowing temperature and humidity changes to be perceived in a controlled manner (Hillenbrand, 1994; Michell, 1996). In these buildings, space was conceived not merely as a functional area for cleansing, but as an environment that supported both bodily and mental purification.

The use of light constitutes one of the defining elements of spatial perception in medieval Islamic baths. Limited light admitted through small circular openings (oculi) in domed roofs created a semi-dark atmosphere, reinforcing the calm and introverted character of the space. The Yalbuga Bath in Aleppo (Syria) and pre-Ottoman bath structures in Jerusalem draw attention through their spatial arrangements in which light functions as a guiding architectural tool (Bianca, 2000).

Acoustic characteristics represent another element that reinforces the experiential quality of these structures. Domes, vaults, and niches enabled sound to spread softly within the space, creating a balanced auditory environment together with the sounds of flowing and falling water. This balance between silence, reverberation, and water sound formed a perceptual threshold that distanced bath spaces from everyday life (Blesser & Salter, 2007). Thus, thermal structures in the medieval and Islamic world became experiential environments that simultaneously offered bodily relaxation and mental tranquility through architectural space.

Ottoman Thermal Structures and Sensory Space

During the Byzantine period, public baths functioned as spaces where various matters were discussed and debated; sources even indicate that musical entertainments were organized and food was consumed in these settings. According to a document dated to 425–430, there were nine large public baths in Constantinople, in addition to approximately 150 smaller baths consisting of one or two rooms that were used by the public for a fee. In the Ottoman period, thermal structures developed through the typologies of baths and hot springs and reached a systematic and mature architectural level. These buildings were positioned as integral components of social life within the urban fabric and were addressed in various contexts, ranging from the neighborhood scale to külliye (complex) arrangements. Ottoman thermal architecture reinterpreted the accumulated knowledge of Antiquity and the Islamic world in terms of plan schemes, spatial transitions, and material use (Eyice, 1997; Kuban, 2007).

In Ottoman baths, spatial organization was formed through volumes differentiated according to temperature levels. The sequential arrangement of the soyunmalık (changing room), ılıklık (warm room), and sıcaklık (hot room) transformed the body's relationship with space into a temporal process. The Haseki Hürrem Sultan Bath in Istanbul, the Yeni Kaplıca in Bursa, the Sokullu Bath in Edirne, and the Hafsa Sultan Bath in Manisa represent this planning approach at different scales (Eyice, 1997; Kuban, 2007). In these structures, architectural space functioned as a tool that guided sensory experience. Stone and marble surfaces, together with the humid environment, intensified bodily perception, while domed roofing systems created a sense of spatial unity.

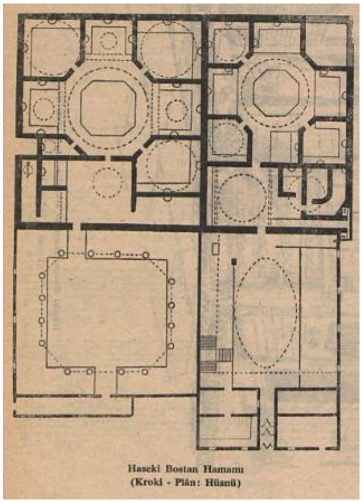
Sound emerges as a prominent component of spatial experience in Ottoman thermal structures. Reverberation beneath domes, combined with the sounds of flowing and dripping water, enhanced the perceptual depth of space (Blesser & Salter, 2007). The auditory environment created in Ottoman baths produced an atmosphere that isolated users from the external world and supported inward orientation. This controlled relationship with silence transformed thermal structures from mere spaces of bodily cleansing into environments of mental relaxation and social interaction. Such an approach strengthened the semantic layer of architectural space and accentuated the multisensory character of Ottoman thermal structures (Erzen, 2012).

The Haseki Hürrem Sultan Bath (Istanbul / Türkiye) is one of the most powerful representations of the monumental and symbolic character of public bath architecture in the Ottoman classical period. Built in 1556 by Mimar Sinan, the structure was conceived not merely as a bath serving bodily cleanliness, but as a public space that organized ritualized bathing practices, social interaction, and mental purification together (Goodwin, 2003; Yegül, 1992).

The double-bath plan arranged separately for women and men is based on an axial and symmetrical spatial organization. The hierarchical sequencing of the changing room, warm room, and hot room according to temperature levels produces an experience reminiscent of the frigidarium–tepidarium–caldarium sequence of Roman baths, yet offers a more introverted and controlled circulation concept characteristic of the Ottoman tradition (Yegül, 1992; Kuban, 2010).

The operational system of the bath was provided through a hypocaust (cehennemlik)-based underfloor heating arrangement. The controlled distribution of hot air and water enabled functional and sensory differentiation between spaces. This technical infrastructure, integrated with architectural design, established a regular and ritualized pattern of use (Kuban, 2010). Interior spaces defined by domes, vaults, and niches display a distinct acoustic character. Controlled reverberation beneath high domes, combined with the sounds of water and human voices, creates an inward-oriented, calming, and rhythmic auditory atmosphere. Unlike the strong reverberation emphasizing spatial scale in Roman imperial baths, this acoustic environment offers a more measured and tranquil sensory experience (Yegül, 1992). In terms of spatial meaning, the Haseki Hürrem Sultan Bath is directly associated not only with cleanliness and purification, but also with the concepts of public representation, the *vakıf* system, and social equality in the Ottoman classical period. In this respect, the structure clearly demonstrates how architecture functioned as a tool guiding bodily, mental, and social experience (Goodwin, 2003).

Figure 11 . Haseki Hürrem Sultan Bath (URL4)



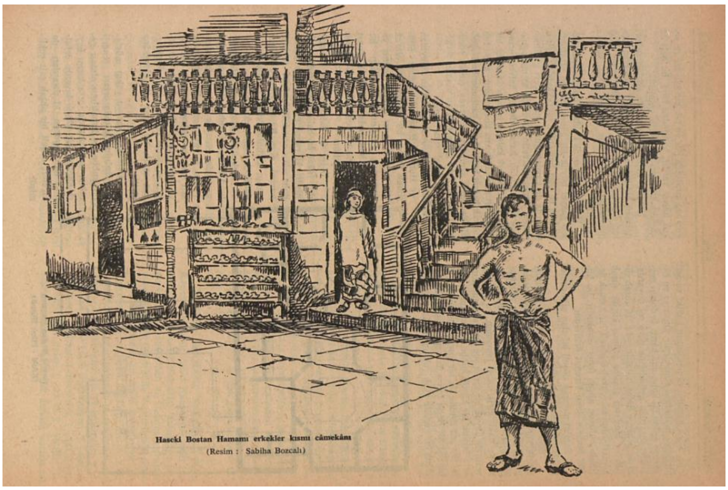


Figure 12 . Haseki Hürrem Sultan Bath Plan(URL 5) Figure 13. Haseki Hamamı erkek bölümü

A comparative reading of thermal structures across historical periods reveals a gradual transformation in the relationship between the body, space, and society. Ancient thermal spaces emphasize a close connection with natural settings and ritual practices, fostering collective experiences with minimal spatial separation. Roman baths, by contrast, prioritize monumentality, public visibility, and social interaction, transforming bathing into a civic and performative act. Ottoman thermal architecture introduces a more inward-oriented spatial logic, characterized by controlled light, acoustics, and privacy, thereby redefining the bathing experience as both physical purification and mental retreat.

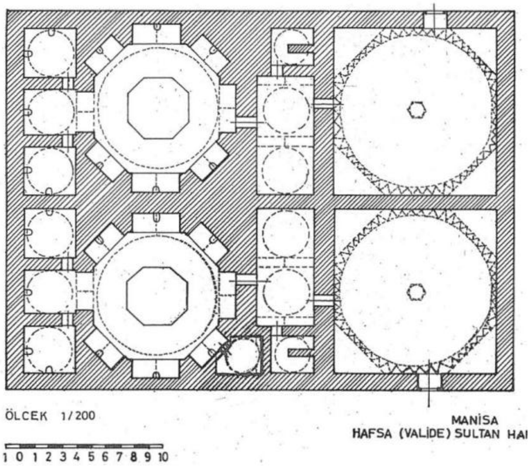


Figure 14. Manisa Sultan Baths (URL 6) Figure 15. Manisa Hafsa Sultan Baths (URL7)

Table 4. Architectural Space and Spatial Configuration in Medieval and Ottoman Thermal Structures in Türkiye

Thermal Structure (City / Country)	Construction Date	Architectural Space Description	Spatial Configuration	Operational System	Spatial Meaning	Sound and Acoustic Characteristics
Hafsa Sultan Bath (Manisa / Türkiye)	16th century, Classical Ottoman Period	Domed and enclosed bath spaces designed according to classical Ottoman hamam typology; human-scaled interior volumes	Spaces differentiated according to temperature levels; double bath layout with back-to-back women's and men's sections; hierarchical circulation	Hypocaust-based underfloor heating system; controlled distribution of hot water and heat	Cleansing, social interaction, daily public life, and mental relaxation	Controlled reverberation beneath domes and within niches; introverted acoustic character dominated by water sounds
Haseki Hürrem Sultan Bath (Istanbul / Türkiye)	1556, Classical Ottoman Period (Architect: Mimar Sinan)	Monumental-scale thermal spaces organized as a prestigious double bath complex reflecting imperial patronage	Axial and symmetrical plan; mirrored spatial organization for women's and men's sections; strong spatial hierarchy	Advanced hypocaust heating system; regulated water and heat distribution integrated with architectural order	Publicness, imperial representation, ritual practice, and collective experience	Pronounced reverberation beneath high domes; strong sense of spatial depth and acoustic presence
Sokullu Bath (Edirne / Türkiye)	16th century, Classical Ottoman Period	Enclosed thermal spaces articulated around a dominant central dome and subsidiary bathing units	Balanced and centralized plan organization with clear spatial hierarchy	Hypocaust heating system combined with controlled water circulation	Cleansing, social gathering, and mental purification	Moderate reverberation beneath the central dome; acoustics supporting calm, focused, and communal interaction

Comparative Evaluation of Thermal Structures in the Ancient, Roman, and Ottoman Periods

Thermal structures have produced diverse spatial configurations in response to changing social structures, belief systems, and perceptions of the body across different historical periods; accordingly, they have developed distinctive architectural solutions that shape both bodily and mental experience. The process extending from the Ancient period through the Roman and Ottoman eras demonstrates that thermal architecture is not merely a technical building tradition but a comprehensive spatial practice shaped by multilayered concepts such as privacy, publicness, ritual, and sensory perception.

In the Ancient period, thermal structures located in Anatolia—such as those at the Pergamon Asklepion and Hierapolis (Pamukkale)—were primarily conceived as spaces dedicated to healing and treatment. In these complexes, architectural organization established a strong relationship with the natural environment; open and semi-open spaces, water sources, and landscape elements became integral components of the spatial experience. The permeability of circulation, the flexibility of spatial boundaries, and the visual and auditory connections with nature offered an experience in which bodily perception was integrated with environmental elements. Within this context, privacy was defined not through individual seclusion but through collective ritual order, while the use of spaces by women and men was largely regulated through temporal distinctions (Yegül, 1992).

During the Roman period, thermal structures became central components of public life, and architectural scale expanded significantly. In examples such as the Pompeii Baths and the Baths of Caracalla, the sequential spatial organization defined by the frigidarium–tepidarium–caldarium progression became clearly articulated, accompanied by the development of axial, symmetrical, and monumental plan schemes. Supported by the hypocaust system, this spatial organization transformed the act of bathing into a controlled and ritualized process. In Roman baths, privacy was conceptualized differently from the inward-oriented approach of the

Ottoman period; the body was accepted as a natural part of the public realm (Ward-Perkins, 1981). Large vaulted halls and domed spaces with pronounced reverberation, combined with the sound of water, created an acoustic environment that enhanced social interaction and collective experience.

In the Ottoman period, thermal architecture—particularly through bath (hamam) buildings—developed a more controlled, inward-looking, and privacy-oriented spatial approach. In examples such as the Hafsa Sultan Bath (Manisa), the Haseki Hürrem Sultan Bath (Istanbul), and the Sokullu Bath (Edirne), the use of spaces by women and men was regulated through strict spatial separation; double-bath layouts and separate circulation systems constituted the principal architectural solutions of this approach (Eyice, 1997). In this period, privacy was not limited to gender segregation alone but was further reinforced through light levels, spatial depth, controlled circulation patterns, and acoustic characteristics. Dimly lit interiors, light filtered through dome openings, and the rhythmic sound of water created an atmosphere that isolated users from the external world and emphasized mental calmness and introspection (Kuban, 2007).

The combined evaluation of these structures demonstrates that the architectural instruments guiding bodily experience in thermal architecture diversified throughout history. While a nature-integrated and ritual-based use predominated in the Ancient period, public life, social interaction, and collective experience became decisive in the Roman period. In the Ottoman period, privacy, inward orientation, and mental purification emerged as the primary determinants of spatial organization. Architectural solutions concerning the use of spaces by women and men can thus be interpreted as spatial indicators that directly reflect the social norms and bodily perceptions of each period.

These architectural differences are further articulated through sensory hierarchies embedded in spatial design. While Roman baths amplify sound and visual openness to reinforce social cohesion, Ottoman hammams employ dimly lit interiors, filtered daylight through domes, and muted acoustics to cultivate introspection and calmness. Such sensory modulation reflects broader cultural attitudes toward the body, privacy, and collective presence, positioning thermal architecture as a mediator between physical function and cultural meaning.

Conclusion

Historic thermal structures, although shaped by changing social, cultural, and belief systems across different periods, have consistently maintained their function of promoting bodily relaxation and mental calmness throughout history. The process extending from the Ancient period through the Roman and Ottoman eras demonstrates that thermal architecture is not merely a technical or functional building type; rather, it offers a multilayered experiential field in which architectural space, sensory perception, and cultural meaning are jointly produced.

Beyond their physical and structural qualities, thermal buildings embody a form of sensory heritage that includes light, sound, spatial rhythm, and ritualized movement. These intangible dimensions are integral to the architectural identity of thermal spaces and should be considered essential components in conservation, restoration, and adaptive reuse practices. Preserving thermal architecture therefore requires not only material interventions but also an understanding of the experiential and sensory values that have historically shaped these environments.

In the Ancient period, Anatolia-centered thermal structures generated healing- and treatment-oriented uses through spatial configurations integrated with the natural environment, characterized by open and semi-open spaces. In centers such as the Pergamon Asklepion and Hierapolis, space was conceived as a medium that connected the body with nature and supported ritual purification. During this period, privacy was not defined through individual boundaries but rather through collective ritual order and temporal patterns of use; the use of spaces by women and men was largely regulated through time-based distinctions.

In the Roman period, thermal structures became monumental architectural exemplars positioned at the core of public life. Architectural scale expanded, and spaces supporting social interaction were produced through symmetrical and axial plan schemes. In examples such as the Pompeii Baths and the Baths of Caracalla, the body was accepted as a natural component of the public realm, and privacy was treated as a secondary concern. Large spatial volumes, reverberant acoustic environments, and the sound of water reinforced the thermal experience as a collective public activity.

In the Ottoman period, thermal structures—through hamam and spa typologies—developed a more controlled, inward-oriented, and privacy-focused spatial approach. Influenced by Islamic cultural principles, the use of spaces by women and men was regulated through strict spatial separation; double-bath layouts, separate entrances, and distinct circulation schemes became the primary architectural tools of this approach. The deliberate limitation of light levels, natural light filtered through dome openings, dimly lit interiors, and the rhythmic sound of water transformed thermal spaces into sensory environments that supported mental calmness and introspection beyond bodily purification.

When these periods are evaluated together, it becomes evident that the architectural instruments guiding bodily and mental experience through space diversified historically. While integration with nature and ritual practices predominated in the Ancient period, publicness and social interaction became dominant in the Roman period, and privacy and inward orientation emerged as defining principles in the Ottoman period. Spatial solutions related to the use of spaces by women and men stand out as architectural indicators that directly reflect the bodily perceptions and social norms of each era.

In conclusion, historic thermal structures should not be understood solely as buildings serving health and hygiene functions; rather, they are meaning-laden spaces that render visible the relationship between body, mind, and culture through architectural space, sound, light, and privacy. In contemporary processes of conservation, restoration, and adaptive reuse, acknowledging these multilayered sensory and cultural qualities of thermal architecture should be regarded as a fundamental requirement for the sustainability of cultural heritage.

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