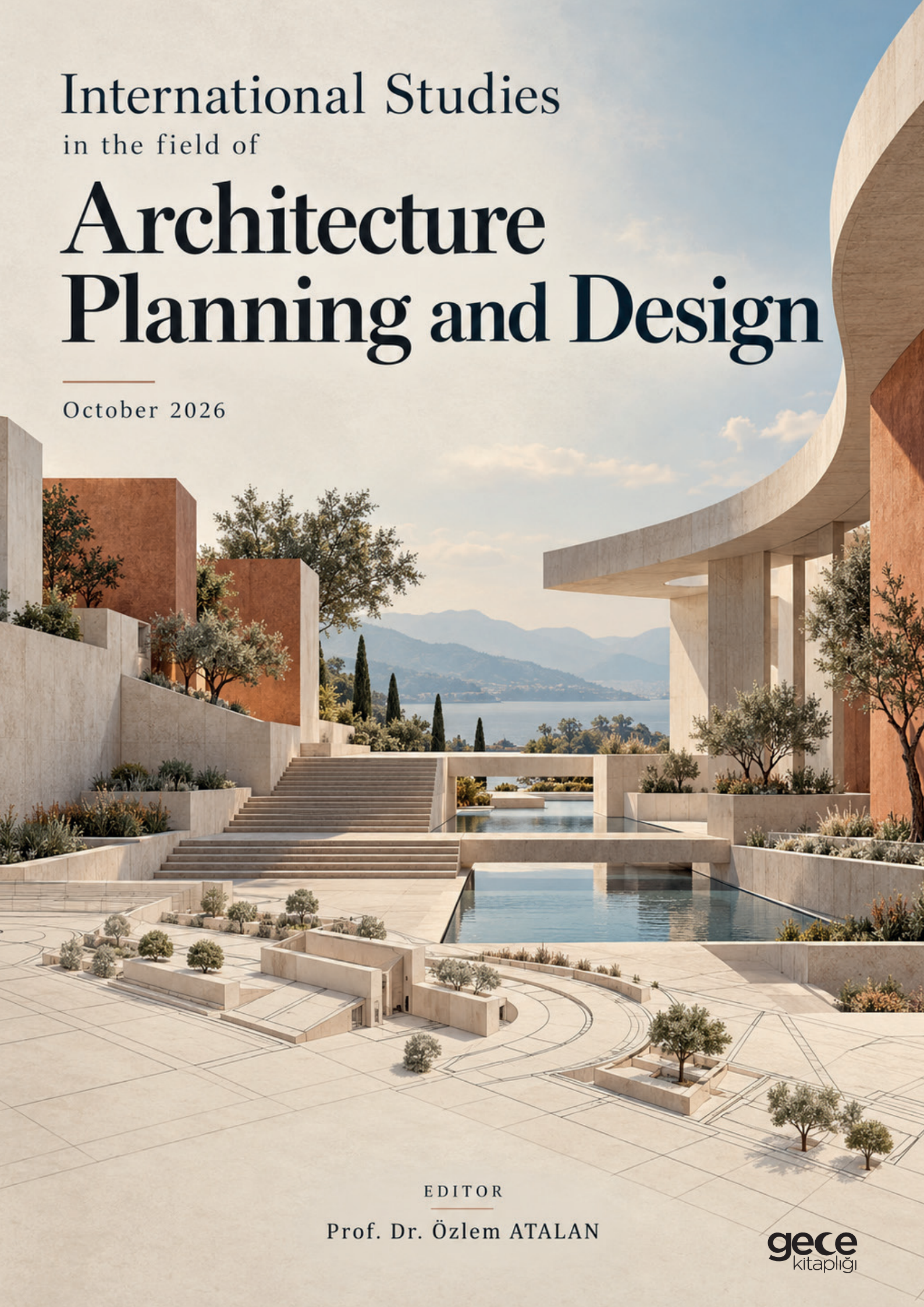


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CHAPTER 1

BIOCIDE TECHNOLOGIES FOR PROTECTING HISTORICAL BUILDINGS AGAINST BIOLOGICAL DETERIORATION

Ahmet Cihat ARI¹

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1. Introduction

Historical buildings play a significant role in preserving and transmitting the architectural designs, construction techniques, and cultural heritage of past eras to the present day. Preserving these buildings contributes to the transfer of technical knowledge regarding the design and construction of traditional buildings to future generations. However, historical buildings undergo physical, chemical, and biological deterioration due to environmental and atmospheric effects (Yan & Wang, 2024). In recent years, factors such as changes in climatic events, rising air pollution, increasing temperatures, and fluctuations in humidity have accelerated biological deterioration processes in historical buildings (Sesana et al., 2021). Consequently, research aimed at developing protection strategies against biological deterioration in historical buildings has gained importance (Figure 1) (Romani et al., 2022).



Figure 1. Development of protection strategies against biological deterioration in historical buildings (Romani et al., 2022)

Biological deterioration is defined as the deformation of the structural properties of building materials resulting from the growth and metabolic activities of harmful organisms on those materials (Cozzolino et al., 2022). The main groups of organisms that damage building materials include bacteria, fungi, algae, cyanobacteria, lichens, mosses, and vascular plants (Cozzolino et al., 2022). These organisms create favorable living conditions on building materials, leading to the proliferation of biotic elements on the surface (Branysova et al., 2022; Cozzolino et al., 2022).

The effects of biological deterioration observed in the materials of historical buildings arise depending on the material's mineralogical composition, porosity, surface roughness, moisture retention capacity, and environmental factors (Pinna, 2021). It accelerates biological

deterioration processes, particularly in stone and mortar materials with high porosity, as these provide a favorable environment for the growth of microorganisms (Liu et al., 2020). Biofilm layers containing extracellular polymeric substances (EPS) form as a result of the growth of microorganisms on building materials (Pinna, 2021). Thanks to these biofilms, microorganisms adapt to environmental conditions and ensure the continuity of colonization. Furthermore, biofilms accelerate the physical and chemical degradation processes of the material (Pinna, 2021).

Biochemical reactions resulting from the effects of microorganisms cause changes in the properties of construction materials (Stanaszek-Tomal, 2020). For example, organic acids produced by certain bacteria, algae, and fungi can affect the mineral structure of building materials (Khan et al., 2023). Moreover, during their growth, cyanobacteria and fungi can penetrate the stone's pore system and alter the pore morphology. This situation causes the formation of new voids in the stone (Gaylarde & Baptista-Neto, 2021). Pigments released as a result of the metabolic activities of lichen and algae colonization cause an accumulation of organic residues on the surface, thereby damaging the aesthetic qualities of historical buildings (Dakal & Cameotra, 2012).

Mechanical cleaning methods and chemical biocides are used in restoration practices to address biological deterioration in building materials (Kakakhel et al., 2019). Quaternary ammonium compounds, isothiazoline derivatives, and other organic biocides limit microorganism growth (Romani et al., 2022). However, certain disadvantages arise from the long-term use of these biocidal materials. These disadvantageous characteristics lead to environmental pollution, harm to non-target organisms, discoloration of building materials, and re-colonization following application (Cappitelli et al., 2020; Cappitelli & Villa, 2021). Additionally, the development of resistance to biocides by certain microorganisms compromises the long-term effectiveness of restoration efforts aimed at addressing biological deterioration in historical buildings (Cirone et al., 2023). Consequently, efforts regarding the restoration of historical buildings affected by biological deterioration have focused on achieving longer-lasting preservation and developing less toxic biocide technologies (Figure 2) (Bartoli et al., 2024; Campostrini et al., 2025; Zuena et al., 2021).

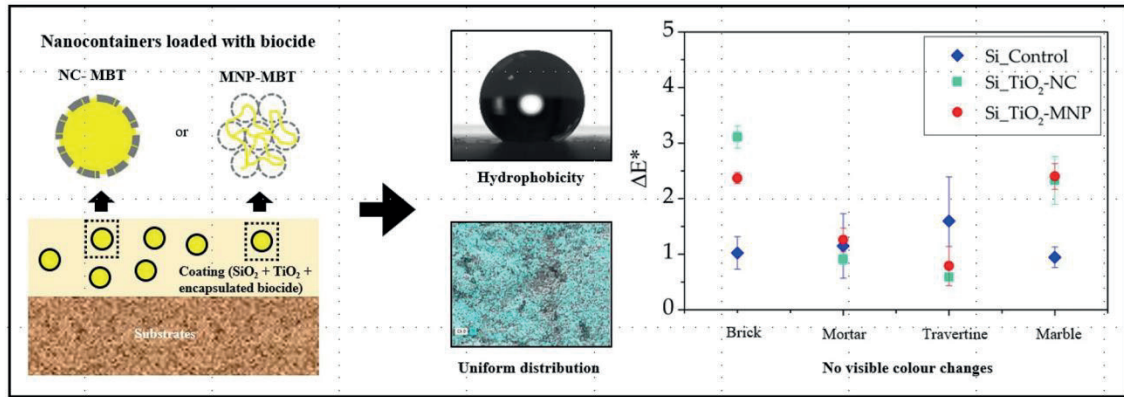


Figure 2. Coatings developed for the protection of historical buildings against biological deterioration (Zuena et al., 2021)

One of the significant approaches in biocide applications is the nanotechnology method. With this method, new protective materials are being developed against the biological deterioration of construction materials. For example, nanomaterials based on silver (Ag), copper (Cu), zinc oxide (ZnO), and titanium dioxide (TiO₂) is used in the development of biocidal materials (David et al., 2020). Furthermore, biocides of natural origin, such as essential oils, are considered to have lower harmful effects on the environment (Palla et al., 2020).

In the biocide treatment of historical buildings today, the aim is both to inhibit the growth of microorganisms and to develop biocides that are compatible with the building materials, reversible, and of low toxicity, while ensuring long-term protection (Soffritti et al., 2019). To this end, the studies address not only the extent to which biocides applied to construction materials limit microorganism growth but also the impact of these biocides on mechanical properties, surface appearance, water resistance, color change, and abrasion behavior (Cao et al., 2026; Frigione & Lettieri, 2018).

Determining the structural and behavioral characteristics of biocides is important for ensuring the preservation of the original material's properties during restoration applications. Furthermore, advancements in molecular biology and microbial analysis techniques have enabled the detailed examination of microorganisms growing on construction materials. Next-generation sequencing (NGS), metagenomics analyses, and advanced microscopy techniques are among the analytical methods used to study biological degradation processes more comprehensively (Marvasi et al., 2019). These microbial analysis techniques contribute to the long-term preservation of the material's inherent properties, in addition to preventing the persistence of microorganism colonization on building materials (Ding et al., 2020).

In this study, biocide technologies for the protection of historical buildings against biological deterioration are examined. The study addresses biocidal materials, their performance, applications, and technological developments. Additionally, biocidal applications developed using modern technological systems have been evaluated against traditional biocidal applications considering their sustainability, efficacy, advantages, limitations, and compatibility with historic building materials within the scope of relevant studies in the literature.

2. Evaluation of Biocide Containing Construction Materials and Their Protective Properties

Construction materials containing biocides are being developed to protect historical buildings against biological deterioration. In this context, it is observed that studies regarding biocide-containing construction materials have been conducted in the literature. For example, in a study conducted by Becerra et al. (2019), the effectiveness of nanoparticle-based biocides in protecting historical limestone structures against biological deterioration was investigated. In the same study, it was determined that Ag and Ag/TiO₂ based nano-biocide coatings significantly inhibited the formation of biofouling (Figure 3).

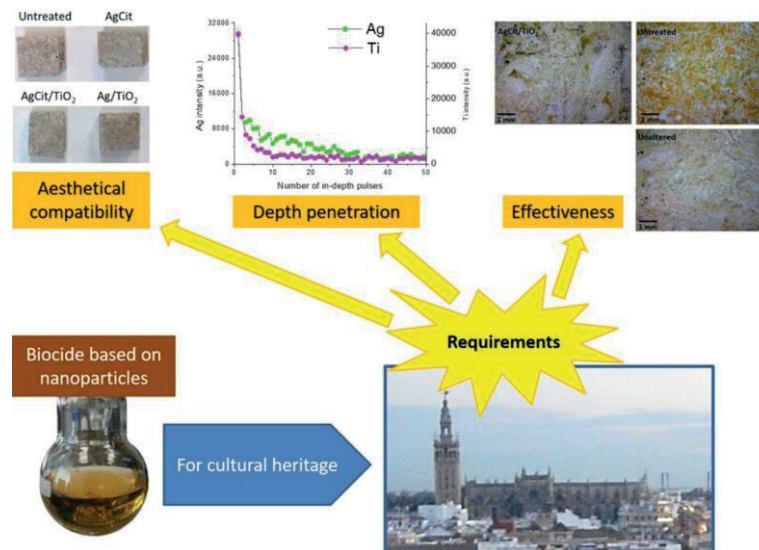


Figure 3. Development of nanoparticle-based biocide coatings for the protection of historical limestone buildings against biological deterioration (Becerra et al., 2019)

Biocide-based mortars are used to prevent the biological deterioration of lime-based mortars in historical buildings. Pastor et al. (2020) examined the protection performance of carbendazim (CBZ)-clay complexes against biological degradation of lime-based mortars. In

the same study, it was demonstrated that the biocide carbendazim is effective in reducing biological contamination and holds great potential for use in restoration mortars (Figure 4).

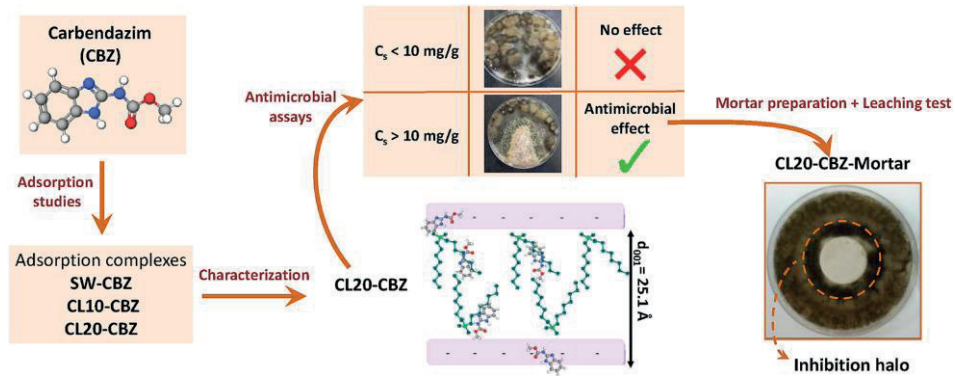


Figure 4. Development of the biocide carbendazim for the protection of lime-based mortars in historical buildings against biological deterioration (Pastor et al., 2020)

Nanoparticle-based coatings contribute to reducing the biological deterioration of historical buildings. In the study conducted by Gemelli et al. (2022), the biological degradation performance of a $\text{TiO}_2/\text{SiO}_2$ -based photocatalytic antifouling coating applied to historical mortar surfaces at the Roman Theatre of Cádiz was investigated. In the same study, it was determined that nanoparticle application resulted in a 40% reduction in organic deposits and a 61% inhibition of biological growth compared to the untreated area (Figure 5).

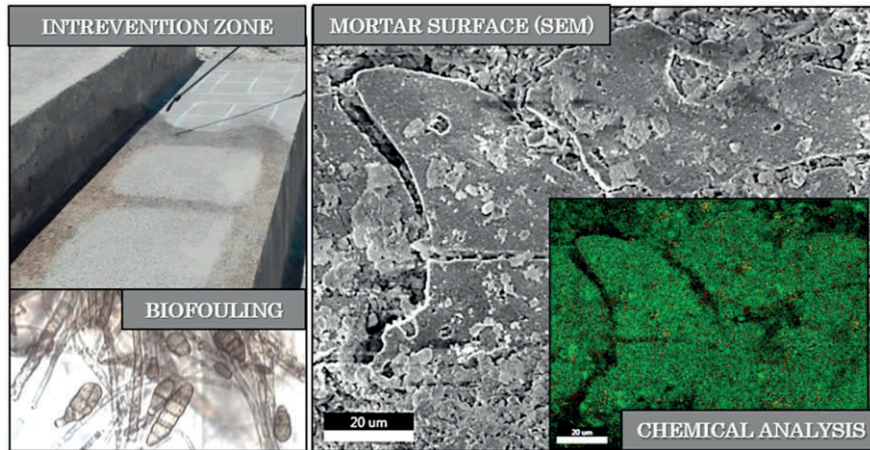


Figure 5. Biological degradation performance of a $\text{TiO}_2/\text{SiO}_2$ -based photocatalytic antifouling coating applied to historical mortar surfaces at the Roman Theatre of Cádiz (Gemelli et al., 2022)

3. Biocide Application Techniques for Building Materials

The application of biocide technologies to building materials inhibits the growth of microorganisms on the surface. Additionally, biocides are applied to prevent biofilm formation and extend the service life of materials (Cirone et al., 2023). The biocide application method is determined based on the porosity and surface roughness of the building material, as well as environmental conditions and physical and chemical factors (Stanaszek-Tomal, 2020). In studies found in the literature, the effectiveness of biocides applied to building materials varies depending on the application method, the dosage of the biocide, and its interaction with the material (Casanova Municchia et al., 2023; Cirone et al., 2023; Fidanza & Caneva, 2019). Furthermore, various application techniques are being developed to prevent biocides from being washed off exterior surfaces by precipitation (Bosch-Roig et al., 2015). Biocides are applied to construction materials using various techniques such as spraying, brushing, and poultice (Casanova Municchia et al., 2023; Fidanza & Caneva, 2019). The most common of these application techniques is the spraying technique. In the spraying technique, a biocide solution is applied homogeneously onto the building materials to inhibit microbial growth (Figure 6) (Zucchelli et al., 2021). With this technique, biocides can be easily applied to facade claddings (Goffredo & Munafò, 2015). However, due to precipitation and the building's facade orientation, a significant portion of the biocides can be washed away from the facade surfaces (Vega-Garcia et al., 2020). Therefore, in spraying techniques, silane/siloxane-based water-repellent chemicals are added during application to enhance the protective effect of the biocide (Eyssautier-Chuine et al., 2018).

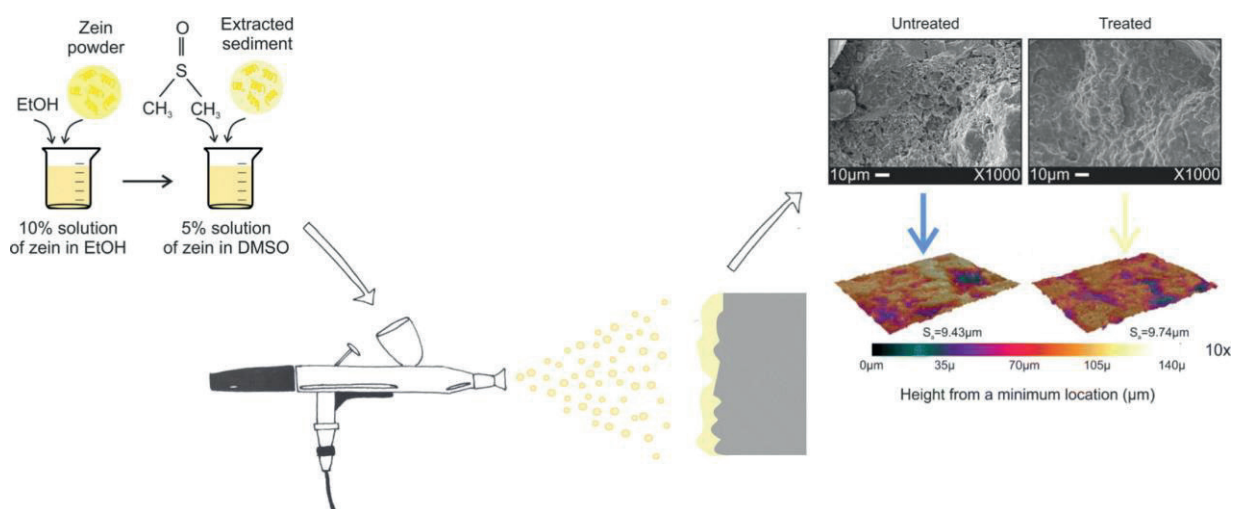


Figure 6. Application of a biocide solution via a spraying technique to inhibit microbial growth on the stones (Zucchelli et al., 2021)

The brushing technique used in biocide applications is preferred for protecting historical stone buildings against biological deterioration (Figure 7) (Caruso et al., 2021; Occhipinti et al., 2024). By applying this technique to the areas of buildings affected by biological deterioration, it can contribute to a significant reduction in the amount of chemicals used (Sanmartín et al., 2020). Moreover, this technique can be considered an application that contributes to enhancing contact with the surface by the biocide (Ilies et al., 2023). However, due to its superficial effects, this technique is insufficient for providing long-term protection (Pinna, 2024). Therefore, this technique is used in conjunction with biopolymers to make it more efficient in terms of application (Caruso et al., 2023).

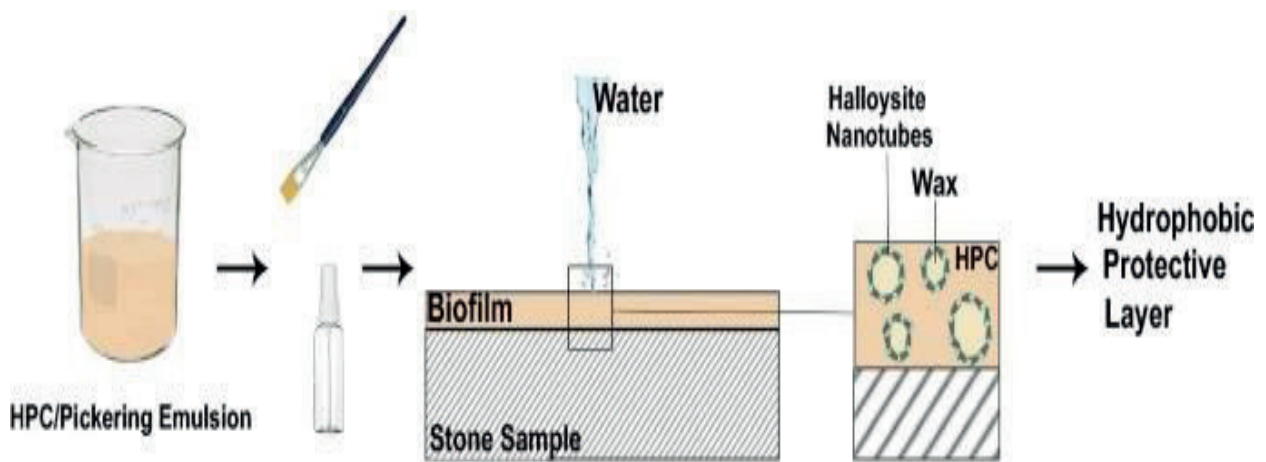


Figure 7. Schematic diagram of the brushing technique used in biocidal treatments of historical buildings (Caruso et al., 2021)

The poultice technique is employed for the application of biocides in a more controlled manner compared to other methods when addressing the biological deterioration of historical buildings. In this technique, a biocide solution is applied to building materials by impregnating clay-based materials (Gallo et al., 2020). In the study conducted by Gallo et al. (2020), it was determined that clay and silica-based poultice materials allow for the controlled transfer of components designed to inhibit microorganism growth onto stone surfaces.

4. Sustainable and Contemporary Approaches to Biocide Technologies in the Conservation of Historical Buildings

Traditional biocides used in the biological preservation of historical buildings have a negative impact on sustainable practices due to factors such as the environmental harm caused by chemical substances, a lack of specific selectivity against microorganisms, and a decline in long-term effectiveness (Russo & Palla, 2023). In this context, initiatives aimed at the

sustainable application of biocides in the construction sector have been launched. The European Union's Biocidal Products Regulation, which concerns the reduction of environmental risks associated with biocides, has been addressed (Coors et al., 2018). Additionally, regarding the use of biocides in structures, emphasis has been placed on research aimed at developing biocides that have lower toxicity and do not harm the environment (Ilies et al., 2023; Mateus et al., 2024; Russo & Palla, 2023).

Nano technological methods make significant contributions to the development of sustainable biocides. For example, silver (Ag), zinc oxide (ZnO), copper oxide (CuO), and titanium dioxide (TiO₂) nanoparticles are considered potential materials for addressing the biological deterioration of cultural heritage, thanks to their antimicrobial properties (Reyes-Estebanez et al., 2018). Furthermore, by limiting the growth of microorganisms, these nanoparticles offer potential for protecting construction materials against biological damage for a longer period (Becerra, et al., 2021). Due to their small particle size, nanoparticles possess a high specific surface area (Altammar, 2023). Therefore, the superior performance characteristics of nanomaterials can contribute to the preservation and restoration of cultural heritage (David et al., 2020).

Bio-based antimicrobial compounds representing one of the sustainable approaches in biocidal technology are used in the preservation of historical buildings (Macchia et al., 2025). Naturally derived compounds such as essential oils, plant extracts, and polyphenolic flavonoids are utilized in bio-based preservative applications (Cao et al., 2026). Additionally, it has been reported in the literature that essential oils derived from plants such as *Thymus vulgaris*, *Syzygium aromaticum*, *Melaleuca alternifolia*, and *Cinnamomum verum* exhibit antimicrobial activity against various microorganisms (Russo & Palla, 2023). In the preservation of historical buildings and the evaluation of sustainable approaches to biocide technologies, the potential for environmental harm alongside resistance to biological deterioration is determined through Life Cycle Assessment (Berti et al., 2024).

Nowadays, thanks to developments in the field of technology, the scope of biocidal applications is expanding. For instance, advanced smart materials contribute to the early detection of biological degradation processes in the preservation of historical buildings. (Wang & Wen, 2026). Moreover, the development of smart materials offers the potential to reduce the need for multiple interventions and enhance protection effectiveness (Wang & Wen, 2026).

5. Conclusion and Recommendations

This study focuses on advancements in biocide technologies for the protection of historical buildings against biological deterioration. According to the literature review conducted as part of the study, biological deterioration in building materials damages the aesthetic qualities, structural integrity, and long-term preservation of historical buildings. Biocides are applied to historical buildings to resolve these problems. However, more sustainable biocide technologies have been developed due to factors such as the high environmental toxicity of traditional biocides, the washing away of a significant portion of the biocide from building material surfaces by precipitation, harm to non-target organisms, and the development of resistance to biocidal substances by microorganisms. In sustainable biocide technologies, the application method, resistance to environmental conditions, and toxicity level are just as important as the effectiveness of building materials against biological degradation. In this context, biocides incorporating nanomaterials are being developed to reduce environmental pollution and enhance protection against biological degradation. Biocides developed using nanomaterials (photocatalytic TiO₂ coatings, metal oxide nanoparticles, and superhydrophobic surface technologies) reduce the use of chemicals and offer the advantage of long-lasting protection.

Naturally derived biocides contribute to the development of sustainable approaches regarding the biological deterioration of historical buildings. These biocide applications reduce microorganism growth. However, these biocides enhance protective effectiveness by imparting new functions such as self-cleaning, water repellency, and dirt resistance. While studies in the literature show that biocide technologies yield successful results under laboratory conditions, there is limited data regarding their performance under field conditions and long-term application. In this context, it is considered beneficial to conduct field studies regarding the long-term resistance of biocide technologies to environmental conditions during their development. Additionally, there is a need to increase interdisciplinary research aimed at the development of biocide technologies.

The following recommendations are presented for research aimed at developing biocide technologies for the protection of historical buildings against biological deterioration:

- Developing biocides using biodegradable and renewable resources to ensure they do not harm the environment.

- Development of construction materials that meet multiple criteria such as photocatalytic, superhydrophobic, and antimicrobial properties to expand the scope of biocide application.
- Development of digital technological systems to monitor biological deterioration in building materials and optimize biocide applications.
- Evaluation of biocide applications on historical structures through life cycle analysis within the framework of holistic and sustainable conservation approaches.
- Development of biocide applications that do not damage the materials of historical buildings and preserve their original and aesthetic characteristics.
- Analyzing the structural properties of biocides using standard test methods before applying them to building materials.

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CHAPTER 2

STEPPED SETTLEMENT MORPHOLOGY AND COMMUNAL SPACE IN VERNACULAR ARCHITECTURE: A COMPARATIVE SPATIAL ANALYSIS OF TRADITIONAL MARDIN HOUSES AND TAOS PUEBLO

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1. Introduction

Vernacular architecture involves considerations of environment, local materials, cultural practice, and tradition of construction techniques. Oliver (2006) discusses shelter in the context of culture, whereas contemporary literature connects heritage conservation to climatic adaptability, reuse, and sustainability (Pardo, 2023; Zong et al., 2025). Cross-cultural analysis can help identify common features amid site-specific processes.

Both Mardin and Taos Pueblo share such features as stepped building massing, flat roofs, and fabric density. However, while Mardin has slope-related stonework homes, Taos Pueblo has stacked adobe houses (Karagülle & Demir, 2010; National Park Service, 2020; UNESCO World Heritage Centre, n.d.-b). This distinction suggests that a comparative study of ways in which similar architectural silhouettes handle dissimilar access, open spaces, and maintenance needs is required.

This chapter analyzes morphology, function, and heritage continuation on the scale of buildings and settlements through orientation, openings, spatial boundaries, materials, and maintenance. Existing data allow interpreting spatial connections and their possible reasons without assumptions about historic intentions.

2. Theoretical Framework and Comparative Methodology

Processes of environment, culture, and construction influence vernacular architecture. Oliver (2006) emphasizes the needs and practices of the community; Pardo (2023) notes research involving typology, construction, conservation, adaptation to climate, and reuse. Therefore, a comparison between Mardin and Taos Pueblo will require an examination of spatial practices and knowledge of building together with massing.

Zong et al. (2025) construct the study of sustainability using such categories as culture, structure, environment, renovation, use, and assessment. Matar et al. (2023) highlight the influence of local conditions of nature and culture. Thus, local materials and passive features constitute starting points of assessment; any claim of sustainability should include information about use, maintenance, and environment.

The framework includes three interconnected aspects: morphology (massing, stepping, relationships of open spaces), use (accessibility, privacy, daily activities), and continuity

(repair, knowledge transfer, and decision-making). The combined use of these aspects separates similar formal characteristics through specific social and technological conditions of existence of each settlement.

According to Poullos (2014), community relationships constitute the heart of living heritage. The ICOMOS Charter on the Built Vernacular Heritage (1999) focuses on local knowledge and participation. Maintenance combines technical activity with social organization. This approach unites plastering of Taos Pueblo with conservation of masonry in Mardin without loss of individual demands (Figure 1).

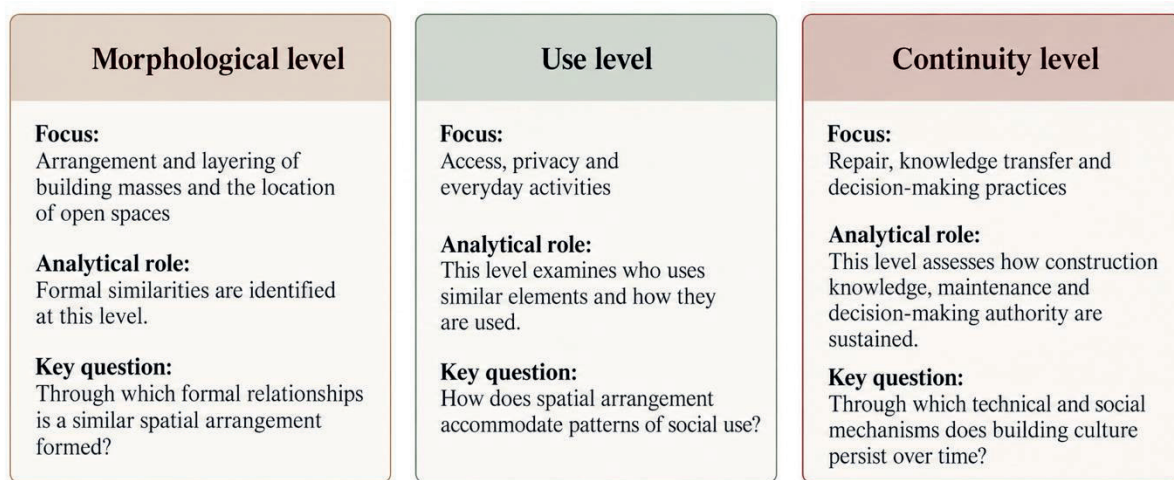


Figure 1. Analytical Framework of the Comparative Analysis: Morphology, Use Patterns, and Continuity

Note. Schematic diagram developed by the authors in line with the theoretical framework of the study.

The comparison in question is a qualitative one using purposely selected published materials. The analysis of documents deals with their provenance, context, and constraints (Bowen, 2009). Sources have been selected based on their pertinence to the topic, information about their publishing and evidential support. The body of sources includes theoretical research, material on Mardin and its simulations, and information about Taos Pueblo.

Case selection pairs similar stepped forms with contrasting topography, materials, and governance. The analytical units are Mardin's building-parcel-street relationships and Taos Pueblo's North and South House clusters and communal spaces. These unequal scales are compared through documented relationships, without assuming a universal settlement type.

Six axes organize the three analytical levels (Table 1). Massing and open space inform morphology; access and activities inform use; materials, maintenance, and governance inform continuity. Evidence is interpreted within its domestic or communal context.

Table 1. Comparative axes and interpretative parameters across the three analytical levels

	Analytical Axis	Relational Scope	Interpretative Boundaries
Morphology	Settlement and Topography	Terrain slope, volumetric massing, stratification/terracing, street and open space interfaces	Formal affinity is not construed as evidence of a shared morphogenetic process.
Morphology	Spatial Determinants of Climatic Adaptation	Solar orientation, fenestration/apertures, self-shading, and open–semi-open–enclosed spatial hierarchies	Spatial attributes alone are not extrapolated into definitive quantitative environmental performance metrics.
Spatial Use	Spatial Thresholds and Circulation	Portals, transitional thresholds, circulation patterns, and historical rooftop access hierarchies	Historical circulation modes are not generalized to reflect contemporary occupancy patterns.
Spatial Use	Open Space and Everyday Occupancy	Courtyards, iwans, terraces, and communal domains in relation to privacy gradients and daily domestic rituals	Domestic versus communal scales and customary use-rights are evaluated distinctly.
Continuity	Materiality, Tectonic Knowledge, and Maintenance	Structural/tectonic systems, surface replastering/refinishing, repair regimes, and intergenerational transmission of tacit knowledge	Material affordances are critically interpreted only in conjunction with operational maintenance regimes.
Continuity	Social Organization and Governance	Communal coordination of maintenance, collective stewardship, occupancy regulations, and intervention protocols	Practices are contextualized strictly within their respective cultural, customary, and institutional frameworks.

3. Traditional Dwellings of Mardin

Mardin's stone dwellings, terraces, and narrow streets form a stepped hillside fabric (UNESCO World Heritage Centre, n.d.-a). Slope, parcels, street access, and southward views shape their relationships. According to Karagülle and Demir (2010), the above conditions should be analyzed within the context of building and settlement scale analysis, especially focusing on the parts where adjacent buildings and open spaces are connected.

Courtyards are used for organizing the open space of homes; iwans are covered transition spaces; terraces and flat roofs are used for outdoor activities (Alioğlu, 2000; Ozorhon & Ozorhon, 2014). The arrangement of these spaces changes depending on the plot size, level, and further addition. Consequently, the house type in Mardin has recurring relational arrangements but not one specific plan. Thresholds between the street and inner rooms determine access and visibility between domestic and visitor space (Karagülle & Demir, 2010; Ozorhon & Ozorhon, 2014). Privacy depends on space arrangement and its usage. The relation between street-threshold-courtyard/iwan-room shows possible connections, but it does not mean that all houses have the same arrangement of those spaces.

Akın's (2020) study of three dwellings documents responses to slope, southern exposure, shading, ventilation, and drainage. Upper openings and inward-splaying window reveals support daylight and airflow. These examples relate opening geometry to massing and interior organization; Figure 2 summarizes their conceptual relationships.

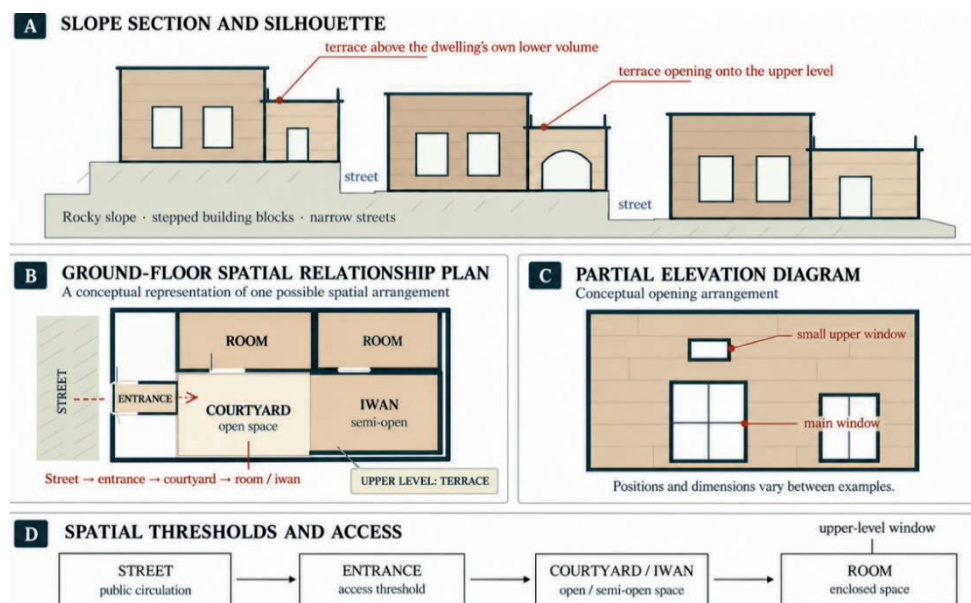


Figure 2. Interrelationships among stratification, spatial syntax, fenestration, and circulation thresholds in traditional Mardin dwellings

Note. A: Stratified building masses along the topographic slope and terrace relationships; B: potential spatial syntax among courtyard, iwan, and living chambers; C: conceptual representation of primary fenestration and upper clerestory aperture; D: circulation and access thresholds among street, portal, open/semi-open domains, and rooms. Panels are not-to-scale conceptual diagrams; they do not represent measured drawings, measured sections, or measured facades of any specific dwelling. The spatial sequence, dimensional attributes of apertures, and terrace configurations may vary across individual cases. Developed and edited

by the authors with the assistance of generative artificial intelligence, based on Akın (2020), Eray (2021), Karagülle and Demir (2010), and Şimşek (2014).

Open, semi-open, and enclosed spaces offer daily and seasonal choices. Eray's (2021) typological analysis addresses these functional relationships. Bekleyen et al. (2015) recorded seasonal temperature differences in one dwelling: the lower room was relatively favorable in autumn and winter, while the iwan in June and lower room in July offered summer advantages. These findings remain case-specific.

The effects of courtyard shape and shading on microclimate have been studied by Ucer, et al. (2024). It should be noted that apart from the geometric features of the plan, orientation, height of surrounding, and time periods of use also affect the microclimatic situation. Street shading depends on height, width, orientation, and time. Different evidence is needed for outdoor and indoor environments even though they are physically connected.

Dursun (2024) identifies the geological and physical variations of "Mardin stone." The properties of the stone make its application possible in building construction, openings, and decoration; nevertheless, restoration requires the same materials and methods to be used as were applied during the construction of the building.

Şimşek (2014) relates entrances and courtyards to parcel boundaries and surrounding constructions. For this reason, any modification needs to consider daylight and relation to other buildings in terms of structure. Figure 3 shows the link between materials, settlement form, and environmental evaluation.

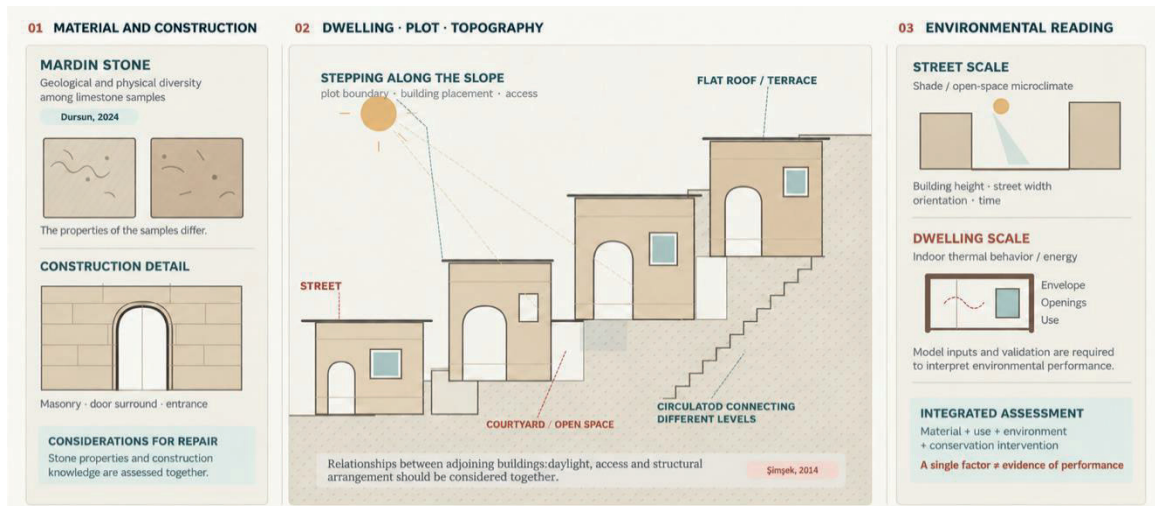


Figure 3. Material properties, building-parcel-topography interfaces, and multiscale environmental evaluation in traditional dwellings of Mardin

Notes. This is an illustration based on the existing literature. The material and settlement relations are read according to Dursun (2024) and Şimşek (2014). The approach to the environmental assessment of the settlement is based on Akın (2020), Sözen and Koçlar Oral (2019), and Matar et al. (2023). Stone samples, geometry of the built-up parts, and solar radiation are illustrative; they do not represent any laboratory test, measurement of the architecture, simulations of solar or shadow studies, and any data about environmental performance. Development and editing by the authors using generative artificial intelligence.

Sözen and Koçlar Oral (2019) have designed a dwelling and its environment to analyze the impacts of the envelope and settlement on the energy consumption. The interpretation depends on material information, occupancy, and underlying model. Costa-Carrapiço et al. (2022) pay attention to monitoring and calibration uncertainties; the conclusions on the environment must be made within the framework of every particular research.

The difference between multipurpose or seasonal use and the adaptability of plans in terms of the structure is that the latter needs documentation about details of the building and interventions performed. It is important to conserve sustainability of the use, masonry technology, and relations with adjacent buildings. Thus, Mardin combines slope-induced morphologies with the domestic threshold and seasonal use; continuity depends on proper maintenance and intervention.

4. Vernacular Architecture of Taos Pueblo

The Taos Pueblo is situated on the River Pueblo de Taos, New Mexico. It includes the two houses of North and South, kivas, religious structures, and a riverfront layout, thus forming a live heritage complex, with the adobe buildings reaching the height of five storeys (UNESCO World Heritage Centre, n.d.-b). The village names for the main complexes are Hlauuma and Hlaukwima (Taos Pueblo, n.d.).

Stacked and adjoining rooms with receding upper levels produce Taos Pueblo's stepped form. Unlike Mardin's hillside parcels, this arrangement depends on clustered rooms and roofs. Open spaces accommodate circulation and community activities. Figure 4 illustrates settlement, massing, and construction relationships.

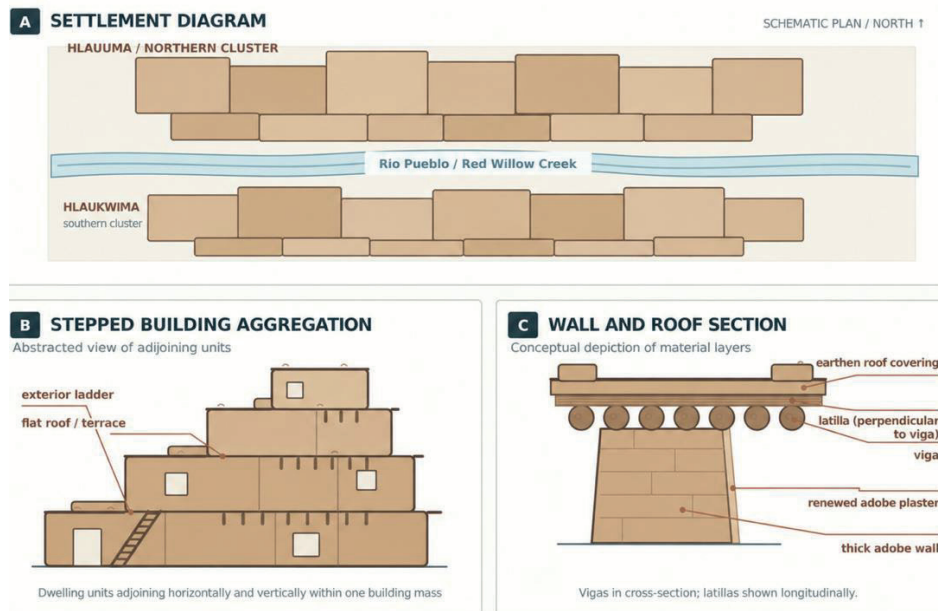


Figure 4. Settlement morphology, stepped structural complexes, and wall-roof assemblies in Taos Pueblo

Note. A: Spatial relationship of the North and South structural complexes with the river; B: horizontal and vertical aggregation of cellular room modules alongside historical exterior ladder access; C: conceptual representation of adobe masonry walls and timber roof assemblies. A not-to-scale schematic diagram prepared in accordance with Taos Pueblo (n.d.), UNESCO World Heritage Centre (n.d.-b), and the National Park Service (2020); it does not represent measured drawings of specific structures, contemporary domestic floor plans, or measured construction details. The ladder in Panel B depicts historical access practices. Developed and edited by the authors with the assistance of generative artificial intelligence.

Family-associated rooms coexist with community stewardship of the wider complex (UNESCO World Heritage Centre, n.d.-b). Open spaces therefore operate at a different social scale from domestic courtyards. Water, sacred surroundings, and tribal authority also inform their interpretation.

Rules of community and calendars regulate access by visitors, which connects spatial use and cultural control (Taos Pueblo, n.d.). This decision-making function is emphasized under the concept of the living heritage (Poulios, 2014). Exterior features cannot determine daily activities in interior areas.

Early access via roof and ladder openings and few exterior openings are mentioned by the National Park Service (2020). Boyer (1985) indicates that access via roofs was common practice in the middle of the nineteenth century but rare at the end of the same period. Few windows and doors were added in the twentieth century (UNESCO World Heritage Centre, n.d.-b).

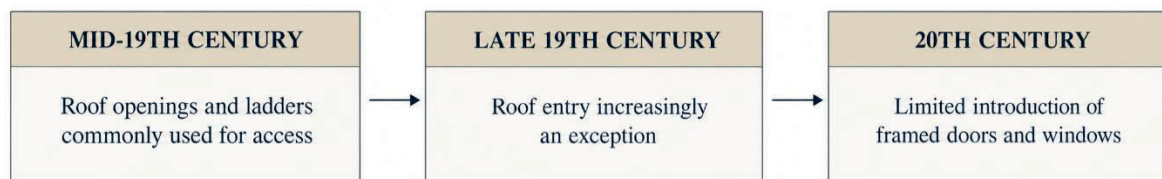


Figure 5. Synthesis of documentary evidence on the historical transformation of entrances and fenestration in Taos Pueblo

Note. The conceptual timeline presents the chronological trends observed in Boyer (1985), the National Park Service (2020), and the UNESCO World Heritage Centre (n.d.-b). This timeline is not a reflection of the evolutionary history of a specific building. It does not mean that the change happened synchronously in all buildings. Created by the authors with the help of generative artificial intelligence.

According to Boyer (1985), the occupation of rooms, their addition, and abandonment affect the building chronology but do not influence current interior organization. Some inhabitants live in houses that are not located in the historic center and are important for the community ceremonies (UNESCO World Heritage Centre, n.d.-b). Living heritage does not presuppose continuous occupation of all the rooms.

The adobe walls serve as the basis for the roofs built of the main wooden logs – vigas, latillas, and earth materials. The sun-dried adobes and mud-straw plaster need replacement (Taos Pueblo, n.d.; National Park Service, 2020). The replastering contributes to the preservation of the building and its authenticity (UNESCO World Heritage Centre, n.d.-b).

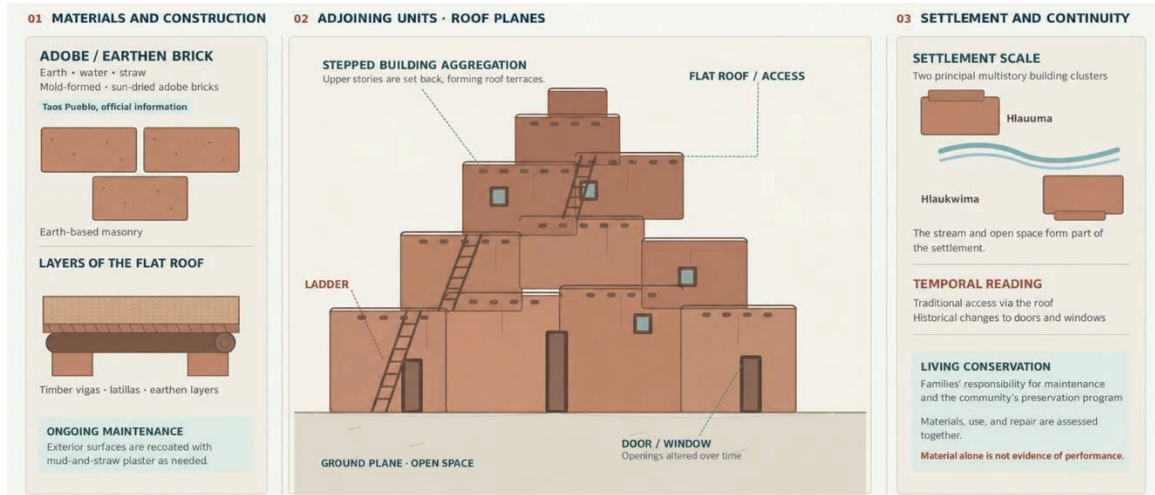


Figure 6. Adobe construction, stratified massing logic, and maintenance regimes in Taos Pueblo

Note. Qualitative, not-to-scale concept drawing based on Taos Pueblo (n.d.), UNESCO World Heritage Centre (n.d.-b), and National Park Service (2020). The four components of material, construction, maintenance, and community relations are represented in a conceptual way. No environmental performance or efficiency of maintenance work is quantified. The concept was created and edited by the authors using the help of artificial intelligence.

Walls, apertures, and roofs are represented in a qualitative manner because the existing information is insufficient for making any thermal comparisons. According to the conservation documentation, traditional material restoration involves apprentice training within the community (World Monuments Fund, n.d.).

The Training Program for Taos Pueblo Preservation (n.d.) explains the process of community member training to be craftspersons and apprentices. These examples connect maintenance work with knowledge transfer and participation, although the descriptions of the programs do not confirm the results of the conservation efforts independently. In this regard, Taos Pueblo is an example of clustered morphology with varying access and community governance. Replastering and craft transmission provide the principal evidence for continuity.

5. Comparative Analysis and Synthesis

The comparison examines stepped forms through morphology, use, and continuity. Mardin's building-parcel-street relationships and Taos Pueblo's room clusters retain their different scales and contexts. Figure 7 summarizes their contrasting configurations.

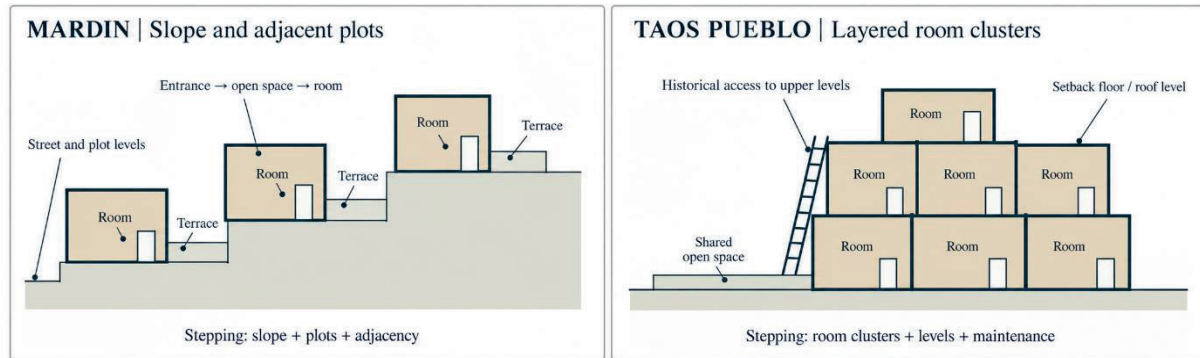


Figure 7. Divergent spatial configurations of stratification in Mardin and Taos Pueblo

Note. A not-to-scale conceptual diagram; it does not represent measured architectural sections or measured drawings. The timber ladder in Taos Pueblo denotes historical circulation practices. Prepared by the authors with the assistance of generative artificial intelligence.

Table 2 compares architectural, use, and governance relationships; Table 3 identifies source types and interpretative limits. Together they connect the qualitative synthesis to its documentary evidence.

Table 2. Comparative matrix of traditional Mardin dwellings and Taos Pueblo

Analytical Dimension & Axis of Inquiry	Mardin: Dwelling and Immediate Context	Taos Pueblo: Building Complex and Settlement	Analytical Synthesis & Evaluation
Morphology — Terrain & Stratification	Stratified stone masonry fabric terraced along sloping topography governed by parcel and street networks.	Adobe cellular room clusters aggregated contiguously and vertically along both banks of the river.	Stepped massing is visually shared; however, topographical integration and the aggregation logic of structural units diverge fundamentally.
Morphology — Orientation & Built Context	Documentation of slope adaptation, southern solar exposure, daylight ingress, and ventilation regimes in selected dwellings.	Archival sources delineate settlement morphology; equivalent microclimatic orientation analyses are absent.	Spatial-environmental relationships must be interpreted strictly within the evidential boundaries of the extant documentation.
Morphology — Environmental Performance	Empirical temperature monitoring, passive design evaluations, and numerical energy simulations available for specific dwellings.	Descriptive archival and technical accounts of the adobe envelope, fenestration patterns, and timber roof strata.	Spatial and material parameters can be critically evaluated; establishing a direct quantitative performance hierarchy remains methodologically invalid.
Use — Thresholds & Fenestration	Articulation of street, portal, courtyard, iwan, and chamber thresholds; upper clerestory windows documented in selected cases.	Historical rooftop ingress shifting toward modified exterior door and window configurations across subsequent eras.	Circulation thresholds and fenestration must be evaluated in direct relation to their specific occupancy contexts and historical horizons.
Use — Open & Semi-Open Realms	Differentiated occupancy gradients among domestic courtyards, iwans, roof terraces, and public street networks.	Communal plazas fronting the structural complexes and historically appropriated multi-tier roof terraces.	Domestic versus communal scalar orders; functional appropriation diverges regarding customary access rights and everyday rituals.
Use — Adaptability & Spatial Flexibility	Seasonal occupancy dynamics and diurnal migration across open, semi-open, and enclosed spatial domains.	Historical accretion, contiguous annexation, and abandonment of individual cellular room modules.	Multi-purpose spatial flexibility must be conceptually differentiated from physical structural transformability.
Continuity — Materiality & Maintenance	Petrographic properties of regional limestone, specialized stone masonry craftsmanship, and compatible	Cyclical maintenance of load-bearing adobe walls, earthen renders, and timber assemblies; periodic	Material continuity must be evaluated alongside the empirical maintenance paradigms intrinsic to

Analytical Dimension & Axis of Inquiry	Mardin: Dwelling and Immediate Context	Taos Pueblo: Building Complex and Settlement	Analytical Synthesis & Evaluation
Continuity — Governance & Knowledge Transmission	conservation imperatives. Imperative for conservation interventions that safeguard building–immediate context interfaces; transmission of lithic tectonic knowledge.	sacrificial replastering. Communal tribal governance, customary familial maintenance duties, and structured apprenticeship training programs.	each distinct tectonic system. The fundamental conservation unit, institutional stewardship, and decision-making frameworks diverge according to socio-political context.

Note. Developed by the authors based on Karagülle and Demir (2010), Şimşek (2014), Ozorhon and Ozorhon (2014), Bekleyen et al. (2015), Sözen and Koçlar Oral (2019), Akın (2020), Eray (2021), Dursun (2024), Boyer (1985), National Park Service (2020), Taos Pueblo (n.d.), Taos Pueblo Preservation Program (n.d.), and the UNESCO World Heritage Centre (n.d.-a, n.d.-b).

Table 3. Sources and evidential scopes of primary comparative propositions

Proposition & Scale	Mardin: Sources & Evidence	Taos Pueblo: Sources & Evidence	Evidential Scope of Inferences
Stratification — Building and Settlement	Karagülle and Demir (2010); empirical field surveys and dwelling-to-settlement spatial syntax. Şimşek (2014); cadastral parcel constraints and party wall dependencies.	UNESCO World Heritage Centre (n.d.-b); morphological documentation of multi-story structural complexes.	Comparable volumetric massing can be established; formulating a unified causal paradigm for their historical genesis remains methodologically invalid.
Access & Fenestration — Building and Structural Complex	Akın (2020); microclimatic orientation and aperture characteristics across three dwellings. Eray (2021); functional spatial orchestration of domestic units.	Boyer (1985) and UNESCO World Heritage Centre (n.d.-b); historical trajectories of access thresholds and fenestration evolution.	Tectonic and architectural thresholds can be comparatively evaluated; comprehensive inferences regarding contemporary interior circulation networks in Taos Pueblo cannot be derived.
Open Realm Appropriation — Domestic and Communal	Ozorhon and Ozorhon (2014), Eray (2021); functional hierarchies of	Taos Pueblo (n.d.) and UNESCO World Heritage Centre (n.d.-b); communal spatial	Spatial scales of occupancy and access protocols can be contrasted; functional or

Proposition & Scale	Mardin: Sources & Evidence	Taos Pueblo: Sources & Evidence	Evidential Scope of Inferences
	domestic open and semi-open spaces.	governance, public rituals, and tribal administration.	operational equivalency must not be presupposed.
Environmental Performance — Building	Bekleyen et al. (2015); empirical in-situ temperature monitoring within a single dwelling. Sözen and Koçlar Oral (2019); calibrated numerical energy simulations of a selected case.	National Park Service (2020) and Taos Pueblo (n.d.); qualitative architectural descriptions of materiality and tectonic assemblies.	Due to the absence of commensurate microclimatic monitoring or calibrated simulation datasets, comparative thermal comfort or energy efficiency rankings cannot be validated.
Maintenance & Continuity — Edifice and Community	Dursun (2024); petrographic and physical properties of limestone. Şimşek (2014); structural interdependencies and physical transformations.	Taos Pueblo Preservation Program (n.d.) and World Monuments Fund (n.d.); institutional program descriptions of cyclic maintenance and apprenticeship initiatives.	Material degradation dynamics and organizational maintenance models can be interpreted; long-term longitudinal efficacies of conservation programs warrant separate empirical investigation.

Note. The table does not encompass the entirety of the examined literature, but delineates the evidential grounding of the primary comparative propositions. Documented attributes reported in the sources and the comparative interpretations advanced in this section are appraised as distinct analytical categories.

5.1. Morphological Configuration and Mass Stratification

Mardin's stepping links slope, parcels, streets, and neighboring structures (Karagülle & Demir, 2010; Şimşek, 2014). Taos Pueblo's stepping combines adjoining rooms, vertical stacking, and upper-level setbacks (Boyer, 1985; UNESCO World Heritage Centre, n.d.-b). Similar silhouettes therefore correspond to different spatial organizations (Figure 7).

The data from Mardin consists of seasonal readings from one house, strategies used from three houses, and an energy modeling example (Bekleyen et al., 2015; Akın, 2020; Sözen & Koçlar Oral, 2019). The Taos Pueblo documentation consists mostly of descriptions of materials and construction. This varied data is good for qualitative analysis but cannot provide any rankings of thermal comfort or energy efficiency. Therefore, stepping needs to be assessed in light of the topography, units, and climate. Simply having it does not mean that it is climatically adapted.

5.2. Spatial Use and Access Thresholds

The courtyards, iwans, and terraces in Mardin allow for everyday life activities, while entrances establish the link between the private building and urban movement (Ozorhon & Ozorhon, 2014; Eray, 2021). The open spaces in Taos Pueblo foster settlement and social interaction. Thus, comparative study requires studying user groups, access, and maintenance.

Akin (2020) relates the openings in Mardin to daylighting and ventilation. The history of changing roof access and openings in Taos Pueblo is demonstrated (Boyer, 1985; UNESCO World Heritage Centre, n.d.-b). The comparison deals with threshold function in particular context, not openings listing.

Seasonal usage of space in Mardin and room construction and abandonment at Taos Pueblo represent different ways of change. The two sites do not demonstrate similar levels of flexibility in physical-planning terms. Therefore, design analysis needs to separate flexibility of shared space use and seasonal adaptation from structural adaptability.

5.3. Materiality, Maintenance, and Continuity

Since the stone in Mardin varies, the repairs should be in accordance with the nature of the material (Dursun, 2024); in contrast, earthen materials at Taos Pueblo require continual renewal (Taos Pueblo, n.d.; UNESCO World Heritage Centre, n.d.-b). In both cases, the continuity of the materials is based on maintenance practices and the transmission of knowledge.

The interventions in Mardin depend on the neighboring fabric (Şimşek, 2014); however, at Taos Pueblo, the conservation depends on the community programs that organize maintenance and training (Taos Pueblo Preservation Program, n.d.; World Monuments Fund, n.d.). The practice of conservation should define the unit of intervention and the institution with decision-making powers.

The cultural approach of Oliver (2006) and the living heritage approach of Poullos (2014) connect form and social processes. However, the agglomeration of space or maintenance practices without historic and ethnographic information is not enough to define household and kinship structures. Therefore, the three levels of analysis relate to material choice, maintenance ability, governing of common space, and factors causing changes.

6. Discussion: Principles Transferable to Design and Conservation Decision-Making

Such a comparison makes morphology, usage, and continuity into questions about mass relationships, spatial use patterns, and maintenance sustainability. Such a conceptual framework is compatible with the approach by Matar et al. (2023); its environmental connotations require independent empirical confirmation.

First, consider stepped housing in relation to the neighborhood section. Mardin uses slope, parcelization, street elevations, and adjacent buildings (Karagülle & Demir, 2010; Şimşek, 2014). New designs and interventions need to jointly address neighboring daylighting and views, circulation, terrace use, and structural interdependences.

Second, plan open spaces together with access and governance. Domestic spaces in Mardin and communal spaces at Taos Pueblo imply different responsibilities (Eray, 2021; Taos Pueblo, n.d.; UNESCO World Heritage Centre, n.d.-b). User types, distinctions between private and communal spaces, maintenance responsibilities, and possible future reuses need to be identified in the process of programming.

Third, examine thresholds in the context of access, light, ventilation, and privacy. Spatial sequences and upper openings make for differentiating interfaces in Mardin (Akın, 2020; Eray, 2021), whereas Taos Pueblo provides the history of their transformations (Boyer, 1985; UNESCO World Heritage Centre, n.d.-b). Differentiate between seasonal flexibility and structural adaptability.

Fourth, specify maintenance with respect to materials. Taos Pueblo associates repairs with apprenticeship (Taos Pueblo Preservation Program, n.d.; World Monuments Fund, n.d.) whereas Mardin implies the need for compatibility with variable limestone (Dursun, 2024). Specifications will need to identify the materials used for repairs, needed skills, responsibilities, and knowledge transfer mechanisms.

Maintenance, in turn, will require governance: family and community maintenance responsibilities are implied at Taos Pueblo (UNESCO World Heritage Centre, n.d.-b), while Mardin requires coordination among adjacent properties (Şimşek, 2014). Any living heritage practice needs to define who is allowed to carry out any interventions, maintain any structures, and transmit knowledge.

Passive strategies require local validation. According to Yang et al. (2022), building performance depends on user adaptation; according to Costa-Carrapiço et al. (2022), uncertainties exist in monitoring and modeling. Shading, daylighting, ventilation, temperatures, and occupancy need to be examined in concert rather than assume that vernacular architecture ensures good performance.

Different documentation and scale limit any generalizations. Further research should combine comparable surveys, environmental monitoring, and user testimony. Research in Taos Pueblo will have to comply with community-defined access, documentation, and knowledge-sharing policies..

7. Conclusions

The other forms found in Mardin and Taos Pueblo have different spatial characteristics: parcels on a slope with adjacent buildings in Mardin and stacked rooms in Taos Pueblo. There are differences between the access methods for residential and public spaces, as well as conservation of masonry and recurring maintenance of adobe, which require different systems of interventions and management.

The morphology-use-continuity approach connects morphology with access rights, maintenance, and management. It leads designers to focus on neighborhood sectors and spatial boundaries and conservationists to look for appropriate interventions and craft continuity. The lessons learned from the documentation can be used to develop context-based criteria for evaluation, which need to be adapted depending on project-specific conditions.

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CHAPTER 3

THE EFFECT OF LIGHTING DESIGN ON SURFACE COLOR PERCEPTION: AN EVALUATION IN TERMS OF ICATUS 2016 ACTIVITIES

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1. INTRODUCTION

Space can be defined as a living environment designed to accommodate various activities and actions in accordance with specific requirements. In addition to facilitating daily activities and actions, the perceptibility of the space itself plays a critical role. This is achieved through the appropriate and effective use of light. Moreover, the success of lighting depends not only on the light source or lighting fixture but also directly on the characteristics of the illuminated objects and surfaces (Akten and Akoğlu, 2017). This is because illuminated surfaces contribute to the formation of the perceptual field of the surrounding environment.

Perceiving the surfaces that define an interior space, meet users' physical and psychological needs, and influence them in their original colors (without color distortion) requires more than lighting that merely makes them visible. Such lighting is insufficient for perceiving the form, texture, and color of surfaces as they actually appear. Failure to illuminate surfaces according to their functions and characteristics may compromise the visual integrity of the space, leading to perceptual errors and potentially various accidents. These undesirable outcomes can be prevented by ensuring visual comfort in lighting. Visual comfort is determined by factors such as the quality and quantity of illumination, luminance contrast, and glare. Furthermore, the visual properties of the surfaces that constitute the space, including form, texture, and color, significantly affect visual comfort. Therefore, all these factors must be considered together in lighting design (Şentürk and Satıcı, 2022). In this context, addressing the interactions between light, surface color perception, and user activities in lighting design supports accurate spatial perception and enhances users' interaction with the space.

A review of the relevant literature demonstrates that research on lighting has been conducted from multiple perspectives. For instance, Odabaşioğlu and Olguntürk (2015) and Sezer and Satıcı (2024) explored the effects of lighting on spatial perception, whereas Yoon and Kim (2014), Manav (2007), and Bayram, Akboğa Kale, and Baradan (2020) investigated the technical and physical characteristics of lighting as well as visual comfort. Conversely, Kavasogulları (2021), Turgay and Altuncu (2011), and Küçük (2023) focused on the impact of lighting on users. In addition to these, there are studies that examine the relationship between light, color, and surfaces. For example, Şentürk and Satıcı (2022) analyzed the interplay between light and the form, texture, and color of surfaces, while Özbudak, Gümüş, and Çetin (2003) investigated how the actions performed within a space relate to color and lighting. Espinoza-Sanhueza et al. (2025) further examined the interaction between surface color and lighting conditions in shaping spatial experience. Despite these contributions, it is evident that

research simultaneously addressing the significance of perceiving surface color in its original state across various activity settings and its relationship to user experience remains scarce. This gap may lead to insufficient recognition of why perceiving surface colors in their original state is particularly important for certain activities in lighting design.

It is believed that evaluations based on existing studies in the literature, across different building types and activity areas, can make the effects of perceiving surfaces in their original colors on a space's function, perception, and user experience more apparent. In this regard, the study is expected to contribute to the more conscious integration of this relationship, which has remained in the background in current design approaches, into the design process. For this reason, the study aims to examine existing lighting design research in the literature, highlight the importance of perceiving surfaces in their original colors, and determine which activity areas are associated with this phenomenon. In this context, the research will seek to answer the question of in which building types, within which activity areas of these buildings, and for what reasons perceiving surfaces in their original colors is of critical importance. Thus, the goal is to raise awareness among designers regarding the impact of lighting design on the perception of surface colors.

In summary, this study seeks to answer the fundamental question: “In which user activities is it important for surface color to be perceived as it is?” As follow-up questions, the study asks: “What perceptual or functional problems might the misperception of surface color cause from the perspective of user experience, and what advantages does the perception of surface color in its original state offer in terms of user–space interaction?”

2. METHODOLOGY

This study examines the effect of lighting design on the perception of surface color in the context of user actions, employing a qualitative and literature-based methodology. The research analyzes user activities in the context of lighting design and surface color perception, drawing on systematically reviewed scientific sources. The study aims to examine the relationships between lighting design, user actions, and surface color perception within a theoretical framework through content analysis.

The research process is structured around four main stages: preparation, implementation, analysis, and evaluation–discussion (Figure 1).

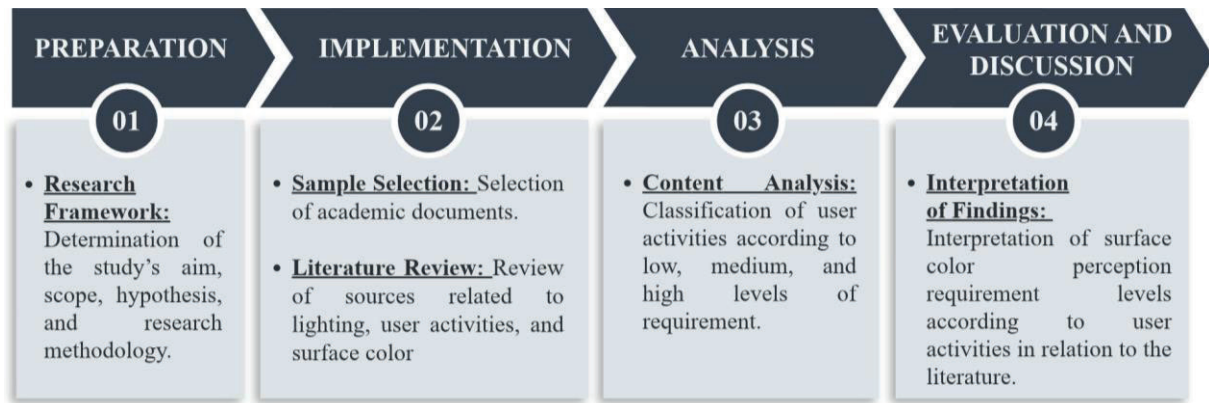


Figure-1. Research Design

In the preparation phase, the study's problem area, main objective, scope, hypothesis, and research methodology were defined.

In the implementation phase, the sample was first determined. Since the study did not require a participant-based approach, a purposive sampling method was used; national and international academic publications discussing the role of lighting on spatial perception, visual comfort, and the perceptibility of surface characteristics were reviewed. Accordingly, written academic documents that theoretically addressed the effect of light on surface color perception and user activities in interior spaces constituted the study's sample. For data collection, a literature review was conducted using academic databases and publication platforms such as Web of Science, Scopus, Google Scholar, ResearchGate, DergiPark, and similar sources. These sources were selected because they provide broad access to academic studies published across different disciplines and support the visibility and accessibility of scientific publications. During the search process, keywords directly related to the study's topic were used, and the retrieved documents were evaluated in terms of their relevance to the topic, academic quality, currency, and suitability for the scope of the study.

The selected sources were chosen because they explain how light shapes spatial perceptibility and reveal why surface color perception is critical for certain activities. Consequently, a coherent and reliable body of academic literature supporting the theoretical framework of the study was established.

At the start of the analysis phase, the collected documents were examined through content analysis. Content analysis, widely employed across various disciplines including social sciences, communication, media studies, history, psychology, and anthropology (Alanka, 2024), is a formal research method that involves drawing inferences from records and transcripts obtained within the scope of the research, as well as from written or visual media content (Olgun, 2008). In the present study, content analysis was conducted utilizing the "ICATUS 2016

International Classification of Time-Use Activities,” recognized as a principal reference document for the classification of user activities.

ICATUS 2016 is a classification system that organizes all activities individuals may perform within a 24-hour period. The system categorizes user actions in a systematic manner. In this study, not all user actions included in ICATUS 2016 were incorporated; instead, activities were evaluated and filtered according to the aims and scope of the research. The filtering criteria included whether the actions occurred indoors, could be associated with lighting conditions, and whether relevant literature existed for those activities. Actions pertinent to indoor environments and whose performance could be influenced by lighting conditions were included in the analysis. Conversely, actions pertaining to outdoor spaces, those not assessable within the context of the indoor environment-lighting relationship, or those lacking relevant literature were excluded (Table 1). While this classification does not explicitly define requirements for lighting or surface color, it provides a framework for analyzing the functional aspects of user activities within interior spaces.

Table-1. International Classification of Activities for Time-Use Statistics 2016 (ICATUS 2016)

Faaliyet	Eylem
Production of goods for own final use	-Making and processing goods for own final use
Unpaid domestic services for household and family members	-Food and meals management and preparation -Cleaning and maintaining of own dwelling and surroundings -Shopping for own household and family members
Unpaid caregiving services for household and family members	-Childcare and instruction -Care for dependent adults
Learning	-Formal education -Homework, being tutored, course review, research and activities related to formal education - Additional study, non-formal education and courses -Other activities related to learning
Socializing and communication, community participation and religious practice	-Socializing and communication -Participating in community cultural and social events
Culture, leisure, mass media and sports practices	-Attending/visiting cultural, entertainment and sports events/venues -Cultural participation, hobbies, games and other pastime activities -Activities associated with reflecting, resting, relaxing
Self-care and maintenance	-Sleep and related activities -Eating and drinking -Personal hygiene and care -Receiving personal and health/medical care from others

Accordingly, during the analysis phase, information regarding lighting found in the literature was examined for each activity, and the importance of lighting in performing the relevant

activity, along with the potential consequences of lighting conditions, was determined. Based on the information obtained, the need to perceive surfaces in their original colors was evaluated in relation to each activity, and the activities were classified into low, medium, and high levels of necessity. In determining these levels, the role of perceiving surfaces in their original colors in carrying out the relevant activity and the potential consequences of color misperception were taken into account. Situations in which perceiving surfaces in their original colors is critically important and color misperception could lead to errors or risks were classified as having a “high” level of necessity; situations in which it affects the nature of the activity but is not a critical determinant were classified as having a “medium” level of necessity; and situations in which it has no significant effect on the performance of the activity were classified as having a “low” level of necessity.

In the final phase of the study, which involved a general evaluation and discussion, each action category was systematically assessed in light of the literature review. Functionally critical domains for surface color perception were identified according to the characteristics of the actions. This methodology facilitates user-centered decision-making in lighting design and enables a more holistic consideration of the effects of light–color interaction on spatial functionality. At this stage, user activities, the necessity of surface color perception, the importance of perceiving surface color in its original state for performing the relevant activities and the potential implications were qualitatively analyzed.

While the research addresses how surface color perception is shaped by lighting conditions at a theoretical level, the evaluations are interpreted in light of existing academic sources and theoretical frameworks, and practical implications are also grounded in this foundation.

3. FINDINGS, EVALUATION, AND DISCUSSION

3.1. Findings and Evaluation Regarding ICATUS 2016 Activity Groups

User activities in daily life, classified according to ICATUS 2016, were evaluated based on the literature with respect to the spaces in which they occur, lighting requirements, and the perception of surfaces in their original colors.

a) Production and Processing Activities: Within the framework of the ICATUS 2016 classification, this activity group encompasses production and processing activities undertaken by individuals in their daily lives to fulfill their own needs. Adequate lighting in the manufacturing sector is of critical importance due to its influence on operators’ visual comfort, work performance, and occupational safety. Insufficient lighting conditions may

result in physiological disorders such as eye strain, migraines, headaches, and general fatigue; such conditions can increase operators' vulnerability to accidents and injuries, thereby elevating occupational safety risks (Yusop, Ahmad, & Ma'arof, 2013). Consequently, the safe, error-free execution of work processes in production areas depends on lighting systems designed to allow surfaces to be perceived in their original colors.

In production areas evaluated within the scope of this activity group, the accuracy of surface color perception stands out as a critical requirement for ensuring that work is performed safely and without errors. In other words, incorrect or inadequate perception of surface colors due to lighting can make it difficult to distinguish between materials, cause details to be overlooked, and increase the risk of errors. For this reason, lighting design in spaces where production activities take place must be approached in a way that accurately renders the colors and contrast characteristics of surfaces, supports visual comfort, and safely maintains the functional relationship between the user and the space.

- b) Household Service Activities:** According to the ICATUS 2016 time-use classification, this activity group comprises domestic activities (including the management and preparation of food and meals, cleaning and maintenance of the home and its immediate surroundings, and shopping) that individuals undertake without monetary compensation to sustain their daily lives.

The planning and preparation of food and meals encompass processes wherein users maintain a continuous and intensive visual engagement with the kitchen environment, necessitating heightened attention and visual precision. Throughout these activities, individuals participate in close-range, concentrated interactions with work surfaces, equipment, and food surfaces. Accordingly, lighting within kitchen spaces assumes a critical role, not only in supporting physical comfort but also in facilitating the effective and efficient completion of tasks. Proper lighting conditions contribute to user comfort and exert a direct influence on the quality of work performed (Entwistle, 1999; cited in Tümer, 2008). Therefore, in kitchen environments where artificial lighting is utilized, the entire space should be designed in accordance with established lighting principles. Specifically, it is imperative to prevent the formation of shadows on work surfaces, ensure that light sources do not shine directly into users' eyes, and avoid light types that distort the natural perception of food colors (Tümer, 2008). Sufficient and appropriate lighting in kitchens enables the processes of food preparation, decoration, and service to be conducted with greater control and success. It has been observed that insufficient lighting in kitchens significantly

increases the risk of workplace accidents (Aktaş, 2001). Preventing glare and shadow formation is crucial, particularly in areas designated for delicate and hazardous tasks, such as cutting and chopping; improper lighting in such zones not only compromises occupational safety but also adversely affects work quality (Cılız, 2019). Within this context, it is underscored that lighting decisions must be made through an expert-driven approach that concurrently considers user performance, occupational safety, and food safety (Ertuğrul, 2023).

Beyond the kitchen area, the shopping activity takes place in an environment where users establish direct visual contact with products and where purchasing decisions are largely shaped by spatial perception. In this process, consumers evaluate products not only in terms of their functional characteristics but also through their perception of color, texture, and quality; the visual conditions offered by the space play a decisive role in their decision-making. In this context, lighting emerges as one of the most important components of retail spaces, serving as a powerful design tool capable of directly influencing the perception of displayed products (Aşçıoğlu, 2014). Differences in lighting conditions within a store environment can cause a product's color to be perceived significantly differently from what the designer intended. This underscores the need for store lighting to accurately reflect the product's texture, color, and quality characteristics in a manner consistent with the designer's original intent (Cardenas et al., 2009). Otherwise, a discrepancy may arise between the product color perceived by users under store lighting and the color targeted by the designer and manufacturer; this may lead to consumer dissatisfaction (Dilgen and Hasırcı, 2022). The combined use of general lighting and accent lighting in retail spaces is important for enhancing spatial perception and highlighting products (Aşçıoğlu, 2014). In this context, to ensure that users can evaluate products accurately, lighting in retail spaces must be designed not only to improve the overall visibility of the space but also to accurately reflect the color and texture of product surfaces. Particularly in retail spaces where color selection is critical, such as clothing stores, the lighting used in product display areas and fitting rooms must accurately reflect the product's characteristics and colors. In such spaces, lighting solutions with a high color rendering index are considered an essential requirement for users to perceive product colors realistically (Winchip, 2011; cited in Aşçıoğlu, 2014).

In the cleaning and organization of the home and its immediate surroundings, lighting is important for ensuring that the environment and surfaces can be adequately perceived. It is noted that lighting supports individuals' ability to perceive visual cues about their

surroundings and to carry out their daily activities safely and comfortably (Aslanoğlu et al., 2021). Øien et al. (2026), who examined the relationship between activities performed in homes and the use of lighting, found that lighting is also used during cleaning activities and that lighting is used to support activities such as cleaning and doing laundry. In this regard, lighting in cleaning activities can contribute to the adequate perception of the work area and surfaces, thereby supporting the performance of the activity in a more controlled manner.

To summarize, within residential service activities, the accurate and natural perception of surface colors is critical in certain tasks. Light is the fundamental element that makes a space visible. It enables the perception of the shape, texture, and color of surfaces, while also being shaped and gaining meaning through its relationship with those surfaces (Şentürk and Satıcı, 2022). In kitchen activities such as food preparation and presentation, as well as in the evaluation of products during shopping, the intense visual relationship with surfaces makes color perception particularly important. In such activities, appropriate lighting not only ensures general visibility but also directly affects the accuracy and safety of task performance, as well as user satisfaction, by accurately reflecting the color and texture of surfaces.

- c) **Care Activities:** Within the ICATUS 2016 time-use classification, care activities encompass unpaid activities addressing care and support needs (childcare and education, care for dependent adults).

Child care and education encompass activities related to the care and development of children. It is noted that, in order for care activities performed in infant and child care rooms to be carried out correctly and to ensure clear visibility, localized lighting tailored to the needs of the activity areas must be used in addition to general lighting (Bilgin, 2021). Lighting also constitutes an important element of the visual environment in children's educational activities. It is noted that inadequate lighting in residential and preschool education facilities can cause physical effects such as eye strain and headaches (Kuşaslan, 2007). It is stated that visual comfort in classrooms in primary education buildings is important for learning efficiency and health, given the intensive visual activities involved, such as reading and writing (Kavaz Altun and Zorlu, 2021).

On the other hand, inadequate lighting during the care process for dependent adults can affect the quality and adequacy of daily activities (Özer Baş, 2021). In particular, the decline in visual perception and contrast sensitivity among older adults can make it difficult to perceive environmental cues and move safely (Karlsson et al., 2013). Furthermore, it is

noted that color selection supported by appropriate lighting techniques can contribute to older adults' safe interaction with their environment (Derebek and Şumnu, 2026). In activities such as medical care and examinations, however, visual requirements differ. It is noted that examination lighting must be of a quality that does not alter the patient's skin and tissue color and must allow for the direct visualization of the shape of the tissues (Özil, 2008).

When evaluating this group of activities, lighting must support the accurate and comfortable performance of care and educational activities. Although perceiving surfaces in their original colors is not a common requirement for all care activities, it becomes particularly important in activities such as medical care and examinations that require assessment of skin and tissue color.

- d) Learning and Educational Activities:** According to the ICATUS 2016 time-use classification, learning and educational activities encompass the actions an individual undertakes as part of their education and learning processes (formal education, research, private tutoring, and self-directed learning).

The learning process can be sustained fully, accurately, and without fatigue only if lighting meets the necessary conditions in both quantity and quality (Bostancı Başkan and Şerefhanoglu Sözen, 2006). Proper lighting creates the environmental conditions needed for effective learning, increasing student motivation and helping them maintain focus for longer periods. Conversely, poor lighting conditions can cause discomfort, leading to distractions and negative health effects. Therefore, even when energy and design requirements are taken into account, it is essential to prioritize users, whose needs may vary by age, when planning lighting (Fördergemeinschaft Gutes Licht, 2012). Similarly, insufficient illuminance can slow reading, cause a loss of focus, and, in the long term, reduce visual performance, thereby hindering the healthy progression of learning activities. On the other hand, excessive or uneven illuminance can pose a risk of glare (Kazanasmaz, 2015). In conclusion, lighting design in learning and educational spaces plays a decisive role in improving students' academic performance, protecting their eye health, and ensuring spatial satisfaction. Accordingly, lighting systems in educational buildings are a critical and strategic issue that must be addressed in a way that supports the visual perception conditions required for learning activities (Çelik and Ünver, 2019).

In spaces where learning and educational activities take place, the perception of surfaces in their original colors is a fundamental requirement for the continuity and efficiency of the learning process. For such positive perceptual effects, the selection of lighting systems

appropriate to the requirements of the space and light sources with the correct spectral characteristics is of critical importance (Ministry of National Education, 2013). A poorly designed lighting system can lead to functional deficiencies, an unhealthy indoor environment, inefficient performance of user activities, and adverse effects on human health (Kazanasmaz, 2015). In this context, lighting conditions that cause the colors of surfaces in a space to be perceived differently from their original colors can negatively affect activities that require reading, writing, and visual attention. Deviations in color perception can lead to a loss of contrast, visual fatigue, and distraction, thereby reducing learning performance.

- e) **Social Interaction Activities:** According to the ICATUS 2016 time-use classification, this activity group encompasses the activities an individual undertakes to maintain social relationships and participate in cultural and social events (socializing and communicating with family, friends, and others; participating in cultural and social events).

Girgin (2026) notes that changes in lighting levels depending on the social context affect the desire to stay in a space and the perception of sociability. Öksüz and Özcan (2025), who examined coffee shops used for socializing, highlight the role of lighting not only in visual comfort but also in fostering a social atmosphere. Accordingly, in spaces where socializing and communication take place, lighting must provide visual comfort while creating an atmosphere conducive to social interaction.

Participation in cultural and social events encompasses activities in which individuals engage in cultural, artistic, and social events. In cultural centers, one of the venues where these activities take place, it is noted that lighting is a crucial design element due to the viewing activities in large auditoriums; it is emphasized that glare and reflections must be prevented, and an appropriate balance must be established between illuminance levels and viewing conditions (Sütlüoğlu, 2007). In meeting and conference rooms, it is noted that inadequate lighting can lead to eye strain and loss of concentration (Yılmaz, 2018).

When evaluating this category of activities, it becomes apparent that lighting relates to the atmosphere of the space and the nature of the event, rather than simply ensuring that surface colors are perceived in their original colors. In socialization and communication activities, color and material properties, together with lighting, contribute to the space's identity and social atmosphere; in cultural and social events, creating an atmosphere appropriate to the event takes center stage. Accordingly, in this activity group, the perception of surfaces in their original colors is not considered a fundamental requirement; instead, it is important to address the relationship between surface color and lighting in a way that supports the spatial atmosphere and the event experience.

- f) Cultural, Sports, and Entertainment Activities:** According to the ICATUS 2016 time-use classification, this activity group encompasses actions individuals undertake to participate in cultural events, make the most of their leisure time, and relax. Participation in these activities largely shapes the individual's relationship with the space through perceptual and experiential processes. In spaces such as museums, exhibitions, and theaters, the user is not merely physically present; through visual and auditory stimuli, they become part of the spatial narrative. In this context, spatial design and environmental conditions emerge as key elements that determine the nature of the relationship established between the visitor and the content.

Lighting that supports storytelling through audiovisual and narrative means is a key design element in museums and exhibition spaces. Consequently, lighting systems play a critical role in ensuring visitors' visual comfort and enabling a rich experience of the exhibited content (Aykut, 2021). Considering the concepts related to the lighting of artworks in museums and the fundamental function of these institutions, it is generally accepted that lighting design has two primary principles: minimizing light-induced damage to the exhibited works and ensuring that the artwork is perceived by the viewer accurately and true to its original form (Yöndem and Akyol, 2017). In this regard, museum lighting should ensure that surfaces are perceived in their original colors. A properly designed lighting scheme strengthens the visual connection between the visitor and the artwork, thereby supporting the integrity of the exhibition experience. In theater, lighting ensures that the actor's and set's form, textures, and colors are conveyed to the audience. This is because light defines the environment it occupies and the texture, form, and scale of the surfaces it illuminates, thereby ensuring the correct perception of the space's functions (Yöndem and Akyol, 2017). On the other hand, when the script requires it, the brightness level, color, and direction of light can be altered to make elements on stage appear different from their actual appearance (Pekin and Ünver, 2016).

In the spaces evaluated within this scope of action, accurate surface color perception is essential to the healthy formation of the individual's experiential relationship with the space. When lighting causes surface colors to appear different from their original colors, it can weaken the meaning intended by the exhibited work or spatial narrative and disrupt the integrity of the user experience. For this reason, lighting design in spaces intended for exhibition-based cultural events should accurately reflect the color and texture characteristics of surfaces, support perceptual continuity, and strengthen the visual relationship between the user and the space.

g) Self-care and Personal Care Activities: According to the ICATUS 2016 time-use classification, this activity group encompasses the activities an individual undertakes to maintain their physiological health and personal hygiene and care (sleeping, eating and drinking, personal hygiene and care, and receiving health or medical care from others).

During sleep, the user experiences their relationship with the space primarily not on a visual level, but on a biological and perceptual level. The effect of lighting on human health is not limited to visual comfort alone; it plays a direct role in regulating the biological clock, circadian rhythms, and hormones such as melatonin and cortisol (Cengiz, 2021). It has been noted that properly designed lighting systems positively influence an individual's sleep patterns, as well as their physiological health and psychological well-being (Manav, 2007). Conversely, it is stated that artificial lighting systems designed without considering daylight in indoor spaces and providing high illuminance levels can negatively affect melatonin levels, leading to sleep disorders and overstimulation (Turgay and Altuncu, 2011). It is recommended that homogeneous, low-level lighting solutions be preferred, with safety as the top priority, especially in sensitive spaces such as nurseries (Başa Apaydın and Göker, 2009; cited in Özkum, 2011). Consequently, lighting in bedrooms is interpreted not so much in terms of the perception of surfaces in their original colors but rather through its impact on human health.

When it comes to eating and drinking, these are among the situations in which users' visual relationship with the space is experienced most intensely. The primary function of lighting in dining spaces is to ensure that users can clearly perceive their surroundings, the menu, and the food on their plates (Jacquier and Giboreau, 2012). Furthermore, the natural and accurate perception of food colors plays a decisive role in taste perception, appetite, and food choices. For this reason, the use of light sources with high color rendering is recommended; it is emphasized that the illuminance level must be sufficient to support the color discrimination of food (Barker, 1997; cited in Ersöz, 2003; Özbudak, Gümüş, and Çetin, 2003). Studies have shown that heavier and fattier foods are preferred under dim or cool lighting conditions, whereas there is an increased tendency toward lighter meals under bright and natural lighting conditions (Jacquier and Giboreau, 2012). This demonstrates that color perception is highly sensitive to lighting conditions and has a direct impact on user behavior.

Similarly, during personal hygiene and grooming activities, users establish a close-range, focused visual relationship with surfaces in the space. Uniform general lighting is a fundamental requirement in bathrooms, while localized lighting around the mirror is

particularly important for precise visual tasks such as applying makeup or shaving (Yazgan, 2004; Thomas Pocklington Trust, 2021). Inadequate lighting, glare, and shadow formation hinder the accurate perception of surfaces and skin tones, thereby complicating personal care activities (Frommhold Hasenjager, 1972; cited in Anıl, 1995). Furthermore, it has been noted that the color and contrast relationships created between light and dark surfaces enhance spatial perception and support visual performance (Thomas Pocklington Trust, 2021). For this reason, the perception of surface colors and tones in their actual colors during personal hygiene and grooming activities stands out as a critical element that not only ensures visual accuracy but also contributes to users performing these tasks safely and without error.

When it comes to receiving personal and health/medical care from others, this is one of the most sensitive and error-intolerant forms of the relationship users establish with the space. Healthcare facilities have complex lighting design requirements because they offer diverse services and serve varying user profiles (Özil, 2008). Hospital lighting requirements are shaped by the visual needs of different user groups, such as patients, doctors, nurses, and technicians (Polat, 2005). In this context, especially during diagnostic and treatment procedures, healthcare personnel's visual needs can take precedence over patient comfort (Altuncu and Tansel, 2009). This intense visual interaction between healthcare personnel and the environment highlights lighting's impact on work performance, attention levels, and the reduction of medical errors. It has been noted that bright lighting similar to natural daylight enhances visual performance and reduces the risk of errors (Selçuk, 2012). For this reason, accurate color distinction is critical, particularly in laboratories, diagnostic rooms, and operating rooms (Altuncu and Tansel, 2009). Operating rooms are among the environments where the human-space relationship demands the highest level of visual accuracy. In these spaces, the primary objective is procedural accuracy and safety, rather than user satisfaction (Polat, 2005). Insufficient lighting negatively affects the field of view, while excessively harsh light can cause eye strain and loss of attention, increasing the risk of error (Eti Aslan and Kan Öntürk, 2011; cited in Kepekçi and Kepekçi, 2020). Controlling shadows cast by the surgeon's hand or the instruments they use, and ensuring that patient tissue, organs, and blood can be perceived in their original colors, requires careful attention to the lamps' color rendering properties, interior surface colors, and light reflectance coefficients (Özil, 2008; Polat, 2005). In this regard, the perception of surface color in spaces where healthcare and medical care activities are performed is considered not only a

factor in spatial comfort but also one of the fundamental components of accurate diagnosis, safe intervention, and the error-free establishment of the human–space relationship.

Among the activities included in this category, sleep stands out as a situation where the accuracy of surface color perception takes a back seat. Since visual perception is not actively used during sleep, the primary role of lighting is not to accurately reflect surface color but to reduce stimulating effects by ensuring that surfaces remain perceptually in the background. In contrast, in personal care, eating and drinking, and health/medical care activities, the accurate perception of surface color is critical to the accuracy and safety of the activity. Therefore, lighting design in spaces where self-care and personal care activities are performed should use different approaches that reflect the importance of surface color perception in each activity.

3.2. General Evaluation

The findings of this study show that the need to perceive surface colors in their original state within interior spaces varies depending on the nature of user activities. Because user activities differ widely according to the function of a space, each activity gives rise to different lighting requirements (Çelik, Küçükkılıç Özcan, and Ünver, 2015). Properly designed lighting can conceal design flaws or complement the design, while an inadequately designed lighting strategy can have negative effects even in well-designed spaces (Göler, 2009).

The activities of production and processing, residential services, care, learning and education, socialization and participation in social events, cultural, sports, and entertainment, self-care and personal care, which are also addressed in the ICATUS 2016 time-use classification, differ from one another in terms of the need to perceive surfaces in their original colors. The importance of surface color perception in these activities varies depending on the nature of the activity and the relationship established with the space. The activities were evaluated based on the literature, considering the contribution of perceiving surfaces' original colors to the safe, accurate, and meaningful performance of activities, as well as the potential negative consequences if such perception cannot be achieved (Table 2). Accordingly, the need for accurate surface color perception was classified into three levels: “high,” “medium,” and “low.”

Table-2. Evaluation of ICATUS 2016 Activity Groups

Activity Group	Activity Type	Type of Space Where the Activity Takes Place	Requirement for Perceiving the Original Surface Color	Potential Positive Outcomes of Being Able to Perceive the Original Surface Color	Potential Negative Consequences of the Inability to Detect the Original Surface Color
Production and Processing Activities	Product manufacture and processing	Workshops, production facilities	High	Accurate perception of materials and their colors; provision of safe working conditions	Errors in distinguishing materials, production errors, increased occupational safety risks
	Food preparation	Residential buildings, restaurants	High	Improved food preparation and presentation quality	Increased risk of errors and workplace accidents
Household Service Activities	Shopping	Supermarkets, stores, shopping areas	Medium	Improved accuracy in product evaluation and increased consumer satisfaction	Differences in the perception of product colors and textures, incorrect purchasing decisions, user dissatisfaction
	Cleaning the home and its surroundings	Homes, residential surroundings	Low	Easier perception of the environment and surfaces	Difficulty detecting dirt and stains
	Childcare and education	Homes, infant and childcare rooms, educational institutions	Medium	Improved perception of caregiving spaces and increased visual comfort during educational activities	Visual strain, difficulty perceiving details, health problems
Care Activities	Care of dependent adults	Homes, care facilities, healthcare facilities	Low	Improved perception of environmental cues and support for daily care activities	Increased difficulty with visual perception and contrast discrimination, risk of accidents
	Reading and learning	Homes, educational buildings, libraries	Medium	Support for visual perception and the continuation of learning activities	Loss of contrast, visual fatigue, reduced attention and learning performance
Socialization Activities	Socializing and communication	Homes, cafés, restaurants, social gathering spaces	Low	Support for spatial identity and social atmosphere	Reduced desire to remain in the space, negative perception of the social atmosphere
	Participation in cultural and social events	Cultural centers, meeting and conference halls	Low	Improved perception of the event setting and support for an atmosphere appropriate to the event	Adverse effects on viewing conditions, fatigue, loss of concentration

Cultural, Sports, and Entertainment Activities	Visiting museums and exhibitions	Museums, exhibition halls	High	Perception of artworks while preserving their color and texture integrity	Inaccurate perception of artwork colors, diminished understanding of the artwork and reduced exhibition experience
	Watching performing arts	Theaters, performance venues	Low	Support for stage narratives and spatial atmosphere	Difficulty perceiving actors and stage sets, diminished impact of the stage narrative
Self-care and Personal Care Activities	Sleeping	Homes, accommodation facilities, healthcare facilities	Low	Support for sleep patterns and biological balance	Increased light-induced arousal and reduced sleep quality
	Eating and drinking	Homes, restaurants, cafeterias	Medium	Perception of the natural colors of food and enhancement of the dining experience	Inaccurate perception of food colors, errors in judging freshness or doneness, reduced appetite and perceptual satisfaction
	Personal hygiene and grooming	Home bathrooms, accommodation facilities, personal care areas	High	Improved precision and quality of personal care	Misperception of skin tones, increased application errors, visual strain
	Receiving health or medical care from others	Hospitals, clinics, treatment and intervention areas	High	Support for diagnostic accuracy and the precision of medical interventions	Difficulty perceiving tissue and organ colors, diagnostic and intervention errors, health and safety risks

The findings reveal that surface color perception is not equally critical for all user activities; rather, its importance varies depending on how each activity relates to the space.

4. CONCLUSION

This study evaluated the relationship between space, light, and the user within a functional framework by examining the effect of lighting design on surface color perception in the context of user activities. A literature review based on the ICATUS 2016 classification of user activities revealed that the need to perceive surfaces in their original colors is not equally critical for all user activities; rather, this need varies depending on the nature of the activity and the spatial context. Accordingly, activities were classified into three groups according to the level of need to perceive surfaces in their original colors: high, medium, and low (Table 3).

Table-3. Activity Types According to the Need to Perceive Surfaces in Their Original Colors

Surface Color Perception Requirement	Relevant Activity Types
High	Production and processing activities (product manufacture and processing); household service activities (food preparation); cultural, sports, and entertainment activities (visiting museums and exhibitions); self-care and personal care activities (personal hygiene and grooming, receiving health or medical care from others)
Medium	Household service activities (shopping); care activities (childcare and education); learning and education activities (reading and learning); self-care and personal care activities (eating and drinking)
Low	Household service activities (cleaning the home and its surroundings); care activities (care of dependent adults); socialization activities (socializing and communication, participation in cultural and social events); cultural, sports, and entertainment activities (watching performing arts); self-care and personal care activities (sleeping)

4.1. Activities Where the Need for Surface Color Perception Is “High”

The study results indicate that surface color perception is highly important, particularly in activities that involve direct interaction with the space and require visual attention, discrimination, and accurate assessment. Activities in this group include production, preparation, personal care, display, and health-related activities. In such activities, the ability to perceive surface colors in their true colors is critical for distinguishing materials, ensuring the legibility of spatial boundaries, providing visual comfort, and reducing the risk of errors. Conversely, failure to perceive surface colors in their true colors can lead to difficulties in visual discrimination, increased application errors, compromised occupational and health safety, and a negative impact on the visual experience. The literature indicates that misperception of surface colors under inadequate or inappropriate lighting conditions can negatively affect user performance and weaken the functional relationship established with the space.

4.2. Activities Where the Need for Surface Color Perception Is “Medium”

In activities where the need to perceive surfaces in their original colors is of medium importance, surface color perception can affect the nature of the activity and the user experience. However, failure to perceive surfaces in their original colors does not necessarily constitute a direct safety risk or a critical operational error in every situation. The activities in this group include shopping, childcare and education, reading and learning, and eating and drinking. In these activities, surface color perception supports visual comfort, environmental assessment, and the quality of the activity being performed. Perceiving surfaces in their original colors helps ensure visual comfort, enables activities to be carried out more effectively, and

supports user satisfaction. Conversely, failure to perceive surfaces in their original colors can reduce visual comfort, negatively affect attention and performance, and lessen satisfaction with the activity being performed. Therefore, while surface color perception is an important design consideration, the level of necessity varies depending on the functional outcomes of the activity and the potential effects of perceptual errors.

4.3. Activities Where the Need for Surface Color Perception Is “Low”

In these types of activities, perceiving surfaces in their original colors can be considered less critical to the performance of the activity than other visual conditions. Activities in this group include cleaning the home and its surroundings, caring for dependent adults, socializing and communicating, participating in cultural and social events, watching performing arts, and sleeping. While appropriate lighting conditions support daily activities, create an atmosphere suitable for the space, and promote visual comfort, the inability to perceive surfaces in their original colors can make the environment more difficult to perceive and negatively affect the visual experience. Consequently, surface color perception is considered a design element of lower priority in terms of its role in the performance of these activities.

The results indicate that lighting design should be guided by decisions that vary according to the requirements of user activities, rather than by a one-size-fits-all approach. The action–space–surface color perception relationship established in this study (Table 2) provides a conceptual framework for lighting design decisions. This framework can help designers view surface color perception not only as an aesthetic element but also as a functional parameter directly related to user activities, and align lighting decisions with the intended use of the space.

Based on existing literature on different building types and their activity areas, this study supports the hypothesis that the effects of perceiving surfaces in their original colors on spatial function, perception, and user experience can be made more apparent. In conclusion, this study contributes to the literature at a conceptual level by systematically examining the impact of lighting design on user experience through surface color perception.

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