

CURRENT DEVELOPMENTS AND THEMATIC REVIEWS IN ARCHITECTURE, PLANNING AND DESIGN

Editors

Prof. Latif Gürkan Kaya, PhD.

Assoc. Prof. Hüseyin Samet Aşıkkutlu, PhD.

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**User-Centred Building Performance Assessment: Integrating Indoor
Environmental Quality and Occupant Feedback**

Gizem Izmir Tunahan

CHAPTER 1

Vernacular Rainwater Harvesting Systems in the Mediterranean Basin

Taiwo Adewale Fatai¹
Hacer Mutlu Danaci²

1. Introduction

Water scarcity is a critical global issue, impacting millions of people and ecosystems worldwide. According to a research carried out by the United Nations in 2014, by 2025, 1.8 billion people will live in regions with absolute water

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scarcity, and two-thirds of the global population will face water-stressed conditions. The primary factors contributing to this crisis include population growth, climate change, urbanization, and inefficient water management practices (Intergovernmental Panel on Climate Change (IPCC), 2014). In many regions, the availability of freshwater resources is diminishing due to over-extraction, pollution, and altered precipitation patterns (World Health Organization (WHO), 2019). This scarcity not only threatens human health and agricultural productivity but also jeopardizes economic development and ecological balance. Stewart & Warnock (2017) identified rainwater harvesting as a viable strategy to alleviate the global water crisis as it is capable of providing a sustainable and resilient water supply.

The term rainwater harvesting is used as an umbrella term for a range of methods of concentrating and storing rainwater runoff, including from roofs (rooftop harvesting), grounds (runoff harvesting), channel flow (flood water harvesting), from various sources (rain or dew) and for various purposes (agricultural, livestock, domestic water supply, environmental management) (Yannopoulos et al. 2017). Rainwater harvesting has been identified as an alternative source of water supply for regions facing water scarcity (Kakoulas et al. 2022). The climatic characteristics of the Mediterranean, marked by hot, dry summers and mild, wet winters, make rainwater harvesting a vital strategy for addressing seasonal water scarcity (Cossio & Angelucci, 2018).

The Mediterranean region, with its diverse cultures and landscapes, has a long history of using rainwater harvesting systems to meet its water needs (Burak & Margat, 2016). This region has a scarcity of water resources, and the development of rainwater harvesting systems has been a vital means of managing water scarcity. The evolution of rainwater harvesting systems in the Mediterranean region can be traced back to ancient civilizations such as the Sumerians, Egyptians, Greeks, and Romans (Kakoulas et al., 2022). Each of these civilizations developed its own unique rainwater harvesting systems, which were adapted and improved upon by later civilizations (Patel et al., 2020) (Kakoulas et al., 2022). The development of rainwater harvesting systems in the Mediterranean region can be seen as a response to the challenges of water scarcity and the need to find sustainable ways to meet the region's water needs. Revitalizing and modernizing these traditional practices can play a crucial role in addressing contemporary water scarcity issues (Fletcher et al., 2015).

The research aims to explore the historical development and contemporary applications of rainwater harvesting systems in the Mediterranean region. By examining ancient practices and their evolution, this study seeks to understand how ancient methods of rainwater harvesting can be integrated into current water management strategies to address the growing challenges of water scarcity, climate change, and urbanization.

2. Materials and Method

A research carried out by Tramblay et al. (2020) concluded that one of the issues confronting the Mediterranean region is urbanization, which leads to an increase in the demand of water supply. This demand is predicted to worsen in the face of climate change and affect water distribution and use, leading to a rapid change in the water cycle due to increased evaporation and less rainfall and also causing increased fire hazard as well as an enhanced risk of forest pests and parasites (Lange 2020). This water issue will be a core concern in the sustainability challenge of the whole region. Land degradation and desertification will be exacerbated, forests will most probably experience an increase in fire & parasitic risks, and animal and plant biodiversity will be at risk because of a displacement of species natural ranges toward the north and toward higher altitudes (Lionello, 2012).

2.1. The Mediterranean Countries

The Mediterranean Sea is bordered by 21 countries with a population of about 529 million. (Ambrosetti, 2020). The Mediterranean countries exhibit a diverse array of geographical features that have shaped their landscapes, climates, and socio-economic dynamics (UNESCO, 2010). The Mediterranean climate, characterized by hot, dry summers and mild, wet winters, plays a crucial role in shaping water availability and management in the region (European Environment Agency, 2019). The majority of rainfall occurs during the winter months, typically from November to March, when cyclonic storms from the Atlantic Ocean bring precipitation to the region (Camarda, 2016). This winter rain is essential for replenishing water sources, recharging aquifers, and sustaining ecosystems, agriculture, and human populations.

The World Atlas (2023) classified the countries bordering the Mediterranean Sea (fig. 1) as follows and it is under this classification that rainwater harvesting systems of the selected countries in the Mediterranean are discussed.

a) **European Mediterranean Countries:** Spain, France, Monaco, Italy, Malta, Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Albania, and Greece

b) **Asian Mediterranean Countries:** Turkey, Cyprus, Syria, Lebanon, Israel, and Palestine

c) **African Mediterranean Countries:** Egypt, Libya, Tunisia, Algeria, and Morocco.



Fig. 1: Countries bordering the Mediterranean Sea (World Atlas, 2023)

2.1.1. Detail of the Mediterranean Basin Climate

The Mediterranean climate is characterized by its accentuated interannual variability, defined also as “climatic infidelity,” and this area is one of the world’s hotspots of climate change, where forecasted global warming and dryness are likely to greatly affect the environment and human activities (Lionello, 2012). The basin and the surrounding lands are affected by interactions between mid-latitude and tropical processes and are influenced by some of the most relevant mechanisms acting upon the global climate system (Ulbrich et al. 2013). The recent temperature record reveals a mean annual temperature for the entire basin that lies about 1.5 °C above late 19th-century levels and approximately 0.4°C above the global average, with significant inter-annual variability (Lange 2020). An increase in atmospheric temperature ranging between 2.2 and 5.1°C is expected by the end of this century, as is a significant decrease in rainfall (ranging between 4% and 27%), and an increase in drought periods. These will result in a higher frequency of days during which the temperature would exceed 30°C and will trigger extreme events such as heat waves, droughts, or floods that could become more frequent and violent (Lionello, 2012). The overall change in climatic conditions has resulted in more frequent and more intense heat waves with midday temperatures continuously above 30 to 40°C and increasing periods of drought since the 1950s (Lange 2020).

Mediterranean droughts are driven both by lack of precipitation and high evaporation rate (Ulbrich et al. 2013). Droughts are difficult to quantify and are usually identified by their effects or by their impacts on different types of systems (Seguí et al., 2016). According to Thiébaud & Moatti (2016), in December 2005, severe drought conditions were recorded in the west of the Iberian Peninsula, southeast France and extensive areas in Turkey, whereas humid conditions prevailed in the eastern part of the Iberian Peninsula, parts of Italy and the Balkans. This is the common pattern of drought occurrence found in the

Mediterranean region, which is characterized by marked spatial variability of drought events, even for the most extreme episodes recorded in the region (Thiébaud & Moatti, 2016).

2.1.2. Differences between the Northern and Southern Mediterranean Climate

The climate of the Mediterranean is mild and wet during winter, and hot and dry during summer. Winter climate is mostly dominated by westward movement of storms originating over the Atlantic and impinging upon the western European coasts (Giorgi & Lionello, 2008). As global temperature rises, a strong general tendency towards longer dry period and shorter wet spells will affect the whole Mediterranean region, but with important differences between the north and south areas (Lionello & Scarascia, 2020). Mean summer temperatures show a gradient from north to south with mean temperatures exceeding 30 °C in the southeast (Ulbrich et al. 2013).

In the summer, high pressure and descending motions dominate over the region, leading to dry conditions particularly over the southern Mediterranean (Giorgi & Lionello, 2008). Summer in southern Mediterranean regions is characterized by high temperatures and lack of rain, leading to drought and marked arid conditions. Total precipitation values show high spatial and temporal variability (Thiébaud & Moatti, 2016). Mean annual precipitation amounts range from less than 200 mm/year (North Africa, Arabian Peninsula) up to 2,000 mm/year over some northern mountainous areas. Winter half-year precipitation accounts for between 30% (western and northern Mediterranean area) and 80% (eastern and southeastern parts) of the annual total precipitation (Xoplaki et al., 2004).

The extent and severity of desertification, water shortage and water quality, food security, risks in public health, sensitivity of valuable ecosystems and indirect effects on national economies are some of the topics indicating the vulnerability of the Mediterranean basin to climate variability (Xoplaki et al., 2003).

2.2. Method

Innovative water management practices have long existed in the Mediterranean region, which has unique weather patterns of hot, dry summers and moderate, wet winters. Rainwater storage systems have been shown to be vital in guaranteeing a dependable water supply all year round and this is evidence in a research carried out by Gougueni et al. (2023). The Minoans, Greeks, Romans, and Phoenicians, who created advanced techniques for gathering, storing, and using rainfall, were among the ancient Mediterranean societies. These systems have changed over millennia and still have an impact on the area's current methods of water management. The systems used for harvesting rainwater

in selected countries (Rome, Greece, Spain, Turkey, Tunisia, and Morocco) of the Mediterranean are examined according to the following criteria; storage system, material, water transportation system, and the filtering of impurities. It is believed that by using these criteria to evaluate the data gathered from several literatures, the different rainwater harvesting systems used in the Mediterranean region will be compared thereby making it easier to sum up results and propose recommendations on how to integrate these systems into the current water management strategies.

2.2.1. A General Overview of the History of Rainwater Harvesting Systems

Water is necessary for human survival. While often repeated, this remains valid both for modern and ancient societies. Especially during the Mediterranean summer, a well-functioning water supply was necessary for societies to emerge, survive and grow (Klingborg, 2023). Cisterns were majorly depended on as one of the means to ensure the continuous availability of water (Angelakis et al., 2021).

The construction and use of cisterns can be traced back to the Neolithic Age (Mays, Antoniou, & Angelakis, 2013). Cisterns held water that had been received from an external source (usually rainwater) and were not intended to receive a constant inflow or facilitate a constant outflow. Installations with a constant inflow and outflow are instead referred to as reservoirs (Klingborg, 2023). The Minoans developed early rainwater harvesting systems, including cisterns at the Palace of Knossos (Koutsoyiannis & Angelakis, 2003). The Minoan water cisterns were of cylindrical shape, constructed with stones under the soil surface, with diameters ranging from 1.5 to 7.0m and depths ranging from 2.5 to 5.0m. At least one layer of hydraulic plaster prevented water losses through the bottom and the walls of the cisterns (Mays, Antoniou, & Angelakis, 2013). One of the salient characteristics of the Minoan era in Crete was the treatment devices used for water supply in palaces, cities, and villages from the beginning of the Bronze Age. The major of such treatment devices are terracotta filters and sand filters (Yannopoulos et al. 2017). Ancient Greeks further refined these techniques, integrating large cisterns into urban planning (Mays, 2010).

Water management in the Greek islands was very critical, mainly because of the lack of natural water resources, such as large rivers or groundwater associated with a semiarid climate. The sources of water for the ancient Greek cities on the islands were mainly rainwater harvesting systems connected to wells or cisterns (Graebing, 2021). The cisterns built during the Hellenistic periods showed that the Hellenes were improving the technology of the Minoans and Mycenaeans (Yannopoulos et al. 2017). Rainwater was also harvested from roof, yards and other open spaces of establishments into the cisterns and these cisterns were varied in construction methods, building materials, and capacity depending on

their private or public use and the needs that had to be covered (Yannopoulos et al. 2017).

The Romans constructed aqueducts and cisterns for rainwater harvesting. Roman cisterns were designed to capture and store rainwater during wet periods, ensuring a steady supply of water during droughts or other times of water scarcity (Osman, 2017). They were typically built underground to minimize evaporation and contamination, and were lined with waterproof cement known as *opus signinum*, which was made from a mixture of crushed tiles and lime (Mays, 2010). The cisterns were often covered with vaulted roofs to protect the stored water from impurities and to stabilize the structure. In addition, these systems helped to reduce the impact of storm water on local waterways, preventing erosion and protecting aquifers and ecosystems.

Roman aqueducts were constructed using large stones and mortar, and typically spanned over rivers and valleys (Angelakis et al., 2021). Although some of the aqueducts were fed by surface water, most of them were supplied by springs, usually augmented by tunnelling to increase the flow of groundwater (Deming, 2020). The aqueducts relied on gravity to maintain a steady flow of water over long distances, often involving intricate engineering solutions to navigate natural obstacles. If the gradient of the topography was not uniform, dips and hummocks had to be overcome by bridges, viaducts, tunnels, or siphons (Deming, 2020). The Romans ensured water purity by meticulously selecting water sources known for low impurities and using settling basin technique, which slowed water flow and ensured that heavier particles settled at the bottom before water continued its movement. In some cases, the Romans used simple filtration methods, such as placing coarse materials like gravel and sand at the intake points to filter out larger debris (Hodge, 2013). The aqueducts did not only supply water for drinking and bathing but also supported public baths, fountains, latrines, and private households. They played a crucial role in maintaining public health and urban hygiene, contributing significantly to the growth and prosperity of Roman cities.

The rainwater harvesting systems in Spain have a long and rich history dating back to the ancient Moorish period during their occupation of the Iberian Peninsula (Mostafaeipour, 2010). This period saw the expansion of constructed Roman structures such as aqueducts, wells, and cisterns to collect and store rainwater (Mays, Antoniou, & Angelakis, 2013). These systems were built using locally available materials such as stone, brick, and tile, and were designed to maximize water collection while minimizing evaporation. There are also rainwater harvesting and collection tanks whose walls and roofing were built with bricks or local stone squared elements according to different dry or wet building technologies (*opus caementicium*, *reticulatum*, *incertum* and, sometimes, *spicatum*), with a roofing of round arches and vaults, often supported by pillars

and faced with *cocciopesto* plaster to prevent any leakage of water from the system. These types of tanks share the same characteristic elements with those present in Italy, Turkey, and France (Reitano, 2011). The qanat systems, used for water transportation, were introduced to Spain by the Arabs (Mostafaeipour, 2010). Other studies claim that they were introduced to Spain by the Moors during their occupation of the Iberian Peninsula and are called *galleria* (Beckers, Berking, & Schütt, 2013). They were excavated using methods inherited from the Romans and Arabs (Carrión et al., 2017).

The earliest evidence of rainwater harvesting in Turkey dates back to ancient Anatolian civilizations. The Hittites constructed extensive systems of dams and cisterns to capture and store rainwater (Özgüler, 2017). The Urartians built an extensive network of canals and reservoirs in eastern Anatolia. During the classical period, Greek settlers constructed aqueducts and reservoirs. The Byzantine Empire built large cisterns, such as the Basilica Cistern in Constantinople (Kuşlu & Şahin, 2009). The long-distance water conveyances in the Aegean and Mediterranean regions of Turkey include spring-water collection chambers; lead, stone, and clay pipes of various sizes; rock-cut and masonry canals; tunnels of over 2m height; inverted siphons up to 190m pressure with lead; and 155m pressure with stone pipes; and aqueducts of up to 40m height (Öziş, 2015). The Ottoman Empire expanded upon earlier systems, developing complex urban rainwater harvesting networks (Özgüler, 2017).

The Moroccan qanat system, locally known as “*khettara*” and originating from ancient Persia, plays a critical role in harvesting and managing rainwater and groundwater in Morocco (Mostafaeipour, 2010). The qanat technique taps into subterranean water in a manner that efficiently delivers large quantities of water to the surface without need for pumping. The water drains relying on gravity, with the destination lower than the source, which is typically an upland aquifer (Mostafaeipour, 2010). A dense series of vertical shafts, or wells, connects the tunnel with the surface and serves as construction & maintenance access shafts and regulates air pressure in the system; the uppermost part of these shafts is called the mother well (Beckers, Berking, & Schütt, 2013). At the exit of the qanat, the water is stored in a tank, whose paving is made of local stone elements laid out and chased with lead to prevent any loss (Reitano, 2011), or re-distributed directly to the users (Chaham, n.d). The Moroccan *khettara*, such as those on the margins of the Sahara Desert, the isolated oases of the Draa River valley and Tafilalet, play a critical role in irrigating agricultural lands (Mostafaeipour, 2010). They provide clean drinking water to rural communities and support livestock, which are essential for the local economy and are also an integral part of sustaining oasis ecosystems in Morocco (Lightfoot, 1996).

Tunisia, like other Mediterranean countries, also had to cope permanently with risks of droughts and perspectives of water shortage that constantly threaten

its water resources equilibrium (Omrani & Ouessar, 2008). A wide variety of traditional and contemporary water harvesting technologies, such as terraces, jessour, tabias, cisterns, gabion check dams and recharge wells were used (Ouessar, Sghaier & Fetoui, 2008). As noted by Ouessar, Sghaier & Fetoui (2008), the terraces were constructed on steep slopes using small retaining walls made of rocks to slow down the flow of water and to control erosion. Jessours were built in the inter-mountain run-off courses and consisted of a series of stone and earth walls, called tabias (or sed, katra), that were erected across the stream beds of narrow valley watersheds. Tabias are usually constructed on foothills, particularly in areas with rather deep soils and gentle slopes. The tabias collect and retain run-off water and silt washed down hillsides by rainfall, forming terraces in a stair-step fashion down the natural slope. Cisterns, locally known as fesquia or majel, were built to collect and store rainfall. The water was used for different purposes including domestic consumption, irrigation and for livestock.

3. Findings

Ancient rainwater harvesting systems in the Mediterranean are influenced by the climate of the area. Different rainwater harvesting structures were developed in the Mediterranean to prevent water scarcity and ensure the continuous availability of water during drought. Some of the systems developed include cisterns, tanks, aqueducts, canals, wells, dams, and tanks, which were designed in several sophisticated methods to ensure water purity and constructed with locally sourced materials such as stones and mortar. These systems utilized settling basins and the use of local materials such as sand and gravels, which allowed particles and sediments to settle before the water was stored and also obstructed the passage of impurities. Water was separated into storage system according to the purpose of use and this separation determined the sizes of the storage systems. Storage tanks were also often covered as another measure towards ensuring water purity. Several of these rainwater harvesting systems in each Mediterranean country perform the same functions but with different names and the origin of these systems is sometimes from a country in the Mediterranean. The analysis of the findings of the rainwater storage systems of each selected country is given in Table 1 – 5.

Table 1: Analysis of Italian rainwater harvesting systems

Italy	Traditional Rainwater Harvesting Systems
Storage system	Cisterns and wells
Material	Large stones, waterproof cement (opus signinum), mortar
Transportation system	Aqueducts (Pipes made of terracotta, stone, and wood were also used in Roman aqueducts and water supply (Deming, 2020)). The aqueducts rely on gravity to keep a constant

	flow of water over long distances as shown in fig 4. Roman aqueducts are thought to be constructed for military or bathing purposes rather than for the purpose of supplying drinking water or promoting hygiene (De Feo et al., 2010). One of the most famous Roman aqueducts is the Pont du Gard in France (fig. 5).
Filtering of Impurities	Settling basin technique, and the use of gravel, sand, tiles, and lime as filtering materials for larger debris.
Examples	Piscina Mirabilis Excavated in a tufa hill, the 72-meter-long and 27-meter-large Piscina Mirabilis (fig. 2) features two step entrances in the north-west and south-east corners (De Feo & Napoli, 2007). The barrel vault is divided into five principal aisles on the long sides and thirteen secondary aisles on the short sides by forty-eight pillars grouped in four rows, giving the structure the imposing appearance of a cathedral (De Feo et al., 2010). The cistern's north-west entrance allowed water to enter from the Serino aqueduct (De Feo & Napoli, 2007). Fig. 2: Piscina Mirabilis: Plan view (top), cross-section view (bottom) and interior (right) (Mays, Antoniou & Angelakis, 2013) Piscina Cardito In addition to storing water, the Piscina Cardito cistern (fig. 3), which is connected to the Campano del Serino aqueduct and divided into two sections (URL 1), was also used to purify water by dividing the second room into fourteen basins that are annexed to the main room, allowing for the sedimentation of debris (ArcheoFlegrei, 2022). The cistern, according to ArcheoFlegrei (2022), is roughly 60 by 15m in total size, with each room covered in a thick layer of opus signinum known as cocciopesto. The main structure is

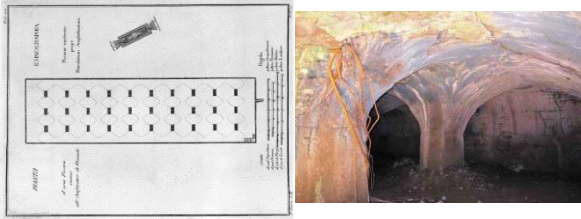
	composed of 30 brick pillars that support the roof vaults (URL 1).  The left image is a black and white architectural plan of the Piscina Cardito, showing a rectangular layout with a grid of 30 small squares representing pillars. The right image is a color photograph of the interior of the structure, showing the brick pillars supporting the vaulted roof. Fig 3: Piscina Cardito: Plan (left) (URL 1) and interior view (right) (ArcheoFlegrei, 2022)
	 The image shows a cross-section of a Roman aqueduct. On the left, a steep slope leads down to a channel. On the right, the channel is covered by a series of arches supported by pillars. Fig. 4: Section of a Roman aqueduct (Smith, 1978)  The image shows the Pont du Gard, a Roman aqueduct in France. It is a multi-tiered stone structure with several levels of arches, crossing a river valley. The surrounding area is lush with green trees and vegetation. Fig. 5: The Pont du Gard (Deming, 2020)

Table 2: Analysis of Greek rainwater harvesting systems

Greece	Traditional Rainwater Harvesting Systems
Storage system	Cisterns or wells, dams
Material	Stones, hydraulic mortar or thick lead sheet
Transportation system	Channels and pipes. Gravity-fed systems were used to minimize manual labor in water distribution.
Filtering of Impurities	The Greeks used covered channels, settling basins and designed the mouth of their water collectors narrowly (fig. 8) to ensure water purity.
Examples	Cistern at Delos The cistern (fig. 6) was used to collect rainwater that fell on the cavea of the theatre, which was then channelled into the 22.5m long by 6m wide slab-covered cistern (Mays,

Antoniou & Angelakis, 2013). Having eight arches that hold the roof and made from granite blocks, the cistern measures 8.3m deep and is capable of holding 270m³ of water (Cartwright, 2013).



Fig. 6: Cistern at Delos (Cartwright, 2013)

Orraon cistern

The cistern in Orraon (fig. 7) is a roofless cistern, located in the northeastern part of town, near the main gate, as it was the city’s highest altitude (Antoniou, Xarchakou, & Angelakis, 2006). It has a closure wall, built out of rectangular stones and limestone, and stairs, which allow residents to access the bottom of the tank to cleanse it and retrieve water (Zikakou, 2024). The enclosure wall is approximately 2m away from the edge of the cistern (Antoniou, Xarchakou, & Angelakis, 2006), and was built higher than the cistern to discourage people from throwing trash into the tank (Zikakou, 2024).

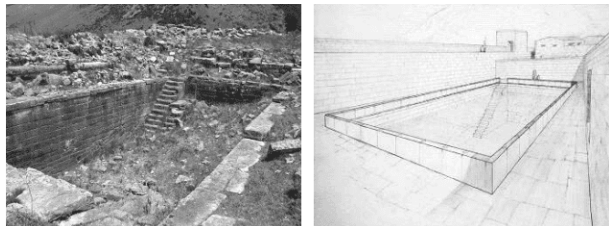


Fig. 7: Orraon cistern: view of the cistern (left) and after reconstruction (right) (Antoniou, Xarchakou, & Angelakis, 2006)

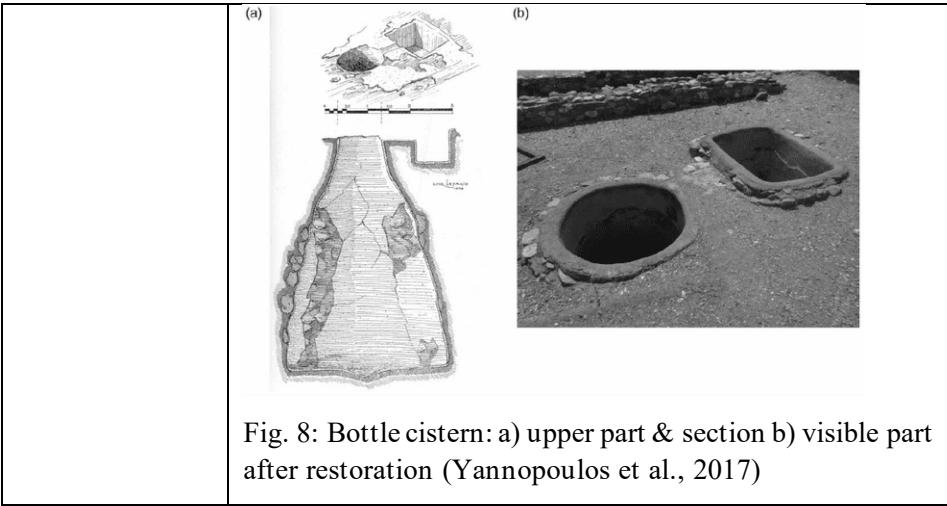


Table 4: Analysis of Spanish rainwater harvesting systems

Spain	Traditional Rainwater Harvesting Systems
Storage system	Cisterns, wells, tanks
Material	Stone, brick, and tile
Transportation system	Aqueducts (galleria). As claimed by Carrión et al. (2017) in their studies, some of the aqueducts in Spain have a total length of 1010m. An example of a Spanish aqueduct is the Mont Cada aqueduct shown in fig. 11.
Filtering of Impurities	-
Examples	The cistern of the Alcazaba de Mérida According to Gostomski (2020), there are two parallel staircases that lead to the subterranean cistern, which lies close to the riverside wall. The cistern (fig. 9) offers access to the river's water level and a number of springs that filter water from the river, resulting in high-quality drinking water (Daza-Pardo & Catalán-Ramos, 2024). The Guadiana River provides the water that filters into the cistern (Gostomski, 2020). The rear side of the galleries that descend to the cistern are constructed with well-squared ashlars, granite parallelepipeds, and other remnants of Roman architectural tradition (Daza-Pardo & Catalán-Ramos, 2024).

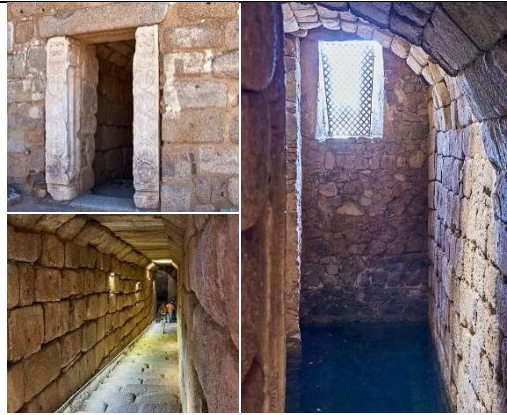


Fig 9: The cistern of the Alcazaba de Mérida: Entrance to the cistern (top left), one of the staircases to the cistern (bottom left), and interior of the cistern (right) (Gostomski, 2020)

Moorish Cistern of Cáceres

The cistern (fig. 10) stretches over 45 feet long and 32 feet wide, and is built with recycled materials from ancient Roman and Visigoth structures (Morato, 2019). Its northwest and northeast wall were dug into the rock, its two remaining sides were closed with 1.5 m thick walls, and its floor was levelled by digging into the ground to resist the massive pressure of water (URL 2). The cistern is adorned with Arab-style horseshoe arches resting on a compact floor made with 30cm of mortar to waterproof the tank (Morato, 2019) and has a slight incline towards the southern side to allow emptying (URL 2).



Fig 10: A view of the Moorish cistern of Cáceres (Janis, 2023)

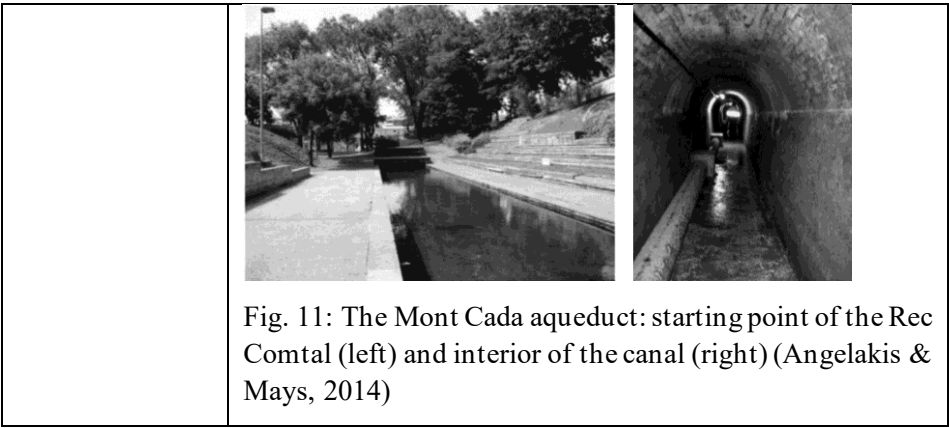


Table 5: Analysis of Turkish rainwater harvesting systems

Turkey	Traditional Rainwater Harvesting Systems
Storage system	Tanks and cisterns
Material	Stone, lead, and clay
Transportation system	Canals and aqueducts.
Filtering of Impurities	-
Examples	Kartça su sarnıcı The Kartça cistern (fig. 12) has a dome roof joined to a gable roof, with a doorway immediately followed by a twelve-step staircase descending to the bottom of the cistern. This staircase gives access to water when the water level is low. The materials used for its construction are limestones and slates. It can be predicted that water was purified using the settling basin method.

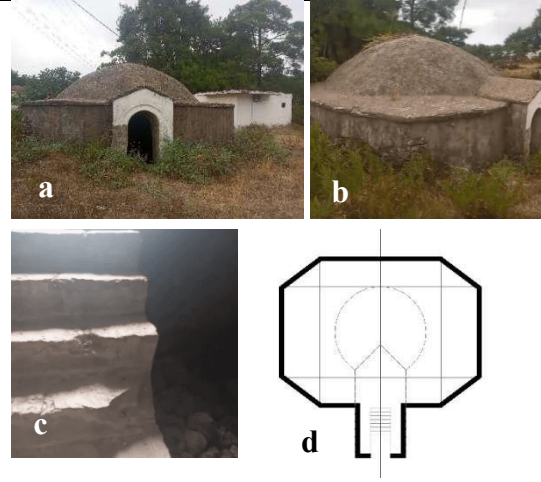


Fig 12: Kartça su sarnıcı a. exterior view showing doorway b. dome and gable roof c. stairs leading to the cistern d. floor plan sketch (Author's field work, 2024)

Mecveddin Cistern

As described by the Alanya Belediyesi, built on a natural rock, the Mecveddin cistern (also called Mecdüddin cistern) (fig. 13) is a barrel vaulted structure with a rectangular plan measuring 13 x 22.20m and consists of two large spaces covered with interconnected pointed arched vaults. The cistern, which is quite deep, can be accessed via two separate staircases located on the north and south sides. The supporting pillars and vault arches of the structure are made of cut stone, while the vault cover is made of brick. A small section with raised walls on the west side gives the cistern a U-shape. The corners and door openings of the rubble stone walls remaining above the ground are made of brick. The walls are covered/joined with horasan mortar plaster and brick is frequently used as a filling material. There are three water intake chimneys and one water leaking hole on the upper portion of the cistern. The chimney edges are made of brick and their tops are specially made of sandstone in a round shape. The walls on the sides of the structure are elevated two meters above the ground to protect the region where water is collected.

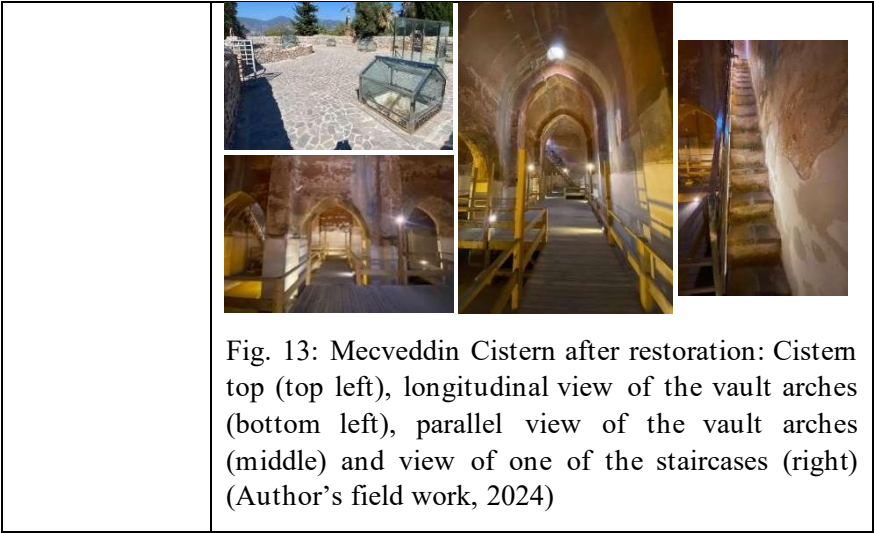


Table 6: Analysis of Moroccan rainwater harvesting systems

Morocco	Traditional Rainwater Harvesting Systems
Storage system	Tanks/Cisterns
Material	Stone, lead
Transportation system	Qanats (khattara). They rely on gravity to drain water and are usually 60–100cm wide, 90cm to 1.5m high, and the length vary from less than 1–80 km (Mostafaeipour, 2010). Fig. 16 shows the construction of a qanat and fig. 17 shows one of the Moroccan khattarras.
Filtering of Impurities	Sedimentation tank and self-purification are relied on during storage (Gougueni et al., 2023). The water naturally filtered through layers of soil and rock as it flows through qanats.
Examples	The Sidi Bou Othmane Cisterns The system used in Sidi Bou Othmane occupies an area of 1300m² and is based on cisterns carved into rocks (Ascanio-Sanchez, Bosa & Pérez, 2019). With a total capacity of 2130m³, the Sidi Bou Othmane cisterns (fig. 14) are made up of two dams, conduits, and a row of nine cisterns set parallel to one another (Couscous, Baali, & El Kamel, 2020). The cisterns are each 4m wide, 5m tall, and 25m long, with several openings in the roof and are separated by 1.5m thick wall (URL 3).



Fig. 14: The Sidi Bou Othmane cisterns: Cistern roof (left) and its interior (right) (Carlos, 2017)

Matfia Cisterns

Matfia Cisterns (fig. 15) are subterranean or above-ground cisterns that receive rainwater from channels called “Segouia or Mejleb” (Matfias Rural Water Reservoirs, n.d.) and are used to retain rainwater to meet household, livestock and garden irrigation needs (Gougueni, et al., 2021). A Matfia cistern comprises of a settling tank, a door and an underground reservoir combined with a rectangular or square shaped collection surface called “Impluvium” which can reach an area of up to 800m² (for collective Matfias). Usually made of stone or cement, the cistern basin has a cemented floor and is surrounded by a low wall that is between 50 and 60 cm in height (URL 4).



Fig. 15: Above ground view of a Mafia cistern (URL 4)

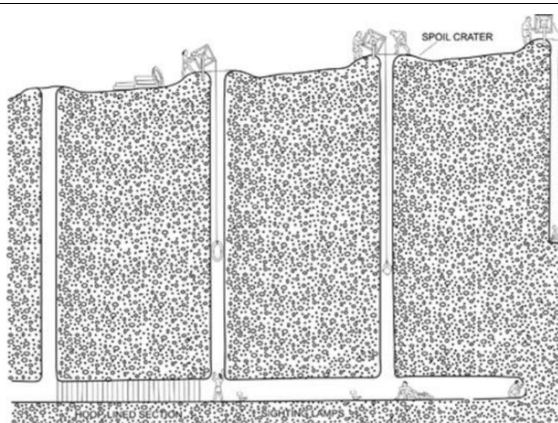


Fig. 16: Constructing a qanat (Angelakis & Mays, 2014)

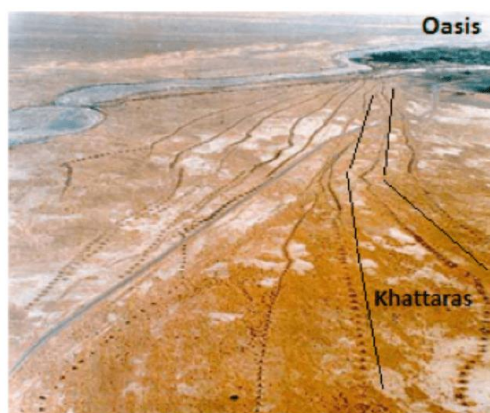


Fig. 17: Aerial view of the Tafilalt khattaras alignment (Chaham, n.d)

Table 7: Analysis of Tunisian rainwater harvesting systems

Tunisia	Traditional Rainwater Harvesting Systems
Storage system	Tabias and cisterns
Material	Stone, earth walls and cement
Transportation system	Lead pipes, jessours
Filtering of Impurities	The settling basin principle was used to ensure water purity. Examples of a cistern designed with such principle are the cisterns at Dar Saniat at Carthage (fig. 19).
Examples	Aghlabid Cisterns

According to Taotaoholmes (2016), the Aghlabid Basins (fig. 18) consist of two interconnected cisterns that collectively constitute an open-air reservoir. The small cistern, with a capacity of 14m^3 , measures 17m in diameter and is reinforced with 17 internal and 26 external buttresses (Jamila, 2024). Sediments are allowed to settle out of the water (sourced from rain and the wadi Merguell via a set of small dams and a canal) in the small pool until a certain level is reached, of which the water is then transferred to the large pool through an opening known as esarh (the outlet) (Archnet, n.d.). The large cistern, measuring 128m in diameter and 4.8m deep, is circular in shape, has 182 buttresses, and can hold $57,000\text{m}^3$ of water—enough to store the water needed for everyday life in towns (Jamila, 2024).

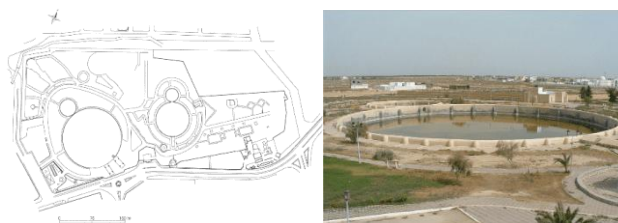
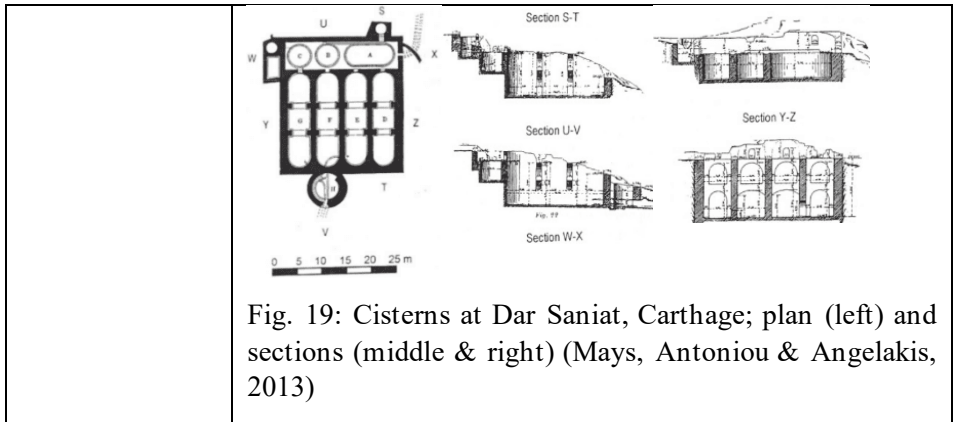


Fig. 18: Aghlabid Cisterns: plan (left) and a view of the reservoirs (right) (Jamila, 2024)

Cisterns at Dar Saniat, Carthage

The Dar Saniat cisterns in Carthage were built with two storage reservoirs and three settling basins, each with two compartments and a $2,780\text{ m}^3$ total storage capacity (Mays, Antoniou & Angelakis, 2013). Water from an aqueduct enters the oval settling tank A, as seen in fig. 19, where it deposits silt before entering the first two-chamber reservoir (D and E). The oval settling tank has a second outlet that directs some of the water into two circular settling tanks (B and C) in turn, decanting the water twice more before it enters the second reservoir (F and G), which holds water that has been more fully cleansed (Wilson, 2001).



4. Result and Discussion

Research into the history and practices of rainwater harvesting systems in the Mediterranean region reveals a rich tapestry of the methods and innovations developed to cope with water scarcity. These systems were vital for sustaining several purposes, such as agriculture, provision of drinking water and supporting urban populations in an area frequently characterized by seasonal rainfall and prolonged dry periods.

In Italy and Greece, sophisticated storage systems were developed such as cisterns and wells. These systems were constructed from stones and stored rainwater transported from other systems. The Italian storage systems stored rainwater transported through aqueducts while those of Greece stored rainwater transported through channels and pipes. The water transportation systems in the two countries both relied on gravity to ensure the constant flow of water and also used settling basin techniques for water purification. Water purification techniques in Italy also included the use of a more controlled method involving materials like sand, gravel, tiles, and lime to obstruct the passage of larger debris. One of the other purification techniques used in Greece is the design of narrow water collectors, which ensured the exclusion of larger debris. The Italian rainwater storage systems had influence on those of Spain as civilizations after the Romans in Spain worked on improving already established Roman structures. It is believed that most of the rainwater structures in Italy and Spain probably followed the same method of construction. Even though it is not clear whether the Arabs or Romans introduced aqueducts to Spain, the agreed claim is that the method of constructing these structures relied on both the Arab and Roman methods.

Similarly, advanced rainwater harvesting systems were also developed in Turkey. The development of Turkish rainwater harvesting systems were influenced by different civilizations including the Romans and Greeks. Although earlier evidence of rainwater systems dates back to ancient Anatolian

civilizations, the influence of the Roman and Greek civilizations led to the modifications in designs of these systems and introduction of systems already developed in Italy and Greece.

Morocco and Tunisia employed unique methods suited to their specific environmental conditions. The Moroccan qanat system, with its underground channels and origin in Persian civilization, exemplifies an efficient method of transporting water in arid regions, along with the jessours in Tunisia. The Moroccan qanats empty their water into tanks and rely on gravity to produce the needed pressure for water movement. Tunisian storage systems consisted of several cisterns with different functions. The reason for this is to ensure water purity by which a cistern holds water for a specific period before being transported to another cistern. This method, called settling basin, ensures the sedimentation of impurities before transportation. Self-purification was relied on for the removal of sediments in Morocco and the water from the qanats was sometimes redistributed directly to the users without storage.

The systems used for rainwater harvesting in the selected countries show similarities in materials used for construction and variation in water storage capacity according to the use of water. Even though the materials bear similar names, differences such as colour and porosity were observed between them. The differences and similarities observed are shown in table 7.

Table 7: Differences and similarities in rainwater harvesting systems used in the selected countries of the Mediterranean

	Storage system	Material	Transportation system	Filtering of impurities
Italy	Cisterns and wells	Tufa stones, cement, mortar	Aqueducts	Settling basin technique, gravel, sand, tiles, and lime
Greece	Cistern, wells, dams	Limestone, hydraulic mortar, or thick lead sheet	Channels and pipes	Settling basins and narrowly design of the mouth of water collectors
Spain	Cistern, wells, tanks	Cut stone, brick, and tile	Aqueducts (galleria)	-
Turkey	Tanks and cisterns	Cut & slate stones, lead, and clay	Canals and aqueducts	-
Morocco	Tanks	Local stone, lead	Qanats (khettara)	Sedimentation tank, self-purification using layers of soil and rock
Tunisia	Tabias and cisterns	Stone, earth and walls and cement	Lead pipes, jessours	Settling basin

It can be seen that harvesting rainwater was important for ensuring the continuous availability of water in the Mediterranean. Even with less technological advancement, several methods were put in place to ensure water purification as shown in table 7. Integrating elements of these practices into contemporary rainwater harvesting systems will help reduce major urban problems such as flood and climate change. Lessons from ancient Mediterranean rainwater harvesting practices that can be incorporated into contemporary rainwater systems are outlined below.

1. Underground cisterns can be integrated with park designs and public spaces by replacing fountains with rainwater harvesting structures. The designs of these structures should include the functions of fountains such as beautification of space and the provision of calming sounds and relaxing ambience.
2. Natural water purification techniques like water passing through sand, gravel, lime, and settling basins are environmentally friendly and cost-effective. Contemporary rainwater systems can use these techniques as pre-filtration methods before storing water in cisterns.
3. Terraces, known as jessours, were used in Tunisia to slow down runoff and also increase water infiltration. Terraced landscapes, artificial hills, and permeable pavements can be used in city designs to slow down runoff, increase rainwater infiltration, support green infrastructure, and also reduce the impacts of floods.
4. The Romans and Greeks relied on gravity for transporting water. Water transportation systems, such as aqueducts, were sloped in directions where cisterns were located. Low Impact Development (LID) techniques not limited to green roofs, rain gardens, and bio-retention cells can all be integrated into urban landscapes to harvest, filter, and store rainwater.

In conclusion, the history of rainwater harvesting systems in the Mediterranean shows a legacy of creativity, flexibility, and teamwork in the management of one of the most important resources, water. In addition to providing for the immediate demands of that time, these antiquated technologies established the foundation for modern sustainable methods of managing water resources.

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CHAPTER 2

The Aristocrat of Mud: Hassan Fathy and the Paradox of Architecture for the Poor

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Introduction

Hassan Fathy is often regarded as a "lonely guru" or a prophet of vernacular architecture who challenged the universalising tenets of Western Modernism (Ismail Serageldin, 2007). His critique was not only stylistic but also deeply ideological, in which indigenous practices were seen as an antidote to the alienating effects of industrialized building. Born in 1900 in Alexandria to a wealthy family, he was educated as an aristocrat within a westernised elite environment under the Beaux-Arts system (Ismail Serageldin, 2007), (Miguel Guitart, 2014). Despite this cosmopolitan background, his career was defined by a quest to provide economical, sanitary, and culturally sensitive housing for the rural poor (Miguel Guitart, 2014). This European pedagogical framework defined the parameters of classical symmetry and monumentalism, very different from the organic, localized aesthetics he would promote later.

His architectural philosophy rested on the "trinity" of architect, builder, and user, advocating for participatory design and the revival of traditional village crafts (Ismail Serageldin, 2007). Fathy sought to democratize building, to close the gap between the professional elite and the agrarian working class, by enabling communities to build their own homes out of locally available materials such as mud brick (adobe). He understood that real architectural sustainability could not be imported; it had to emerge from the soil and the social fabric of the community. However, his legacy is deeply complex; he is simultaneously viewed as a pioneer of appropriate technology and a romanticist whose "invented traditions" were often rejected by the very people they were meant to serve (The Cairo Observer, 2016). To some critics, his stress on Nubian vaults and domes was an idealized projection of an idyllic past, rather than a pragmatic response to the desires of a rural population demanding modern, concrete symbols of upward mobility. This article synthesises these competing narratives to provide a multi-dimensional portrait of his impact on 20th-century architecture.

2. Historical Review: Postwar Identity and Global Development

Fathy's emergence as a social architect coincided with a period of nationalistic reawakening in Egypt following years of British occupation (Miguel Guitart, 2014). This geopolitical shift brought with it the intellectual urgency of decolonizing Egyptian culture and creating an authentic self-determined architectural language. In the 1940s, Egypt faced acute housing shortages, land disparities, and uncontrolled urbanization (Panayiota Pyla, 2009), problems that were hugely exacerbated by the widespread poverty in the countryside and lack of state infrastructure. The ruling elite largely embraced Western customs, leading to what many saw as a cultural identity crisis (Miguel Guitart, 2014). This upper class obsession with European styles further marginalised indigenous practices, as they were seen as outdated and inferior. Fathy proposed a return to the past, not as a stagnant tradition, but as a "historical continuum" necessary to

shape a modern Egyptian identity (Miguel Guitart, 2014), arguing that real progress could be achieved only by building on ancestral knowledge and not by borrowing foreign models.

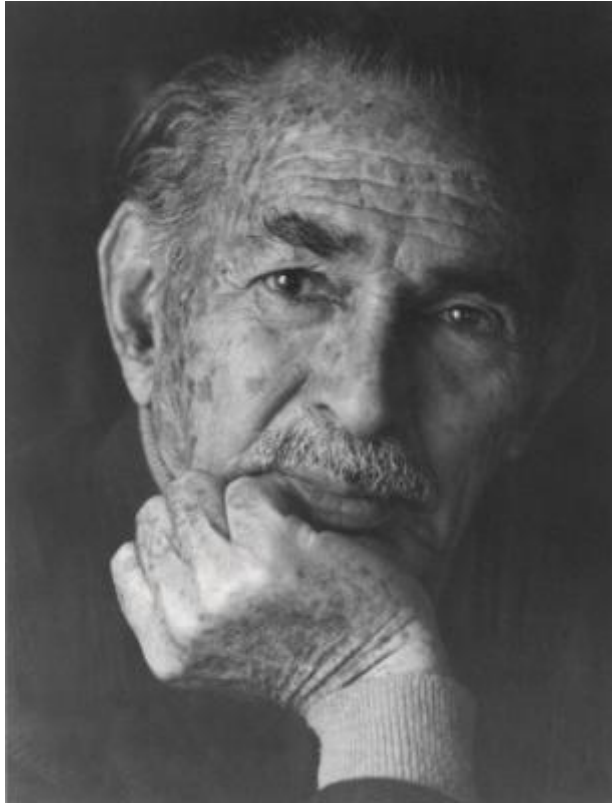


Figure 1. The architect Hassan Fathy (Christopher Little, 1984).

Following the 1952 revolution and the rise of Gamal Abdel Nasser, Fathy entered a self-imposed exile in Greece in 1957 (Panayiota I. Pyla, 2016). Ideological friction with the new regime's preference for state-led, industrial concrete development. He joined the firm of Constantinos Doxiadis, where he attempted to align his vernacular sensibilities with "**Ekistics**"—the science of human settlements (Panayiota I. Pyla, 2016). This collaboration challenged Fathy to extend his organic, craft-based philosophies to apply to large scale and systematic master planning. During this period, he moved from being a local Egyptian architect to a global "housing expert," designing mass housing for Iraq and Pakistan (Panayiota I. Pyla, 2016). This era was crucial as it forced Fathy to rationalise his preferences for mud brick and courtyards through scientific data and quantifiable thermal performance (Panayiota I. Pyla, 2016). He translated traditional architectural passive cooling techniques into engineering metrics, and

was able to convince an international, technocratic audience that the vernacular methods were thermodynamically superior to modern concrete structure.

3. The Works of Hassan Fathy: From Dreams to Reality

Fathy's body of work, though numbering only about 30 built projects, had an outsized impact on architectural discourse (Ismail Serageldin, 2007) (Panayiota I. Pyla, 2016).

3.1 New Gournia Village (1945–1948)

Commissioned by the Egyptian Department of Antiquities to relocate villagers living atop Pharaonic tombs, New Gournia utilized sun-dried mud bricks (adobe) and Nubian vaulting techniques (Panayiota I. Pyla, 2009). This design avoided costly and imported materials such as steel and cement and instead took advantage of the local earth and the expertise of masons in Upper Egypt. The village included a mosque, market, theatre, and school, all organized around traditional courtyards (Panayiota I. Pyla, 2009). These common spaces were designed to foster social cohesion and to preserve the familiar spatial hierarchies of rural Egyptian life. The formal character reflected Fathy's aesthetic sensibilities, combining masterful domes with a sensitive play of shade and light (Panayiota I. Pyla, 2009). This created a microclimate that passively reduced indoor temperatures relative to the blistering outdoor heat. However, the project was never completed; the villagers, resenting the forced relocation and associating domes with funerary architecture, sabotaged the site by flooding it (Panayiota I. Pyla, 2009). This resistance revealed a profound ideological divide: Fathy saw the domes as a triumphant revival of historic peasant crafts, while the local population linked them with death, mourning and institutional dislodgement.

3.2 Greater Mussayib, Iraq (1957)

Working with Doxiadis, Fathy proposed new villages for 3,000–5,000 households. He analyzed the *badgir* (wind-catcher) as a traditional solution that could be adopted for mass housing, instructing research centres to test its efficiency "under the light of scientific observation". Fathy attempted to bridge the gap between traditional cultural heritage and modern empirical science by treating these ancient architectural features as testable thermal engineering systems. He attempted to standardise the courtyard house for mass production, though the firm often stripped his designs of tectonic detail to fit the mass production logic (Panayiota I. Pyla, 2009). This institutional stripping foregrounded a tension that would run throughout Fathy's career: the corporate, assembly-line mechanics of Doxiadis's firm were fundamentally at odds with Fathy's deeply rooted belief in individualized, participatory hand-craftsmanship.

3.3 New Bariz (1967) and Dar al-Islam (1980)

New Bariz, designed for the Kharga Oasis, featured sophisticated natural cooling systems based on scientific principles of air movement. Here, Fathy combined massive wind vents and shaded public loggias (open-sided galleries) to successfully reduce interior temperatures several degrees without electricity. The 1967 Arab-Israeli War, another of his visionary public experiments failing because of regional geopolitical instability, halted construction. Later, the Dar al-Islam Foundation in New Mexico demonstrated the supranational aspirations of his methods, as Fathy taught American artisans the principles of mud brick construction (Panayiota I. Pyla, 2009). The international project proved that his philosophy of earth-based architecture was not limited to Egypt, but could be translated around the world as a universal model for ecological sustainability.

3.4 Residential Architecture for the Elite

Ironically, many of Fathy's most celebrated built works were private residences for the wealthy, such as the Akil Sami House (1978), which used limestone due to a government ban on mud-brick, and the Mit Rehan (1982), which owner-oversight rendered one of his most elegant residential works (Panayiota I. Pyla, 2009). This paradox clouded his image as an architect for the poor, for while rural communities regularly turned down his mud-brick villages, the educated, cosmopolitan elite embraced his work with enthusiasm, seeing his vernacular designs as high-status symbols of cultural authenticity.

4. Analysis: Science, Tradition, and Controversy

4.1 Thermal Performance and Materiality

Fathy justified the use of mud not just as a traditional material, but also as a superior technical one (Janmejy Gupta, 2023). He found that industrial materials like concrete and corrugated iron absorbed and radiated heat quickly, rendering modern buildings in desert climates practically uninhabitable without mechanical air conditioning. Research confirms that mud brick has a high thermal mass, which naturally regulates interior temperatures by shifting the "thermal lag" (Janmejy Gupta, 2023). That means the material acts as a thermal sponge, soaking up the intense heat of midday within the thick walls, and then slowly releasing it into the living spaces during the cold desert night. In winter, the thermal time lag keeps interior temperatures at approximately 13°C even when outdoor temperatures drop to 3°C (Janmejy Gupta, 2023). Fathy's courtyards were designed to manipulate air pressure and provide natural ventilation (Janmejy Gupta, 2023), using microclimatic zoning, drawing cool air from the shaded courtyard into adjacent rooms as warm air rises and escapes.

4.2 The "Architecture for the Rich" Paradox

A major critique of Fathy's legacy is that while he designed for the poor, his most well maintained buildings are private residences for the urban elite (Ismail Serageldin, 2007). Some architectural historians have characterized his career as a tragic contradiction in which wealthy clients looking for an aesthetic escape from westernized urban sprawl ultimately commodified his egalitarian theories. Critics argue that his refusal to provide modern amenities like running water—which he saw as a threat to traditional social rituals—made his designs impractical for the masses (Panayiota I. Pyla, 2016). His concern for historical authenticity and not just domestic convenience meant that he unintentionally compelled the disenfranchised rural population to sacrifice modern comfort to preserve his idealized perception of community. His students defend this by claiming he built for the rich to establish a "trend" that the poor would copy (The Cairo Observer, 2016), that adoption of mud-brick architecture by high society figures would strip the material of its lower-class stigma, making vernacular housing aspirational rather than shameful.

4.3 The "Invented Tradition" and Paternalism

Scholars have noted that Fathy's "Egyptian tradition" was a hybrid that combined Mamluk Cairene courtyards with Nubian domes, a style alien to the Saidi villagers who associated domes with mosques and tombs (The Cairo Observer, 2016). This architectural conflation meant that he was imposing a generalized, pan-Islamic vocabulary on regional communities that had completely different cultural sensibilities and domestic needs. Furthermore, New Gurna is often viewed as a "colonial project" in its approach, as Fathy imposed his vision on a local population following state orders rather than following the residents' desires (Miguel Guitart, 2014). Instead of creating genuine grassroots empowerment, Fathy assumed a very paternalistic role as a top-down state agent who knew best what was good for the community without actively taking their vocal protests into account in his master plan.

5. Adobe (Sun-Dried Mud Brick): Properties and Performance

"Sole hope for rural reconstruction," Hassan Fathy believed, was "mud brick" (Hassan fathy, 1976). His liking of this material was not aesthetic or sentimental but because of its physical qualities and its potential for economic emancipation (Hassan fathy, 1976).

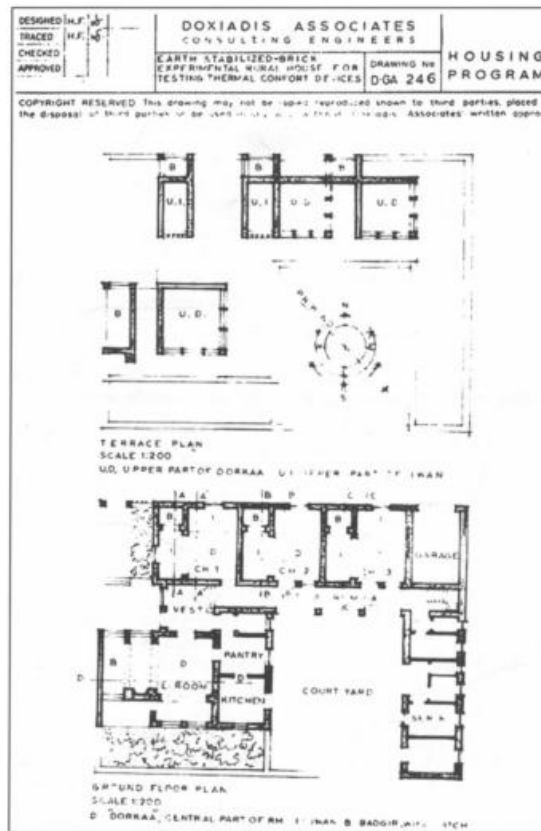


Figure 2. Fathy's experimental rural house. For the purposes of this experiment, each room had a wind-catcher fitted with different designs of air cooling arrangement so as to determine the most effective one (1958). (Courtesy Hassan Fathy Archive.), (Panayiota I. Pyla, 2007).

5.1 Physical and Structural Characteristics

Adobe is a mixture of clay soil, water, and sometimes straw which is dried under the sun and not fired in a kiln (Janmejoy Gupta, 2023).

- **Plasticity and Versatility:** Mud is highly plastic and can be used to make a wide range of structures from desert huts to multi-storey homes (Janmejoy Gupta, 2023).
- **Nubian Vaulting:** Fathy brought back the old Nubian method of making catenary vaults and domes from mud bricks (Hassan fathy, 1976). The innovation in the structure was important because it allowed for roofing without the expensive and rare timber or steel centering (Panayiota I. Pyla, 2007).
- **Compressive Strength:** Mud-brick has its limits, but Fathy demonstrated that when combined with appropriate vaulted geometries it can support significant loads without industrial reinforcement (Miguel Guitart, 2014).

5.2 Thermal Efficiency and Environmental Performance

Fathy defended the use of mud as a technically better material for hot-arid climates.

- **Thermal Mass:** Mud brick is a material with high thermal mass. This means that it is a “thermal sponge,” storing heat during the day and releasing it slowly at night.
- **Thermal Lag:** Studies show that the “thermal lag” is changed by the mud walls so that the temperatures inside remain constant (Janmejy Gupta, 2023). For example, the temperature outside in winter can be as low as 3-4°C, but mud dwellings can be as warm as 13°C inside.
- **Conductivity:** Mud has a thermal conductivity (K-value) of about 0.6 Watt/Metre Kelvin that is much lower than RCC (1.582) or normal brick (0.811) (Janmejy Gupta, 2023).

5.3 Sustainability and Economic Benefits

Fathy had several reasons for preferring adobe to traditional materials:

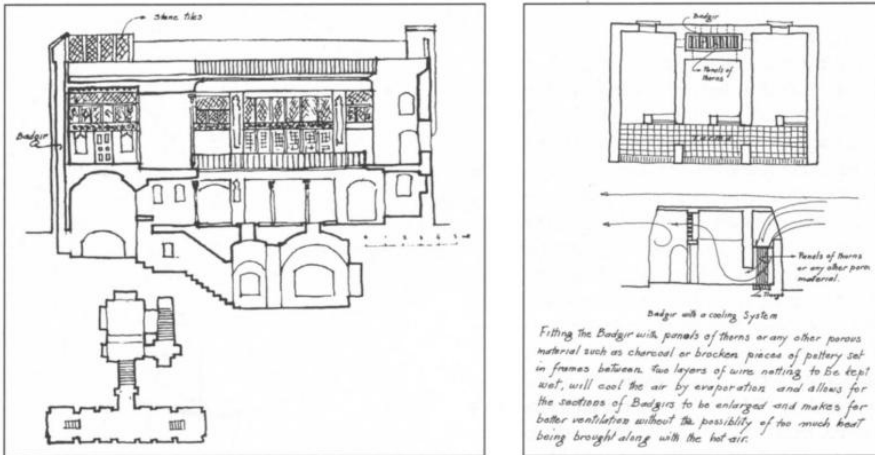


Figure 3. Fathy's studies of the Badgir and his proposed improvement. Fathy explained that the traditional badgir had a small outlet that limited airflow; he suggested the enlargement of the badgir and the inclusion of devices to cool the increased quantities of hot air (1957). (Courtesy Hassan Fathy Archive.), (Panayiota I. Pyla, 2007).

- **Low Embodied Energy:** Adobe requires little energy to be produced and transported compared to concrete or steel, as the soil is usually extracted from the building site (Panayiota I. Pyla, 2009).
- **Affordability:** It is the most easily available and cheapest material for rural population (Janmejy Gupta, 2023). Fathy said that the administration was often against mud bricking because contracts with cement and steel companies made bigger dollars (Miguel Guitart, 2014).

- **Hygroscopic Properties:** Earthen materials have an inherent ability to regulate the interior relative humidity, resulting in better indoor air quality (Janmejy Gupta, 2023).

6. Architectural Relationships and Design Principles

Fathy's approach was a "blend of social realism and utopianism." His principles of design were directed towards the reconciliation of cultural identity and climatic necessity (Miguel Guitart, 2014).

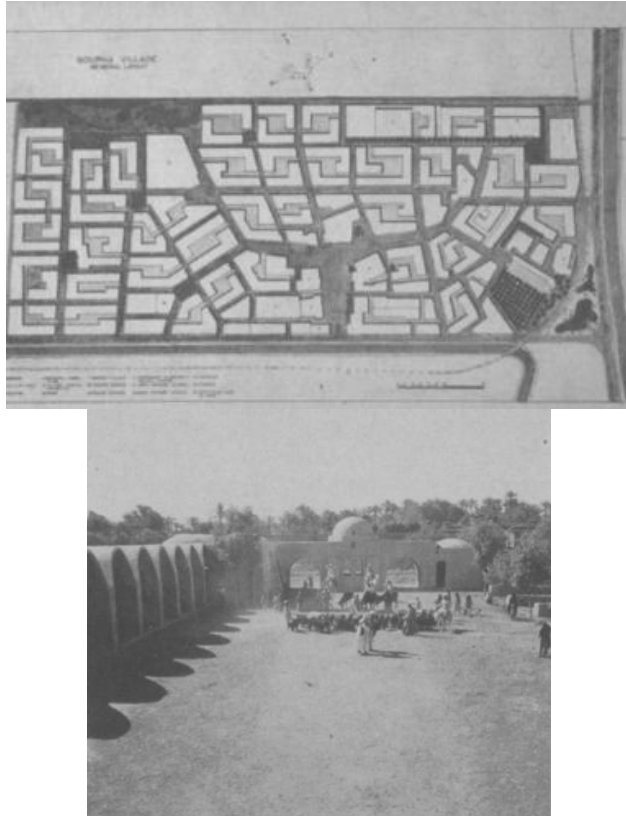


Figure 4. New Gourna, master plan and photo of built parts (1945 and 1968). (Courtesy Hassan Fathy Archive and Papademos Archive.), (Panayiota I. Pyla, 2007).

6.1 Spatial Organization and the Courtyard

Fathy's residential buildings were organized around the internal courtyard (Panayiota I. Pyla, 2007).

- **Microcosm:** Fathy considers the courtyard to be a "microcosm that parallels the order of the Universe" (Panayiota I. Pyla, 2007).

- **Privacy and Social Rituals:** The courtyard was a private outdoor space for families, especially in Mamluk Cairene houses, which were sensitive to the local demand for women's privacy (Panayiota I. Pyla, 2007).
- **Hierarchy of Space:** His plans had a clear sequence from public squares to semi-public streets to private courtyards (Panayiota I. Pyla, 2007).

6.2 Passive Environmental Strategies

Fathy incorporated many traditional passive cooling devices in his forms:

- **The Badgir (Wind-Catcher):** These are roof-mounted vents, which pull cool prevailing winds down into the living spaces (Hassan fathy, 1976). Fathy tried to “scientifically observe” and increase their efficiency by adding cooling devices such as wet charcoal or porous pottery to the airflow (Panayiota I. Pyla, 2007).
- **Mashrabiyya:** Fathy used traditional wooden lattice screens to filter light and increase air pressure, which cools the air by suction. He adapted it into mud-brick versions (Miguel Guitart, 2014).
- **Thermal Massing:** The thick mud walls were the primary defence against the desert sun as mentioned above (Panayiota I. Pyla, 2007).

6.3 The "Trinity": Architect, Builder, and User

Fathy's most revolutionary principle was the reestablishment of the "trinity" of owner, architect and artisan.

- **Participatory Design:** He advocated for ‘aided self-help’ where the villagers themselves would participate in the designing and building of their homes (Ismail Serageldin, 2007).
- **Training:** Fathy provided on-the-job training in traditional crafts such as vaulting to empower the community economically and psychologically (Hassan fathy, 1976).

7. Documentation and Analysis Software

The sources do not include information on the use of Adobe Photoshop, Illustrator or InDesign software in the documentation or research process of Hassan Fathy. Most of Fathy's work dates from the 1940s to the 1980s, before professionals commonly used these digital devices. Sources include historical photographs, hand-drawn architectural plans, and scientific charts produced for Doxiadis Associates (Panayiota I. Pyla, 2007).

8. Key Findings and Outcomes

The study of Hassan Fathy's work reveals a complex legacy of theoretical success and practical friction.

Table 1. Thermal Conductivity (K Values) of Building Materials (Janmejoy Gupta, 2023).

Building Material	Thermal Conductivity (k) (Watt/Metre Kelvin)
Mud (Adobe)	0.6
Thatch	0.35
Brick (Fired)	0.811
Window Glass	0.815
Cement Mortar	0.951
RCC (Reinforced Concrete)	1.582
G.I. Sheet	60.47

8.1 The "Failed Utopia" of New Gourn

- **Outcome:** The relocation project was interrupted in 1948 and remained largely uninhabited by the original target population (Panayiota I. Pyla, 2007).
- **Reasoning:** The villagers sabotaged the project because they associated Fathy's domes with funerary architecture and resented the forced relocation (Panayiota I. Pyla, 2007).
- **Significance:** New Gourn became a "theatre of ideas," successfully challenging High Modernism in international academic circles even if it failed as a social experiment (Panayiota I. Pyla, 2016).

8.2 The "Architecture for the Rich" Paradox

- **Outcome:** Fathy's most well maintained surviving works are private villas for the elite rather than housing for the poor (Panayiota I. Pyla, 2016).
- **Significance:** This created a new "Hassan Fathy Style" that became a status symbol for the urban rich seeking cultural authenticity (Panayiota I. Pyla, 2009).

8.3 Fathy as a Pioneer of Sustainability

- **Outcome:** Fathy is now internationally recognized as a pioneer of green architecture (Ismail Serageldin, 2007).
- **Significance:** His focus on **embodied energy, local materials, and passive energy systems** provides a vital template for addressing the 21st-century housing and climate crisis (Ismail Serageldin, 2007).

9. Results: Impact on Modern and Sustainable Discourse

Alternative Modernism: Fathy’s 1973 book arrived as the "International Style" was being challenged, making him a hero of the Post-Modern movement (Panayiota I. Pyla, 2016). His landmark publication, Architecture for the Poor,

served as a powerful critique against the uniform, concrete boxes that were dominating global landscapes. At a time when architects worldwide were growing disillusioned with the cold, sterile uniformity of corporate Modernism, Fathy offered a poetic and functional alternative that celebrated cultural specificity, regional identity, and historical memory. He demonstrated that architectural modernism need not equate with Westernization or industrial standardization and justified the use of indigenous forms – vaults, arches, microclimatic courtyards – as valid expressions of contemporary design.

Pioneer of Sustainability: His work was an early model for green architecture, using local materials and passive energy to reduce the “embodied energy” of a building (Panayiota I. Pyla, 2009). He almost eradicated the enormous carbon footprint of producing and transporting industrial materials like steel, concrete and fired bricks, by advocating the use of sun-dried mud bricks (adobe) from the very earth beneath the building site. Furthermore, his reliance on passive cooling and heating strategies displayed a profound understanding of thermodynamics. Instead of relying on energy-intensive mechanical air conditioning units, Fathy used architectural geometry, thick thermal massing, wind-catchers (*badgirs*), and strategically oriented courtyards to regulate indoor microclimates naturally. In an era currently defined by climate change and skyrocketing energy costs, his empirical approach offers invaluable, low-tech solutions for creating climate-responsive, low-carbon human settlements.

Participatory Design: He was a pioneer of the architect as “facilitator” rather than a top-down master planner, a concept that is now central to humanitarian architecture (Ismail Serageldin, 2007). Instead, he advocated a bottom-up, community-based approach in which the architect works directly with local residents, involving them in the physical design, planning and construction of their own homes. When he taught the villagers traditional crafts such as Nubian vaulting, he did not just build. He gave back vital skillsets to the community, creating economic independence and a profound psychological ownership.

10. Conclusion

Hassan Fathy remains an enigmatic figure whose contributions transcend his built works (Ismail Serageldin, 2007). His true monument is not a vast portfolio of completed buildings, but the enduring shifts of mind he provoked in the international design dialogue. While projects like New Gurna failed as social experiments in their time, they succeeded as **"theatres of ideas,"** forcing the architectural world to reconsider local knowledge and the human dimension of shelter (Panayiota I. Pyla, 2016). These physical sites were living manifestos that exposed the psychological, cultural, and political frictions that occur when an architect attempts to translate abstract communal ideals into tangible reality. They

proved that housing is not a technical problem of arranging bricks and mortar but a complicated sociological negotiation, intimately bound to the identity, memories and explicit consent of those who live in it. His collaboration with Doxiadis proves that he was not an "anti-modernist" but rather a critic who sought to reform modernity from within (Panayiota I. Pyla, 2016). Fathy was not calling for a naive, regressive retreat from modern life, but for a more scientifically rigorous and humanistic modernization. As the world faces a 21st-century housing crisis and climate change, Fathy's "revisited" methods provide a vital template for an ecologically and culturally sustainable future (Janmejy Gupta, 2023). His preoccupations with zero-carbon materiality and self-build empowerment have never felt more radical, in an era now plagued by the shocking carbon emissions of the global construction industry and a dire lack of dignified urban housing. Fathy's legacy is ultimately a plea for contemporary architects to reject top-down paternalism and corporate conformity, and it provides a rich pathway for a future where architecture celebrates the planet, empowers the disempowered, and respects the irreplaceable cultural fabric of human settlements.

Hassan Fathy remains an enigmatic figure whose influence transcends his 30 built projects (Ismail Serageldin, 2007). While his attempt to impose "invented traditions" on rural populations met with resistance, his calibration of science and tradition into a "vernacular modernity" changed the global architectural dialogue (The Cairo Observer, 2016). His work serves as a reminder that architecture must respond to the human dimension—psychological, cultural, and environmental—to truly provide shelter (Ismail Serageldin, 2007).

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CHAPTER 3

**Evaluation of the Radial City Plan Model
from the Perspective of Landscape Design:
The Case of Aydın Atça**

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INTRODUCTION

Landscape planning and design is an interdisciplinary field that addresses the relationships among natural, cultural, and built-environment components through a holistic approach, shaping the ecological, functional, and aesthetic dimensions of spatial organization (Düzenli et al., 2024; Eren et al., 2018; Güneroğlu et al., 2025). Within this context, concepts such as the continuity of urban open and green space systems, accessibility, spatial legibility, identity, and user experience are regarded as key determinants of planning and design decisions (Mumcu et al., 2017; Özkan & Yılmaz, 2019; Özkan et al., 2024; Sezgin & Alpak, 2025). The formation of urban form is influenced not only by the physical configuration of settlements but also by the organization of social life, the quality of public space, and the nature of human–nature interactions (Şatiroğlu & Bayramoğlu, 2024; Yavuz, 2015, 2016). Therefore, historical urban planning models are considered not merely as morphological examples belonging to the past, but also as significant references capable of informing contemporary spatial strategies in landscape planning and design. In particular, geometrically structured planning schemes provide a strong foundation for landscape design in terms of organizing open spaces, defining focal points, establishing axial systems, and ensuring visual continuity (Yılmaz & Kurak, 2022; Yılmaz & Kurak, 2024).

Since the early periods of urban planning history, the spatial organization of cities has reflected social order, aesthetic values, and the relationship between humans and nature. In this context, the radial city plan—characterized by its symmetrical and geometric structure radiating from the center to the periphery—stands out as a representation of both spatial order and societal ideals. Rooted in ideal city models such as Palmanova, developed in 16th-century Europe, this planning approach was reinforced by Haussmann’s transformation of Paris in the 19th century and later inspired modernist urban movements in the early 20th century (Mumford, 1961).

In Turkey, with the planned urbanization movements of the early Republican period, Atça emerged as one of the earliest spatial applications of this model (Öztürk, 2009). Located in the Sultanhisar district of Aydın Province, Atça represents the first Turkish settlement designed according to a radial city plan, making it a noteworthy example both in terms of spatial organization principles and landscape design. In this respect, Atça offers a valuable model for reinterpreting a historical planning heritage through contemporary landscape strategies.

The radial city plan establishes both visual and functional orientation through streets and avenues extending outward from a central focal point. From the perspective of landscape design, this structure is directly associated with the concepts of spatial legibility (Lynch, 1960) and place identity (Norberg-Schulz, 1980). The five urban elements identified by Kevin Lynch—paths, edges, nodes,

districts, and landmarks—are strongly represented within the geometric organization of the radial plan. The central park functions as a “node,” while the radiating avenues serve as “paths” that shape users’ spatial experiences and mental maps of the city.

From the standpoint of landscape architecture, the radial plan model is not merely an aesthetic form but also a spatial system that organizes human–nature interaction. The radial structure provides a potential framework for creating green corridors extending from the center toward the periphery (Forman, 1995). This structure can support key landscape principles such as ecological connectivity, microclimate regulation, and visual continuity. In the case of Atça, the vegetative structures placed along the eight radiating avenues from the central core represent significant potential for maintaining urban ecosystem continuity (Aksoy & Korkmaz, 2019). However, the fragmentation of this green network over time and the loss of its functional integrity pose critical challenges from the standpoint of landscape planning continuity.

The Spatial Organization of the Radial City Plan

The radial city plan is a form of urban organization characterized by symmetrical and geometric structures formed by roads radiating outward from a central point. Throughout history, this plan type has been regarded both as a rational expression of spatial order and as a representation of social ideals projected onto space (Mumford, 1961). The spatial organization of the radial plan is defined by multidirectional axes extending from a central focal point—typically a square, administrative building, or monumental area—toward the periphery. These axes constitute both the visual and functional framework of the city.

From a spatial perspective, radial plans operate through a centripetal configuration, in which all spatial relationships converge toward a single focal point. This configuration generates a guiding effect in terms of both movement and perception, enabling the urban user to establish a visual or physical connection with the center regardless of their location. Owing to this characteristic, the radial plan is one of the most legible urban forms (Lynch, 1960). The “path” and “node” components identified in Kevin Lynch’s *Image of the City* are clearly manifested in the spatial organization of the radial plan. The center functions as a node, forming an attractor where all routes intersect, while the axes operate as paths shaping the user’s sense of orientation.

This structure also establishes a hierarchical organization among urban spaces. The center possesses the highest public intensity, which gradually decreases toward the periphery as residential and rural areas emerge. Thus, the radial plan creates a functional gradient within the city (Trancik, 1986). Public buildings (administrative units, squares, and commercial areas) are typically located at the core, semi-public spaces (schools, markets, and parks) occupy the

middle ring, and residential zones are positioned at the edges. This spatial hierarchy shapes both the city's social structure and its visual composition.

The spatial organization of the radial plan is further defined by the principle of axiality, a key concept in landscape and urban design that ensures perceptual continuity. Linear routes extending from the center provide a strong perspective effect, reinforcing spatial hierarchy and orientation (Norberg-Schulz, 1980). These axes serve not only as transportation routes but also as visual corridors and landscape axes. In the case of Atça, each of the eight primary avenues radiating from the central park functions as both a physical connector and a visual continuity element (Aksoy & Korkmaz, 2019).

Another defining aspect of the radial plan's spatial order is the principle of symmetry and proportion. The evenly spaced axes radiating from the center lend geometric balance to the urban fabric. This symmetry enhances the legibility of the urban environment, allowing users to orient themselves easily and mentally reconstruct the overall spatial scheme (Lynch, 1960). However, the rigidity of this order may at times lead to conflicts with natural topography. Contemporary landscape approaches, therefore, advocate for flexible morphologies that preserve the radial organization while integrating it with the natural environment (Forman & Godron, 1986).

From the standpoint of spatial continuity, the radial plan model is conducive to the creation of green spine systems radiating from the center. When the central square or park is conceived as an ecological core, the green belts extending along the radial axes can serve as the city's "ecological veins" (Forman, 1995). These corridors provide permeable connections that support both pedestrian accessibility and biodiversity. Consequently, the radial plan reinforces not only spatial organization but also ecological integrity.

From a socio-spatial perspective, radial plans emphasize the centrality of public space. The center, functioning as a communal gathering point, serves as a symbolic space beyond its physical role. In the early Republican period of Turkey, this planning approach represented the organization of public life within a rational urban order (Keleş, 1993). Therefore, the spatial organization of the radial plan constitutes not only a formal symmetry but also a physical manifestation of social order.

In conclusion, the spatial organization of the radial city plan can be defined as a holistic system characterized by focality, axiality, hierarchy, legibility, and symmetry. This model establishes a balanced relationship between the center and the periphery through both urban form and landscape systems. Today, the reinterpretation of this historical model through sustainability principles—by enhancing ecological connectivity, ensuring the continuity of green corridors, and improving climatic comfort—can align the rational order of the radial plan with the ecological and social needs of contemporary urban life.

Analysis of the Atça Settlement

During the early Republican period, planned urbanization initiatives in Turkey represented some of the most significant spatial manifestations of the ideals of social modernization. In this context, the settlement of Atça, located in the province of Aydın, serves as a unique example of the systematic implementation of planned city principles on a small scale. Based on a radial city plan, Atça can be regarded both in its spatial organization and symbolic meaning as a “small-scale laboratory of modern life” (Öztürk, 2009). The planning model developed in Turkey during the 1930s should be understood not merely as a physical urban layout, but also as the spatial projection of a rational, symmetrical, and orderly vision of society (Keleş, 1993).

The history of Atça is closely linked to the agricultural and cultural continuity of the Aydın region since antiquity (Yurtkulu, 2018). Throughout history, the area has been influenced by settlements established on the fertile lands of the Menderes Plain, serving as a rural production center during the Byzantine and Seljuk periods (Mumford, 1961). During the Ottoman era, Atça gained administrative status as a *nahiye* (subdistrict) affiliated with Sultanhisar and established its municipal organization by the late 19th century (Öztürk, 2009). However, during the Greek occupation between 1919 and 1922, the town was almost entirely destroyed and burned down (Aksoy & Korkmaz, 2019).

Following the proclamation of the Republic, Atatürk’s visit to the town marked the beginning of its urban redevelopment process. Deeply moved by the devastation left by the war (Figure 1), Atatürk initiated discussions in 1924 with Engineer Abdi Hıfzı Bey, a native of Atça educated in Paris, and Public Works Officer Halil Bey, leading to the proposal of a new and modern urban plan for the town (URL-12, 2017).

During these consultations, it was decided that all the burned structures from the occupation period would be demolished, and a new urban plan would be designed based on the remaining undamaged buildings. Although the local population initially opposed the proposal, the plan was gradually developed with the support of the then-mayor, Nuri Kara. In line with the Republican ideal of planned urbanization, the reconstruction of Atça became one of the first urban experiments emphasizing geometric order, hygienic environment, accessibility, and spatial symmetry.

Inspired by his architectural education in Paris, Engineer Abdi Hıfzı Bey sought to adapt elements of Parisian urban design to Atça. Together with Halil Bey, he designed a city plan modeled after the radial form of the Étoile Square—today known as Charles de Gaulle Square—where several of Paris’s famous avenues, including the Champs-Élysées, converge (Figure 2) (Yurtkulu, 2018; Köroğlu, 2017).

Thus, the Atça plan represents one of the earliest applications of European-inspired radial planning principles in Republican Turkey, reflecting both the modernization aspirations of the new state and the integration of spatial design with sociocultural reform.

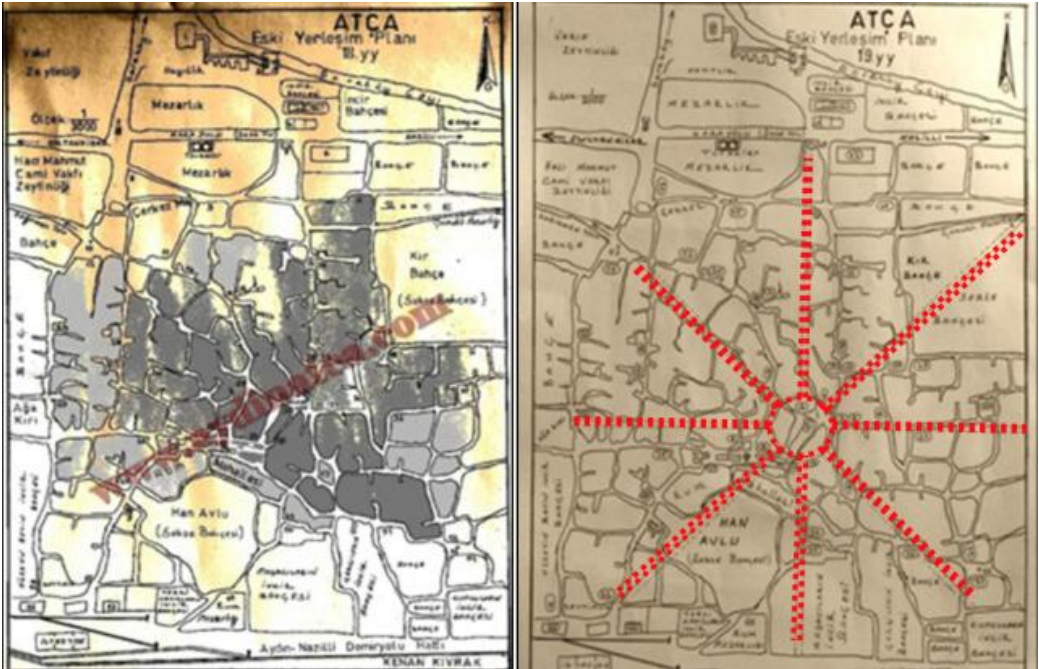


Figure 1. Town After the Destruction During the Occupation(URL-1) **Figure 2.** The New Radial Plan (URL-2)

In this planning scheme, a composition of eight radial streets extending outward from a central circular square was adopted. Through this arrangement, the axes radiating from the center toward the periphery established both visual and functional continuity, integrating the central public spaces with the surrounding residential fabric. This configuration can also be interpreted as an extension of the “ideal city” concept. The radial planning approach exemplified in cases such as Palmanova (1593, Italy) and Versailles (17th century, France) (Figure 3) symbolizes the principles of order, balance, and control (Trancik, 1986). The plan of Atça, therefore, can be regarded as a localized reinterpretation of these ideals within the context of Republican-era Turkey. At the core of the plan lies Atça Park, which serves as the heart of urban life; the surrounding public buildings—such as the school, municipality, mosque, and market area—constitute elements that foster social cohesion and spatial orientation within the settlement.



Figure 3. Charles de Gaulle (URL-3).

Atça was planned with a grid system formed by secondary axes intersecting the main radial avenues at 45-degree angles, thereby creating a series of urban blocks (Figure 4) (Salkım, 2017). The radial plan of Atça exhibits a high degree of spatial coherence and visual continuity from a landscape architecture perspective. Tree-lined avenues extending along the radial axes, symmetrical landscape arrangements, and green belts surrounding the central park are key components that enhance the legibility of the urban environment (Aksoy & Korkmaz, 2019).

This configuration aligns closely with Kevin Lynch's (1960) urban image theory, particularly the concepts of nodes and paths. The central park functions as the symbolic node of Atça, while the landscaped streets act as paths that strengthen residents' spatial orientation and wayfinding experience.

Moreover, the green system of Atça plays a crucial role in regulating microclimatic conditions. The pine and citrus trees planted along the streets not only provide shade but also influence wind direction and air circulation. This arrangement demonstrates that even during the early Republican period—when the term “ecological planning” had not yet been introduced—there was an implicit awareness of environmental comfort and its local-scale application.

However, in contemporary times, urban development pressure and increasing traffic density have partially disrupted this landscape continuity, leading to the fragmentation of green structures along the peripheral axes (Forman, 1995).

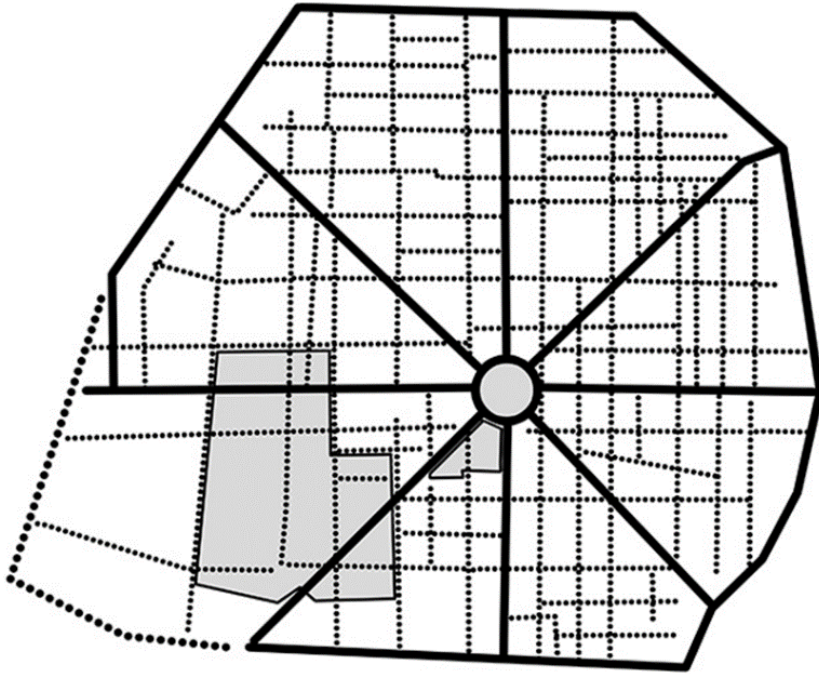


Figure 4. The Octagonal Urban Form of Atça (URL-4).

Although Atça is morphologically a small-scale settlement, it possesses a compact urban structure in which social life is concentrated around the city center. The high density of public functions—such as cafés, shops, the municipal building, and the cultural house—surrounding the central park enhances social interaction and strengthens the sense of belonging within the space. This phenomenon can be explained through Relph’s (1976) concept of the “meaning of place.” The spatial identity of Atça has been sustained through both its urban layout and user experience, creating a strong sense of place in the collective memory of its inhabitants.

Atça also holds a strong cultural identity. The region is closely associated with “Efe culture,” particularly the figure of Atçalı Kel Mehmet Efe, who symbolizes justice, freedom, and resistance in the local cultural memory (Kıyak, 2018). Thus, the urban identity of Atça is shaped not only by its geometric order but also by social values and historical narratives.

Today, although Atça largely preserves its historic planned city identity, it faces new challenges related to spatial sustainability due to increasing traffic, the effects of climate change, and rising building density. To maintain the green spine function of its radial axes, there is a need for landscape-based planning strategies such as ecological corridor design, the use of permeable surfaces, and the revitalization of native plant species (Forman & Godron, 1986). In this regard, a

proposed “Green Ray Project” could aim to restore ecological connectivity along the axes radiating from the center, support microclimatic balance through the use of local vegetation, and redesign social spaces to enhance public use. Through such strategies, Atça could evolve into a sustainable small-scale urban model, preserving its historical identity while embracing contemporary landscape principles.

From the perspective of Turkey’s urban planning history, Atça constitutes a unique example of both historical and spatial heritage. The radial plan form is not merely an aesthetic arrangement but also a spatial expression of social organization. From a landscape architectural standpoint, Atça demonstrates a strong design integrity through its open–green space continuity, spatial legibility, and symbolic focal points. However, integrating this model with contemporary urban ecology depends on its reinterpretation through sustainable landscape principles. Preserving Atça’s spatial heritage does not simply mean maintaining a historical plan—it also provides a reference model for the green infrastructure–based transformation of small-scale cities in Turkey. Hence, Atça can be regarded as a symbolic space that unites the planned city ideals of the past with the sustainable living visions of the future.

The radial plan of Atça creates a strong spatial unity in terms of landscape organization. The centrally located Atça Park constitutes the city’s primary focal point and, through the eight main streets radiating from it, establishes both functional and visual continuity. This street configuration generates a symmetrical order that guides the urban fabric and facilitates users’ spatial perception. Field observations indicate that along each axis, distinct tree alignments, sidewalk greenery, and localized focal spaces are present (Aksoy & Korkmaz, 2019). However, it has also been observed that the continuity of green spaces is concentrated around the central area and weakens toward the periphery, indicating a fragmentation of the ecological network initially established by the radial plan. Furthermore, increasing vehicular traffic restricts the continuity of vegetation along the streets and contributes to the urban heat island effect (Keleş, 1993). Nevertheless, recent landscape interventions around Atça Park—such as the enhancement of shaded areas and the renewal of pedestrian pathways—have made positive contributions to the quality of public life and the overall livability of the town.

Conclusion and Recommendations

The radial plan model strongly supports the concepts of focality and orientation in landscape design. The axial layout developing around the central park enhances the legibility of the space while reinforcing individuals’ sense of direction and belonging. The components of the urban image identified by Lynch (1960) are clearly observable in the Atça plan: the central park functions as a node, the main streets act as paths, and the surrounding neighborhoods serve as

districts. However, for this spatial organization to fully align with contemporary sustainable landscape principles, the enhancement of ecological connectivity is essential.

The symmetric and rigid geometry of the radial form can, in certain cases, create conflicts with natural topography. Therefore, contemporary landscape approaches recommend integrating this form with flexible green infrastructure strategies (Forman & Godron, 1986). For instance, the design of “green ray” corridors radiating outward from the center in Atça could both enhance biodiversity and improve microclimatic conditions. In addition, the implementation of permeable surfaces, rain gardens, and planting schemes using native species can preserve the aesthetic symmetry of the radial plan while enhancing its ecological functionality.

The case of Atça demonstrates that the radial city plan serves as a significant research laboratory for the field of landscape architecture. This planning model successfully incorporates core design principles such as spatial orientation, focal development, visual continuity, and public space organization. However, the contemporary needs of urban landscapes necessitate a reinterpretation of this historical plan through the lens of sustainability. Supported by landscape solutions such as ecological corridors, permeable pavements, shading systems, and microclimate regulation, the radial plan model can contribute both to the preservation of cultural heritage and to the advancement of a contemporary green city vision.

In this context, Atça stands as a strong example for the landscape-based re-evaluation of Turkey’s planned urban heritage, illustrating how historical spatial structures can be adapted to meet the ecological and social demands of modern urban life.

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CHAPTER 4

Emerging Trends in Coastal Design: A Bibliometric Perspective

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Introduction

Coastal areas have historically constituted critical spaces for meeting fundamental human needs, including food provision, trade, transportation, and settlement, owing to their biological richness and distinctive morphological characteristics. Their natural resources, favorable climatic conditions, and productive capacities have made coastal areas economically and socially attractive, transforming them into important settlement nodes where cultural practices and social interactions have become highly concentrated (Erkal, 2015; Kannen et al., 2008). This multifunctional use of coastal areas highlights their strategic role in regional development and in maintaining ecological balance. However, growing population pressures, uncontrolled development, sea-level rise, and extreme weather events, together with increasingly diversified land-use patterns, have made it imperative to pursue sustainable development and enhance the resilience of coastal areas (Ülger, 2022; Garipağaoğlu et al., 2014). Addressing these challenges requires integrated planning and design approaches that take into account the social, cultural, economic, and ecological dynamics of coastal environments (Ahern, 2011; Temmerman et al., 2013; Wong & Brown, 2009).

In this context, the literature emphasizes that coastal areas require approaches that prioritize the conservation of natural resources (Beatley, 2014; Temmerman et al., 2013), promote sustainable use (Ahern, 2011), and are grounded in integrated design principles (Wong & Brown, 2009). Such approaches seek to reconcile the diverse and often competing functions of coastal areas while maintaining their ecological integrity and supporting the long-term sustainability of coastal settlements.

Against this background, the aim of this study is to provide a comprehensive assessment of the contemporary literature on coastal planning and coastal design through a bibliometric analysis of publications, focusing on the themes addressed, the approaches adopted, and the design principles proposed. The study systematically identifies the major trends emerging in the literature concerning the sustainable management of coastal areas, the conceptual frameworks employed, and the key principles shaping contemporary coastal design. In addition, it seeks to identify underexplored issues and areas requiring further scholarly attention with regard to design principles for coastal areas, while highlighting opportunities for strengthening interdisciplinary integration. In this respect, the study aims to contribute to the literature by providing a systematic overview of the evolution, thematic structure, and conceptual orientations of research on coastal planning and design, and by clarifying the principal knowledge areas that can inform more integrated and sustainable approaches to coastal environments.

Methodology

The study adopts a qualitative analytical framework that integrates quantitative bibliometric indicators with thematic assessments. A systematic literature review approach was employed, whereby the literature was examined based on predefined databases, keywords, and explicitly established inclusion and exclusion criteria. The studies identified through this process were subsequently subjected to bibliometric analysis to reveal the broader trends and dominant themes characterizing the field.

The literature search was conducted using the Web of Science database. The analysis was limited to academic articles published in English and Turkish between 2010 and 2025. To identify research addressing planning and design approaches for coastal areas, the following keywords were used: “coastal design,” “urban waterfront design principles,” and “water sensitive urban design.”

The analysis included only peer-reviewed journal articles that focused on design or planning principles related to coastal areas and for which full-text access was available. Conference proceedings, book chapters, theses, and technical project reports were excluded from the analysis. Publications primarily concerned with assessing ecological impacts, but with limited spatial and design-oriented content, were also excluded.

Bibliometric analysis was employed to identify the quantitative characteristics of the literature and to integrate these findings with the thematic assessment. The distribution of publications by year, authors and institutions, countries and regions, citation patterns, keywords, and thematic networks was analyzed and visualized through graphs and maps. Keyword analysis was conducted using VOSviewer software (van Eck & Waltman, 2010), while Microsoft Excel (Microsoft Corporation, 2021) was also used for data organization, classification, and analysis.

Within each identified theme, the major trends in the literature, representative studies, and existing research gaps were examined, providing the basis for establishing a conceptual framework of design principles for coastal areas. Accordingly, the study aims not only to systematically synthesize the existing body of academic knowledge on coastal design but also to make interdisciplinary research trends more visible and to clarify the conceptual and thematic directions shaping contemporary approaches to coastal planning and design.

Findings: Bibliometric Analysis

Coastal design and coastal planning constitute multidisciplinary fields of research that encompass ecological, social, spatial, and economic dimensions. Accordingly, a bibliometric analysis was conducted using the keywords “coastal design,” “urban waterfront design principles,” and “water sensitive urban

design.” The literature search was performed using these predefined keywords in the Web of Science database.

Web of Science Search Results for “Coastal Design”

A literature search was conducted in the Web of Science Core Collection using the keyword “coastal design” across all subject categories and covering publications from 2010 to 2025. The search identified a total of 225 publications. The distribution of publications across Web of Science categories indicates that the literature is predominantly concentrated in Environmental Studies and Hospitality, Leisure, Sport & Tourism, with 58 publications in each category. These are followed by Green & Sustainable Science & Technology (49 publications), Environmental Sciences (48 publications), and Urban Studies (47 publications). In addition, Architecture (32 publications), Regional & Urban Planning (29 publications), and Ecology (26 publications) account for notable shares of the literature (Figure 1).

Although represented by fewer publications, fields such as Geography, Development Studies, Biodiversity Conservation, Water Resources, Economics, and Environmental Management also contribute to the body of research. Overall, the distribution demonstrates that coastal design is a multidimensional and interdisciplinary field situated at the intersection of environmental sustainability, urban and regional studies, spatial planning, and related disciplinary domains.



Figure 1. Distribution of research categories identified through the “Coastal Design” keyword search in the Web of Science database (2026)

An examination of the annual distribution of publication and citation counts in the retrieved literature (Figure 2) reveals a general upward trend in publication output from 2010 onward. This growth became particularly pronounced from 2017, when the number of publications reached 20, and peaked in 2021, with a total of 36 publications. Following 2021, however, publication output exhibits a relative decline.

The analysis of citation counts (Figure 2) shows a gradual increase beginning in 2010, followed by a marked turning point and acceleration from 2020 onward. Citation counts remained at relatively high levels throughout the 2021–2025 period, ranging between 500 and 670 citations. Taken together, these patterns point to a close relationship between publication productivity and citation dynamics within the literature.

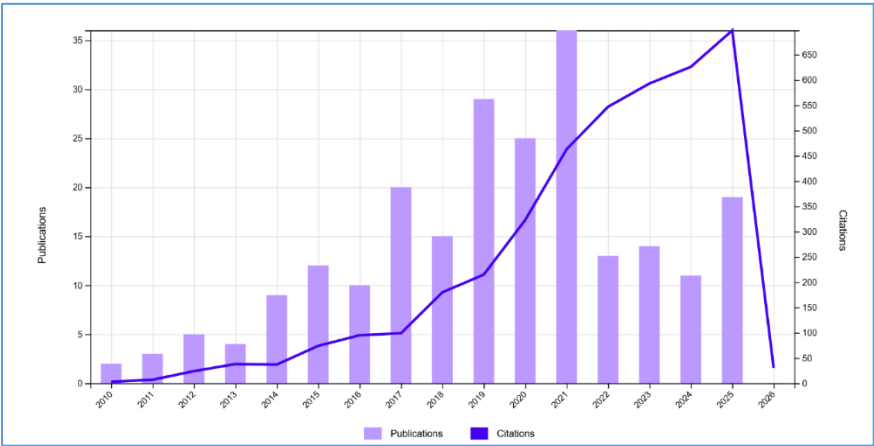


Figure 2. Publication and citation analysis of research on coastal design (Web of Science, 2026)

An examination of the geographical distribution of publications (Figure 3) indicates that the oldest and highest concentration of publication activity and network interaction is centered on the United States (USA), which occupies a central position in the network. The size of the nodes and the density of connections in the map demonstrate the USA’s prominent position in terms of both research output and collaboration within the “coastal design” literature.

The temporal distribution of colors further indicates that some countries represent earlier contributions within the network, including the USA, the Netherlands, France, and Australia, whereas others have become more visible since 2020. In particular, the use of colors corresponding to more recent periods for countries such as Türkiye, India, Bangladesh, and Vietnam suggests that the focus on “coastal design” has gained increasing prominence in these countries in recent years.

At the same time, the labels of some countries—including Germany, Belgium, South Africa, Sweden, and Türkiye—are less clearly readable in the visualization due to label overlap. Nevertheless, their network positions and connection patterns indicate that these countries also play a role in international research collaboration networks, alongside countries such as India, Scotland, Thailand, and Estonia (Figure 3).

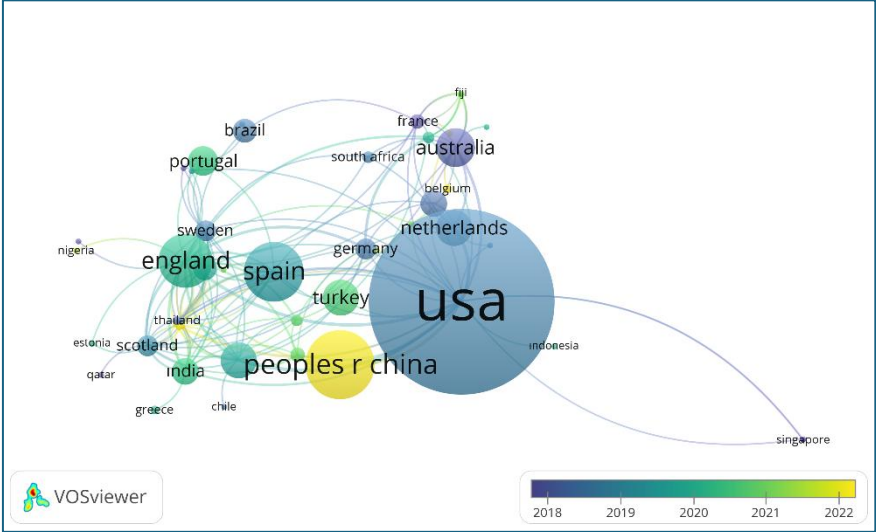


Figure 3. Country distribution of publications identified through the “Coastal Design” keyword search (Web of Science, 2026)

An examination of the keyword co-occurrence network (Figure 4) reveals that “climate change” occupies a central position within the network and represents the keyword with the highest connection density. According to the network visualization, the concepts most closely associated with “climate change” and most frequently co-occurring with it in the literature include sustainability, climate change adaptation, vulnerability, risk, sea-level rise, flooding, coastal resilience, urban coastal areas, and adaptive capacity.

In addition, concepts such as tourism, green infrastructure, urban design, and sustainable development are also represented within the network, indicating that coastal design is addressed through interconnected social, environmental, and spatial dimensions. Overall, the distribution of keywords demonstrates that the coastal design literature is predominantly structured around climate change, adaptation strategies, and vulnerability, while also exhibiting a distinctly interdisciplinary research orientation.

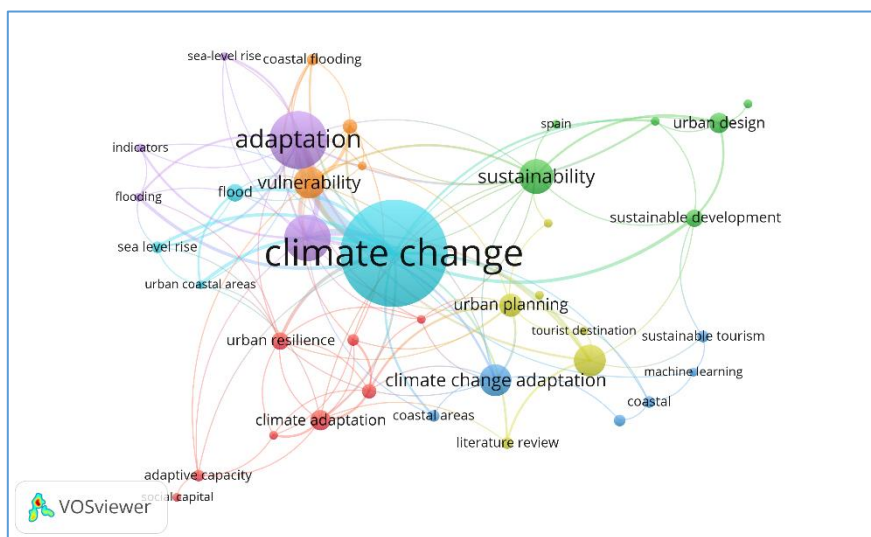


Figure 4. Keyword co-occurrence analysis of publications identified through the “Coastal Design” search (Web of Science, 2026)

The temporal overlay visualization of the keyword analysis (Figure 5) shows that “climate change” occupies a central position within the network and represents the most frequently used concept in the literature. The color distribution indicates that the focus on climate change became particularly pronounced from 2017 onward, with the average publication year positioned around 2019–2020. In contrast, concepts such as tourism, literature review, green infrastructure, and coastal resilience are associated with relatively earlier studies, whereas sustainability, climate change adaptation, and vulnerability became more prominent after 2018.

Among the keywords representing the more recent period, “sea-level rise,” “risk,” “indicators,” and “urban coastal areas” are particularly prominent, especially during 2020–2022. This finding suggests that recent research within the coastal design literature has increasingly focused on the impacts of climate change—particularly sea-level rise and flood risk—as well as on adaptation and resilience-oriented approaches (Figure 5).

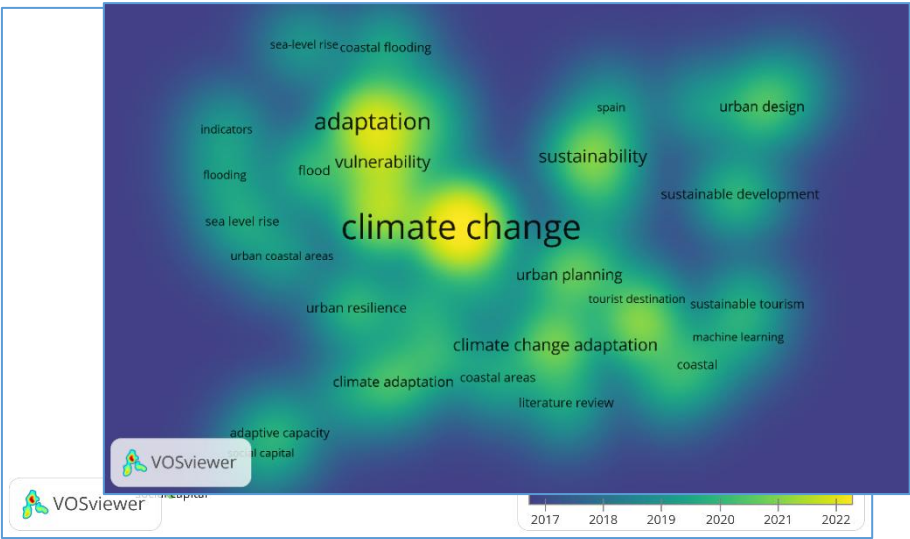


Figure 5. Temporal overlay visualization of keywords identified through the “Coastal Design” search (Web of Science, 2026)

The results of the density visualization illustrating the thematic concentration of keywords (Figure 6) indicate that a total of 11 clusters were identified through the VOSviewer analysis. The density map clearly demonstrates that “climate change” and climate-related risk factors, including vulnerability and flooding, constitute the core of the literature. In addition, concepts such as tourism, green infrastructure, coastal resilience, urban design, and sustainable development are located within areas of moderate density, whereas some keywords, such as built environment, appear relatively peripheral and are represented by lower-density areas within the network. Overall, these findings indicate that the coastal design literature is strongly concentrated around climate change-related themes, with the diversity of research topics structured around a set of core concepts.

Figure 6. Density distribution of keyword clusters identified through the “Coastal Design” search (Web of Science, 2026)

According to the results of the keyword analysis conducted using VOSviewer, the 11 identified clusters reflect the diverse conceptual and applied dimensions of coastal design research (Table 1).

Table 1. Distribution of keyword clusters identified through the “Coastal Design” search

Cluster 1	Cluster 2
Climate change	Climate change adaptation
Sea-level rise	Coastal resilience
Flooding	Adaptive capacity
Risk	Urban coastal areas
Indicators	Cities
Vulnerability	
Cluster 3	Cluster 4

Sustainability Sustainable development Green infrastructure	Urban design Built environment Spatial planning
Cluster 5	Cluster 6
Tourism Coastal tourism Place attachment	Social vulnerability Community resilience Human- environment interaction
Cluster 7	Cluster 8
Urban infrastructure Coastal infrastructure Flood risk management	Indicators Risk assessment Vulnerability assessment
Cluster 9	Cluster 10
Machine learning Data-driven analysis Modelling	Literature review Conceptual framework
Cluster 11	
Spain Regional context Case study	

The presence of shared keywords across some clusters indicates the interdisciplinary nature of the field, in which climate change, sustainability, urban design, and environmental risk perspectives are addressed in an interconnected manner. Furthermore, the keywords comprising these clusters demonstrate that coastal design research extends beyond a predominantly physical design-oriented perspective, encompassing a multidimensional range of social, environmental, and governance-related dimensions.

Web of Science Search Results for “Urban Waterfront Design Principles”

A search was conducted in the Web of Science database using the keyword “urban waterfront design principles” across all research categories. The search yielded a total of 22 publications (Figure 7).

The results indicate that the publications are predominantly concentrated in the field of Urban Studies, with 16 publications, followed by Geography (9 publications) and Environmental Studies (7 publications). Regional & Urban Planning also represents a notable share of the literature, with five publications. Although represented by fewer publications, the search also identified studies in fields such as Architecture, Development Studies, Ecology, Environmental Sciences, and Green & Sustainable Science & Technology.

This distribution demonstrates that research on urban waterfront design principles constitutes an interdisciplinary field situated primarily at the intersection of urban studies, geography, and environmental disciplines.

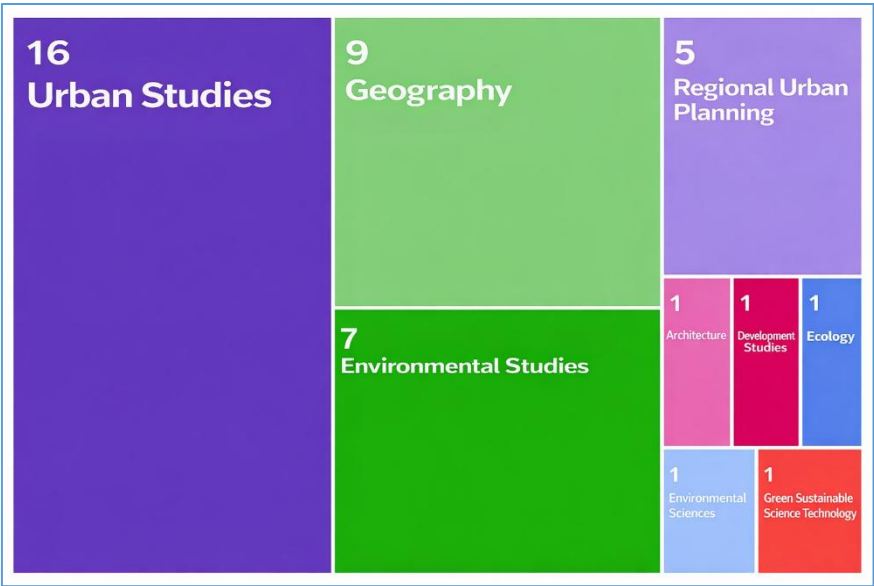


Figure 7. Distribution of publications by research category in the “Urban Waterfront Design Principles” search (Web of Science, 2026)

An examination of the publication and citation patterns in the retrieved literature indicates an overall increase in research activity on the topic from 2011 onward (Figure 8). Although the annual number of publications fluctuates, the highest publication output was recorded in 2018, with four publications. Publication activity remained relatively high during the 2020–2022 period, with three publications in each of 2020 and 2021 and two publications in 2022. Following 2023, however, a declining trend in publication output is observed, with one publication recorded in each of 2023 and 2024.

The analysis of citation counts (Figure 8) shows a gradual increase from 2011 onward, followed by a marked turning point and acceleration during 2019–2020, when citations increased from approximately 70 to 90. Citation counts reached their highest levels in 2023–2024. Following the decline in publication output, citation activity also appears to have begun decreasing after 2025, with approximately 10 citations recorded in 2026. This decline should be interpreted with caution, as it may primarily reflect the fact that the 2026 publication year has not yet been completed; therefore, the observed decrease should be regarded as provisional rather than indicative of a sustained decline in research impact.

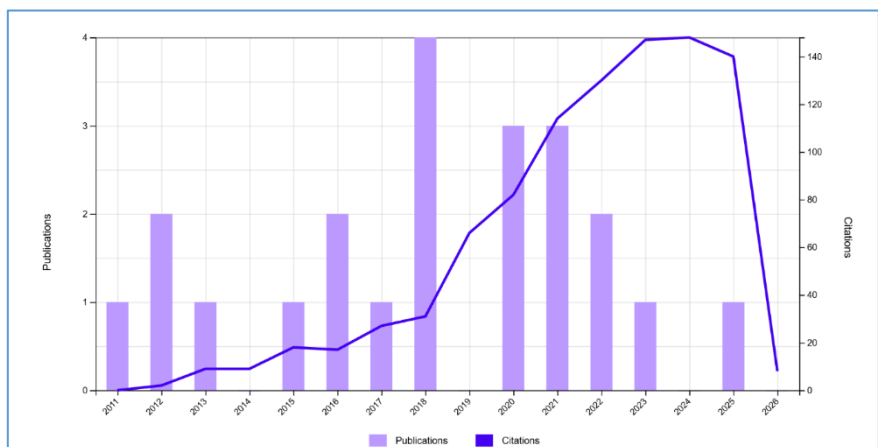


Figure 8. Publication and citation analysis of the “Urban Waterfront Design Principles” search (Web of Science, 2026)

An examination of the geographical distribution and temporal patterns of studies on “urban waterfront design principles” (Figure 9) indicates that the literature is concentrated in a relatively limited number of countries.

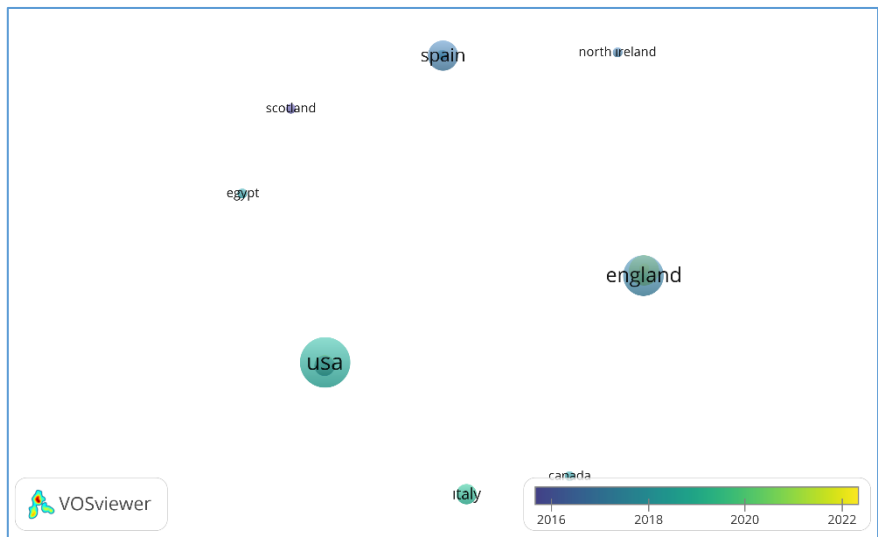


Figure 9. Country distribution of publications identified through the “Urban Waterfront Design Principles” search (Web of Science, 2026)

The temporal distribution of colors suggests that England and Spain are the principal countries representing research in this field. While England appears to account for relatively earlier contributions, Spain is represented more prominently by publications from more recent periods. The United States, by comparison, has a more limited presence in the network, while international research collaboration in this area appears to remain relatively low. Overall, this

distribution suggests that research on urban waterfront design principles has yet to develop into a broad and densely interconnected global research network.

An examination of the keyword co-occurrence network (Figure 10) shows that the concepts of “waterfront” and “waterfront redevelopment” occupy central positions in the network and are among the most frequently co-occurring keywords in the literature. The network further indicates that concepts such as urban political ecology, ecological urbanism, biophilic urbanism, circular city, inclusive spaces, and the competitive city paradigm are associated with urban waterfront design principles within the broader context of urban design and planning approaches.

In addition, keywords such as infrastructure, fragmentation, policy mobilities, and connection with the waterfront highlight the importance of governance, spatial integration, and infrastructure in the redevelopment of waterfront areas. The presence of place-specific keywords, including Toronto waterfront, Belgrade waterfront, Delhi, and European Capital of Culture, further suggests that a substantial proportion of the literature is grounded in case studies and specific urban contexts.

Overall, the keyword distribution indicates that the literature on urban waterfront design principles has a multidimensional and interdisciplinary structure, bringing together design, ecological, governance, and socio-spatial perspectives.

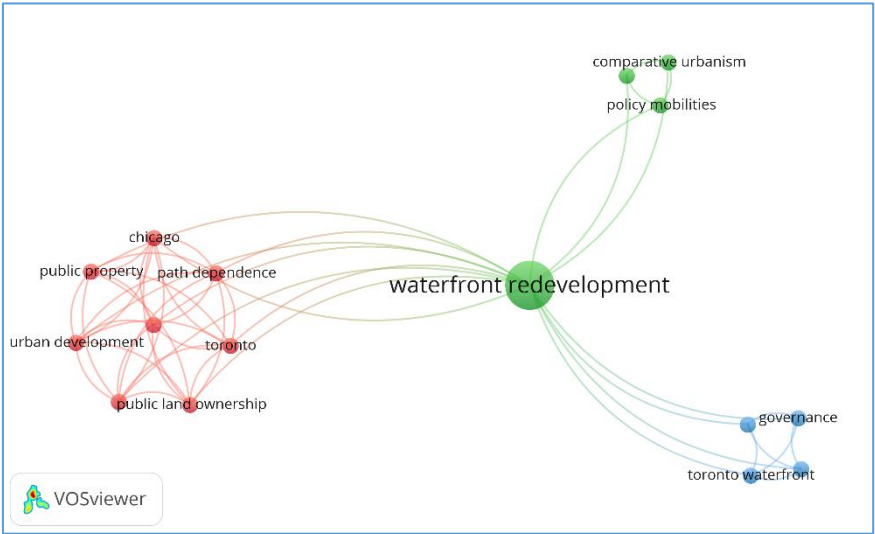


Figure 10. Keyword co-occurrence analysis of the “Urban Waterfront Design Principles” search (Web of Science, 2026)

An examination of the temporal overlay visualization of the keyword analysis (Figure 11) indicates that research within the “urban waterfront design principles” literature has largely emerged from 2016 onward. The temporal distribution of colors suggests that concepts such as waterfront redevelopment, urban political ecology, and ecological urbanism are associated with relatively earlier contributions to the field. In contrast, keywords including circular city, connection with the waterfront, infrastructure, and fragmentation have become more prominent in studies published from 2019 onward.

Furthermore, concepts such as biophilic urbanism, inclusive spaces, and policy mobilities have gained increasing visibility in the literature in recent years. The distribution of colors across different periods for place-specific keywords such as Toronto waterfront, Belgrade waterfront, and Delhi indicates that research has diversified over time through studies focusing on specific urban contexts and case studies. Overall, this temporal pattern suggests that the literature on urban waterfront design principles has evolved in recent years toward greater conceptual diversity and the incorporation of emerging approaches in urban planning and design (Figure 11).

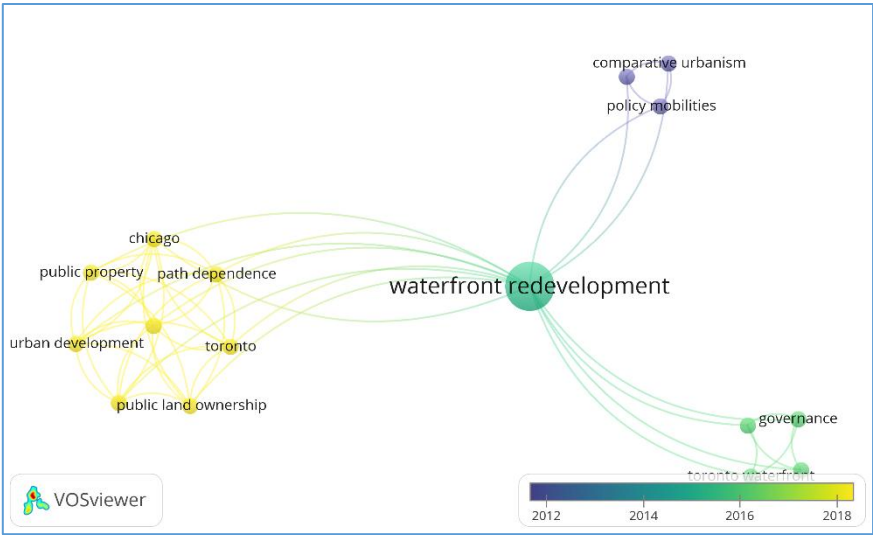


Figure 11. Temporal overlay visualization of keywords identified through the “Urban Waterfront Design Principles” search (Web of Science, 2026)

According to the keyword analysis, the density visualization of the identified clusters (Figure 12) shows that the keywords “waterfront” and “waterfront redevelopment” exhibit the highest density and occupy central positions within the literature. A high concentration of keywords such as policy mobilities, urban political ecology, and ecological urbanism is observed around these core concepts. The keywords infrastructure and fragmentation are also located within areas of relatively high density, whereas circular city, connection with the

waterfront, biophilic urbanism, and inclusive spaces are represented at moderate levels of density.

Place-specific keywords, including Toronto waterfront, Belgrade waterfront, Delhi, and European Capital of Culture, are positioned within distinct clusters, highlighting the significance of case-based research in the literature (Figure 12).

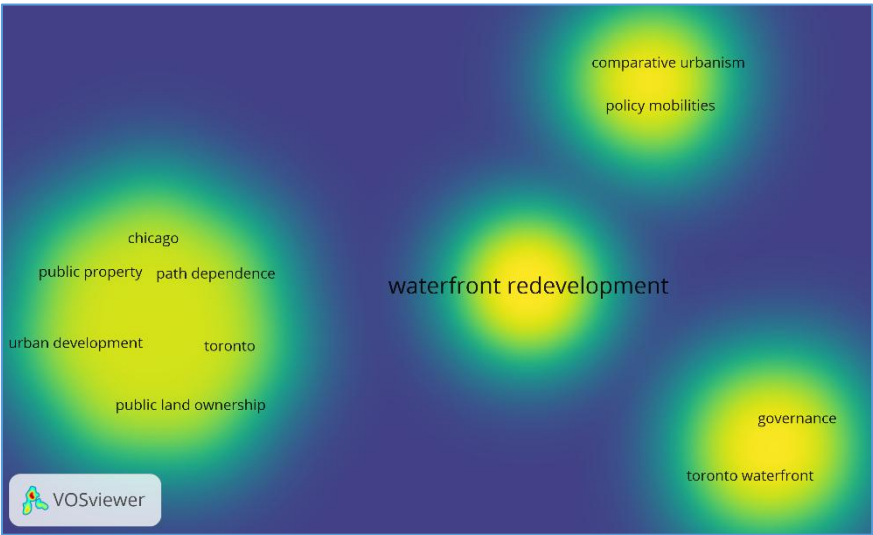


Figure 12. Density distribution of keyword clusters identified through the “Urban Waterfront Design Principles” search (Web of Science, 2026)

According to the results of the keyword analysis conducted using VOSviewer on the Web of Science dataset, seven clusters were identified within the literature on urban waterfront design principles. An examination of the keywords comprising these clusters reveals that themes such as waterfront redevelopment, urban political ecology, ecological urbanism, and policy mobilities are particularly prominent. At the same time, concepts including inclusive spaces, biophilic urbanism, infrastructure, and urban connectivity also occupy an important position within the literature.

These findings demonstrate that research on urban waterfront design principles extends beyond a focus on the physical design of waterfront spaces and constitutes an interdisciplinary field that integrates environmental, social, and governance-oriented perspectives within a holistic framework. Accordingly, the distribution of keywords across the identified clusters is presented in Table 2.

Table 2. Distribution of keywords across clusters identified through the Web of Science search: Urban Waterfront Design Principles

Cluster 1	Cluster 2
Waterfront Waterfront redevelopment	Urban political ecology Ecological urbanism
Cluster 3	Cluster 4
Policy mobilities	Connection with the waterfront Inclusive spaces Biophilic urbanism
Cluster 5	Cluster 6
Infrastructure Fragmentation	Circular city Competitive city paradigm Pop-up landscape design
Cluster 7	
Toronto waterfront Belgrade waterfront Delhi European capital of culture	

Web of Science Search Results for “Water Sensitive Urban Design”

A search was conducted in the Web of Science database using the keyword “Water Sensitive Urban Design” across all research categories, yielding a total of 24 publications. The results (Figure 13) indicate that the literature is predominantly concentrated in the field of Urban Studies, with 14 publications, followed by Environmental Studies (10 publications), Ecology (5 publications), Green & Sustainable Science & Technology (5 publications), and Regional & Urban Planning (5 publications). Forestry (4 publications), Plant Sciences (4 publications), and Construction & Building Technology (3 publications) also make notable contributions to the literature.

Although represented by fewer publications, studies are also found in fields such as Energy & Fuels, Physical Geography, Geography, Economics, Civil Engineering, Environmental Sciences, and Architecture. Overall, this distribution indicates that water-sensitive urban design is primarily examined at the intersection of urban studies and environmental disciplines, while also constituting a multidisciplinary field that encompasses perspectives from ecology, forestry, plant sciences, engineering, and related areas (Figure 13).



Figure 13. Distribution of research categories in the “Water Sensitive Urban Design” search (Web of Science, 2026)

An examination of the publication and citation patterns (Figure 14) indicates that research on water-sensitive urban design began to gain visibility from 2015 onward. Publication output was limited during the initial years, with only one publication recorded in 2015; however, a noticeable increase occurred from 2019 onward, rising from two publications in 2019 to three in 2020. Publication activity remained relatively consistent between 2020 and 2025, with the number of publications stabilizing at approximately three per year, particularly from 2021 onward. This pattern indicates that water-sensitive urban design has emerged as an increasingly prominent and contemporary area of research in recent years.

The citation trend (Figure 14) shows a steady increase from 2018 onward, beginning at approximately 15 citations, followed by a marked acceleration during the 2023–2025 period. Citation counts increased from approximately 60 in 2023 to around 110 in 2025, reaching their highest level in 2025. The substantial increase in citations despite the relatively limited growth in publication output suggests that research in this field has achieved considerable scholarly impact and has become influential in discussions concerning policy, sustainability, and climate-responsive urban design. The comparatively low citation count recorded for 2026 should be interpreted cautiously, as the year has not yet been completed.

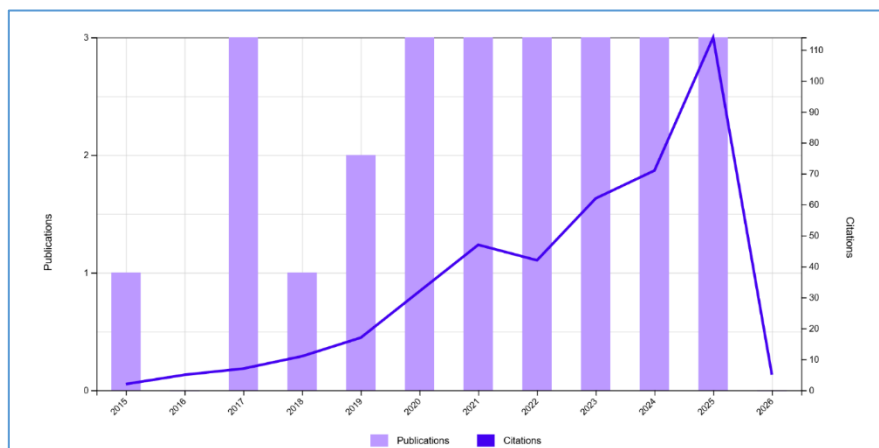


Figure 14. Publication and citation analysis of the “Water Sensitive Urban Design” search (Web of Science, 2026)

The results of the country-level publication and collaboration analysis (Figure 15) indicate that Australia occupies a central position within the research network, serving as an important link between New Zealand and the Netherlands. In particular, strong academic collaboration is evident between Australia and New Zealand, as well as between Australia and the Netherlands.

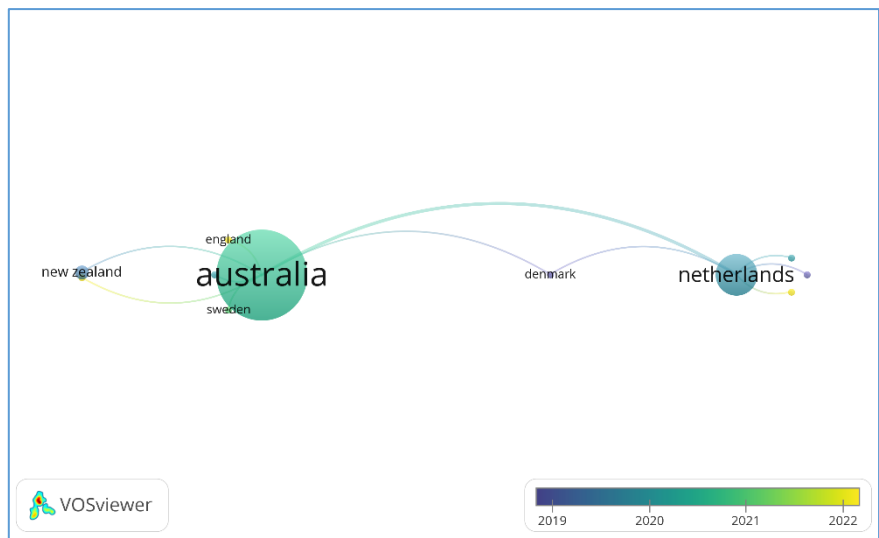


Figure 15. Country distribution of publications identified through the “Water Sensitive Urban Design” search (Web of Science, 2026)

This pattern suggests that the origins and major areas of application of the water-sensitive urban design approach have developed predominantly along an Oceania–Northern Europe axis. Australia’s central position in the network further

indicates that the country has played a leading role in the development of both theoretical frameworks and practice-oriented approaches to urban water management. The more limited connections of other countries suggest that research in this field remains geographically concentrated, while also demonstrating considerable potential for wider global diffusion and international collaboration.

The concepts most closely associated with the “Water Sensitive Urban Design” keyword and attracting the highest volume of research include climate change, sustainability, climate change adaptation, green infrastructure, urban design, urban greening, biophilic urbanism, and biodiversity (Figure 16).

Furthermore, the central positions occupied by the concepts of “climate-resilient cities” and “climate change adaptation” indicate that water-sensitive urban design is primarily framed within the contexts of climate-resilient urban development, ecological planning, and sustainable urban development. The distribution of keywords demonstrates that this approach extends beyond being a technical water management strategy and instead represents an integrated planning framework that brings together urban design, landscape planning, and environmental sustainability.

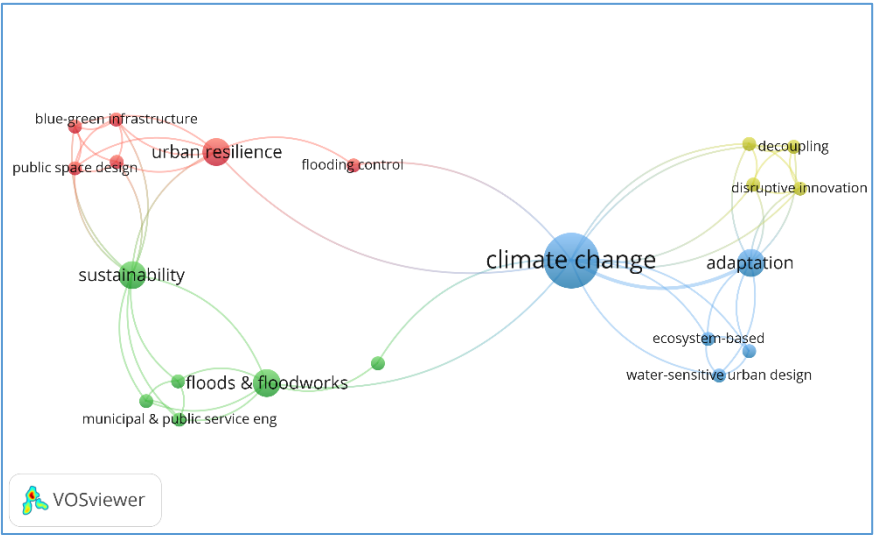


Figure 16. Keyword co-occurrence analysis of the “Water Sensitive Urban Design” search (Web of Science, 2026)

The temporal overlay visualization of the keyword analysis indicates that research in this field has predominantly emerged from 2018 onward (Figure 17). Earlier studies are characterized by concepts such as biodiversity, landscape elements, urban design, and cultural norms. From 2019 onward, however,

research became increasingly concentrated around climate change, sustainability, climate change adaptation, and climate-resilient cities.

Among the most recent research trends, keywords such as green infrastructure, urban greening, biophilic urbanism, and climate-resilient cities have become particularly prominent. This temporal shift indicates that water-sensitive urban design is increasingly being conceptualized within a climate-responsive, ecological, and integrated urban planning framework.

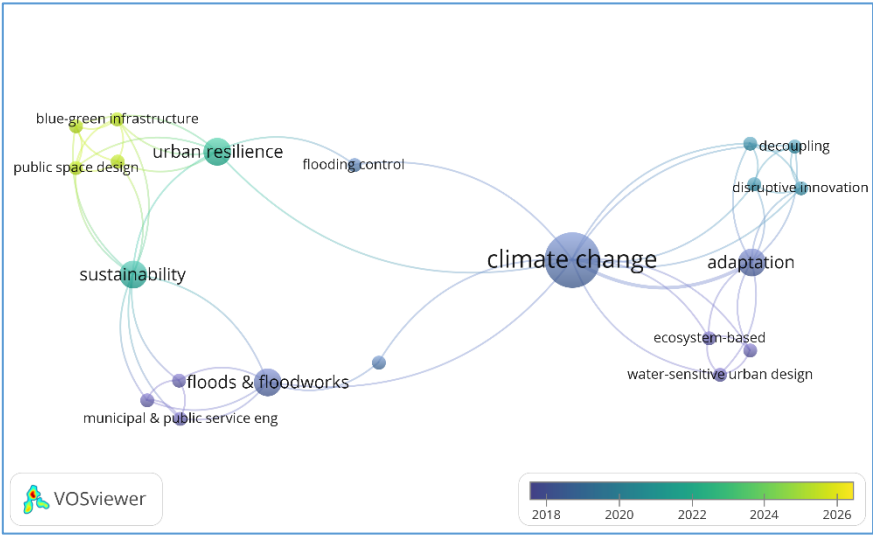


Figure 17. Temporal overlay visualization of keywords identified through the “Water Sensitive Urban Design” search (Web of Science, 2026)

The density visualization of the keyword analysis shows that “water sensitive urban design” occupies a central position within the literature and is strongly associated with a wide range of related concepts (Figure 18). In particular, sustainability, climate change, climate change adaptation, and climate-resilient cities emerge as high-density themes. At the same time, keywords such as green infrastructure, urban greening, biophilic urbanism, and landscape aesthetics indicate that water-sensitive urban design is increasingly examined in conjunction with ecological and nature-based solutions.

Although represented by lower-density areas, concepts such as biodiversity, urban design, cultural norms, and landscape elements remain important within the research network, demonstrating that the approach encompasses not only environmental concerns but also socio-cultural and spatial dimensions. Overall, the density visualization suggests that research on water-sensitive urban design has increasingly evolved into a climate-responsive, sustainability-oriented, and multidisciplinary field of inquiry.

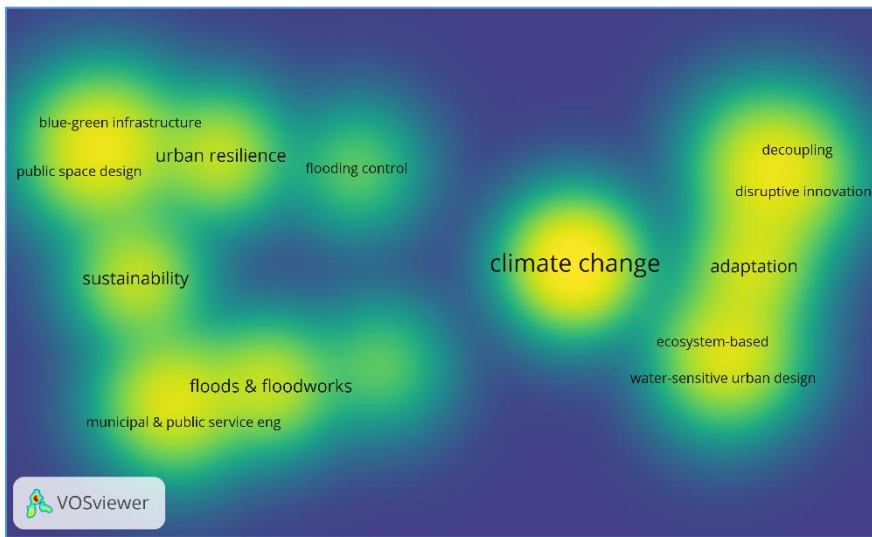


Figure 18. Density distribution of keyword clusters identified through the “Water Sensitive Urban Design” search (Web of Science, 2026)

According to the results of the keyword analysis conducted using VOSviewer on the Web of Science dataset, the *water sensitive urban design* literature comprises seven clusters, reflecting the ecological, spatial, climatic, and analytical dimensions of the water-sensitive urban design approach (Table 3).

An examination of the clusters shows that the cluster comprising keywords such as *water sensitive urban design*, *green infrastructure*, *urban greening*, *biophilic urbanism*, and *landscape aesthetics* represents urban design approaches centred on nature-based solutions and green infrastructure. In addition, the cluster incorporating the concepts of *climate change*, *sustainability*, and *decoupling* highlights theoretical research developed around climate change and sustainability. The keywords *climate change adaptation* and *climate-resilient cities* further demonstrate the relationship between water-sensitive urban design and climate resilience and adaptation strategies.

The cluster comprising *urban design*, *cultural norms*, and *landscape element* reflects studies focusing on the cultural and perceptual dimensions of spatial design. While the keyword *biodiversity* represents environmentally oriented approaches centred on biological diversity, clusters including *linear regression*, *diversity and similarity*, and *diagnostic point* point to methodological and analytical research within the field.

Overall, the cluster structure demonstrates that the *water sensitive urban design* literature extends beyond technical approaches to urban water management and encompasses interconnected ecological, spatial, climatic, socio-cultural, and methodological dimensions.

Table 3. Distribution of keywords across clusters identified through the Web of Science search: Water Sensitive Urban Design

Cluster 1	Cluster 2
Water sensitive urban design Green infrastructure Urban greening Biophilic urbanism Landscape aestheticss	Climate change Sustainability Decoupling
Cluster 3	Cluster 4
Climate change adaptation Climate- resilient cities	Urban design Cultural norms Landscape element
Cluster 5	Cluster 6
Biodiversity	Linear regression Diversity and similarity
Cluster 7	
Diagnostic	

The publication and citation analyses conducted using the Web of Science database indicate that the research fields of “coastal design,” “urban waterfront design principles,” and “water sensitive urban design” have gained increasing momentum over time. Research on coastal design is predominantly concentrated in the fields of Environmental Studies, Green & Sustainable Science & Technology, Urban Studies, and Environmental Sciences, and is structured around concepts such as climate change, sustainability, sea-level rise, flooding, risk, and urban coastal areas. The literature on urban waterfront design principles is primarily situated within the fields of Urban Studies and Geography and is closely associated with concepts such as waterfront, waterfront redevelopment, urban political ecology, and ecological urbanism. In the field of water-sensitive urban design, Urban Studies, Environmental Studies, and Ecology are particularly prominent, while sustainability, climate change, climate change adaptation, green infrastructure, urban greening, and biophilic urbanism emerge as highly cited thematic concepts. Taken together, these three keyword domains demonstrate interdisciplinary interactions at both conceptual and applied levels and indicate that, in recent years, research addressing climate change, sustainability, and urban design has become particularly influential in shaping citation patterns within the field.

Discussion And Conclusions

The publication and citation analyses conducted using the Web of Science database indicate that the literature on “coastal design,” “urban waterfront design principles,” and “water sensitive urban design” has gained increasing momentum over time. Research on coastal design is predominantly concentrated in the fields of Environmental Studies, Green & Sustainable Science & Technology, Urban Studies, and Environmental Sciences, and is structured around concepts such as

climate change, sustainability, sea-level rise, flooding, risk, and urban coastal areas. The literature on urban waterfront design principles is primarily concentrated in Urban Studies and Geography and is associated with concepts such as waterfront, waterfront redevelopment, urban political ecology, and ecological urbanism. In the field of water-sensitive urban design, Urban Studies, Environmental Studies, and Ecology are prominent, while sustainability, climate change, climate change adaptation, green infrastructure, urban greening, and biophilic urbanism emerge as key thematic concepts. Overall, these three keyword domains demonstrate interdisciplinary interactions at both conceptual and applied levels and indicate that research on climate change, sustainability, and urban design has become increasingly influential in recent years.

This study employed bibliometric analysis to examine the literature published between 2010 and 2025 on coastal planning and design using the Web of Science database. The analyses reveal the multidisciplinary structure of the literature, its evolution over time, and current research trends in the context of sustainable coastal management. In line with the objectives of the study, the main findings can be evaluated through three interconnected dimensions.

The first concerns emerging trends in the sustainable management of coastal areas. The findings indicate that climate change, sea-level rise, and flooding have become dominant research themes, particularly since 2017. Whereas earlier studies tended to focus more on tourism and conventional coastal protection, recent research has increasingly concentrated on vulnerability, climate change adaptation, and urban resilience. In addition, the growing use of data-driven approaches, including computational fluid dynamics (CFD) and numerical simulation, particularly in engineering-oriented studies indexed in Scopus, demonstrates an increasing emphasis on analytical and predictive methods in coastal management.

The second concerns the conceptual frameworks underpinning coastal design. The literature indicates that coastal areas are increasingly considered not merely as physical boundaries but as integrated ecological and urban systems. Particularly within the context of water-sensitive urban design, blue-green infrastructure, nature-based solutions, and biophilic urbanism have emerged as important conceptual frameworks. In addition, urban political ecology and the circular city paradigm indicate that socio-spatial and ecological justice dimensions are increasingly incorporated into waterfront redevelopment processes.

The third concerns the key principles guiding contemporary coastal design. The findings indicate that these principles extend beyond physical interventions toward a more integrated framework. Based on the most recurrent keyword networks, ecological integration and sustainability, inclusivity and publicness, and multifunctional infrastructure emerge as prominent principles. These include

protecting natural water cycles and adopting best management practices, improving access to the waterfront and creating inclusive spaces, and developing multifunctional blue-green infrastructure that can contribute simultaneously to disaster risk reduction, recreation, and landscape quality.

Overall, the coastal design literature is moving away from conventional and fragmented approaches toward an interdisciplinary framework that is increasingly climate-responsive, focused on ecological restoration, and supported by data-driven analyses. Future research should therefore continue to focus on integrated approaches connecting climate adaptation, ecological systems, spatial planning, urban design, and sustainable development.

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CHAPTER 5

Transforming Liminal Spaces Into a Multidisciplinary Exhibition Platform: The Case of a University Corridor

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1. Introduction

In the disciplines of architecture and interior architecture, the concept of “liminal space” examined in the context of spatial classification refers to areas situated between two functional units, such as corridors and thresholds, that serve as transitional spaces and are typically excluded from design interventions. This approach results in the social and functional potential of these spaces not being sufficiently evaluated and, consequently, the failure to develop design approaches that would support their active use. However, recent literature studies indicate that liminal spaces can be transformed into active spaces that support flexible use, encounters, informal learning, and social interaction processes. The discrepancy between this practical approach and the understanding presented in the literature forms the starting point of this research. In particular, liminal spaces within design and art schools offer significant opportunities for exhibiting student work, fostering interdisciplinary interaction, and conveying institutional identity to users.

In this context, the study examines the entrance corridor of the dean’s office at the design faculty of a public university as its research area. Accordingly, the problem addressed by the study is how liminal spaces which are primarily limited to a transitional function in practice can be reimaged in line with the social, functional, and educational potentials identified in the literature, and how they can be integrated into design processes. The objective of the research is to identify design principles that support the active use of transitional spaces in design faculties based on the theory of liminal spaces to develop a design proposal in line with these principles, and to evaluate it through an applied project. As the first space users encounter upon entering the building, this transitional area which reflects the faculty’s institutional identity and serves as a showcase has been redesigned as a multidisciplinary exhibition platform in accordance with the principles of flexibility, continuity, and balance within the framework of liminal space theory.

The design concept aims to rethink the processes of pausing, exploring, and interacting as a whole, rather than relying on the traditional circulation-focused mode of use. Accordingly, the process was presented through a design proposal, an implementation project, technical drawings, and as-built photographs; design decisions were grounded in theoretical foundations, resulting in a proposed model for the refunctioning of liminal spaces in similar university buildings.

2. Method

This study examines the design process aimed at transforming a corridor in a design school into a multipurpose liminal space by giving it an exhibition function. The study adopts the Research through Design (RtD) approach, recognizing that design is not merely an end product but also a tool for generating knowledge. According to (Behnam-asl et al., 2024), Research through Design is

an approach that uses design thinking as the primary tool for knowledge production and examines research problems through the design process, prototype development, and evaluations conducted with users. Similarly, (Zimmerman et al., 2010) views the design process not merely as problem-solving but as a systematic research approach that serves to generate new knowledge, theories, and insights. (Koskinen et al., 2013), on the other hand, defines Research through Design as an approach that uses design thinking as a research tool to generate new knowledge and address research questions. In this vein, studies in the field of interior architecture adopt a holistic approach to the theoretical framework, implementation, and post-use observations should support not only design production but also knowledge production.

Accordingly, this study was conducted in three phases within the framework of the Research Through Design method: the establishment of a conceptual framework and problem definition, the development and implementation of the design, and post-use observations (Figure 1).

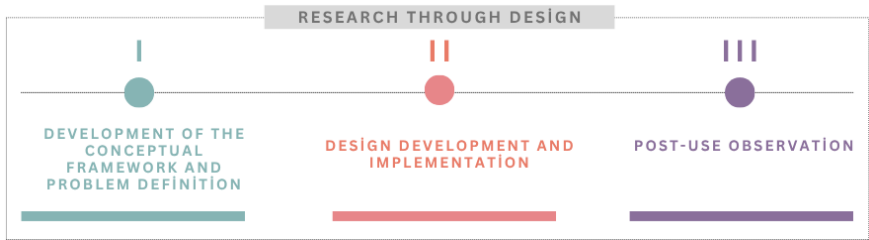


Figure 1. Steps in the Design-Based Research Method

2.1. Establishing the Conceptual Framework and Defining the Problem

The corridor in question is located on the ground floor of a design school, between the faculty building and the student classroom building, and serves as a connecting corridor. The corridor is approximately 15 m long, 3.80 m wide, and has a clear ceiling height of 3.40 m. There is a total of 8 window openings 4 on each side, spaced evenly along the right and left axes, as well as 2 garden doors facing each other. Currently, the walls are painted white over plaster, and the floor is covered with 60x60 granite tiles. As with the wall surfaces, neutral paint finish over plaster was used on the ceiling, and the structural floor was left exposed. Based on daily observations, the corridor’s traffic consists of faculty members, staff, and students, with an average of 50–100 users passing through daily (Figure 2).



Figure 2. Images of the Corridor's Current Condition

During the planning meetings held with the joint participation of the faculty administration and the project team, the following issues were identified: high foot traffic in the corridor, its long and linear spatial structure, irregularities in natural light distribution and uncontrolled light ingress, the lack of functionality in the existing walls, undefined surfaces, the monotonous uniformity of the floor covering, the circulation-focused and inappropriate positioning of the lighting, and the insufficient representation of the institutional identity were identified as key problems requiring solutions during the design process. In this context, a theoretical framework has been established for reimagining corridors particularly in design-focused educational units as active spaces that go beyond their passive role as mere circulation routes to serve functions such as welcoming, informal learning, socializing, and interaction, thereby enabling the display of work from various disciplines; the existing literature on the liminal space approach has also been reviewed. In his study (Sfinteş, 2012), the author states that in architecture, the structural boundary is defined by the building envelope, while thresholds consist of structural openings within this envelope, such as corridors, doors, and windows. According to the author, these thresholds are spatial elements that not only facilitate passage but also establish a relationship between interior and exterior spaces. (Josian & Gandha, 2021) define threshold spaces as transitional spaces situated between two distinct spaces or functions within a building or, on a broader scale, within a built environment. In contrast, according to Van Eyck, the in-between space is a spatial construct that strengthens not only relationships among people but also those between people and space, between structures, among the qualities of a structure, and across different time periods (Özer, 2023). Similarly, (Naja et al., 2024) define liminal space as the intermediate state or transitional phase between point A and point B. This transition can be experienced both psychologically on a mental level and spatially within an architectural context.

(Mick, 2025) states that liminal spaces in the built environment not only possess both visual and experiential qualities but can also create a sense of temporary tension felt between mental states. According to (S. Yıldırım & Erol, 2025), if transitional spaces are designed in accordance with visual perception parameters, it is possible for them to transform into more livable, experiential, balanced, and reusable spaces, thereby neutralizing this tension. According to

(Sharif, 2022), corridors are not merely circulation areas that support basic activities taking place in studios, offices, or similar spaces; they are also important spaces that host a much wider variety of social, every day, inevitable, informative, recreational, collaborative, and celebratory interactions. (Aronis, 2022) approaches liminal architecture not merely as a physical interface but as a fundamental component of the concept of “communicative architecture,” one that makes processes of transfer, sharing, and two-way interaction visible. (Tavakoli et al., 2023) state that liminal spaces create areas for encounters and reconciliations among different groups of people, noting that these spaces support the formation of fluid identities and allow for their intermingling across boundaries. (Liedgren et al., 2023); It highlights that Victor Turner describes liminal spaces as environments that exist outside of productive and everyday life, offering extraordinary experiences. (Turner, 1966) and (Gennep, 1909) ground the concept of liminal space in the disciplines of architecture and interior design, basing it on states of in-between-ness, transition, and the potential for transformation. (Hertzberger, 1991) also treats the threshold as a permeable space rather than a rigid boundary. When all these approaches are considered together, it becomes evident that liminal spaces can be designed as active spaces that go beyond mere circulation to facilitate pausing, gathering, interaction, encounters, informal learning, and social interaction.

2.2. Design Development and Implementation

In this study, theoretical findings aimed at solving the problems observed in the spatial context were incorporated into the design process, and an implementation project was developed in accordance with design principles that support the active use of threshold spaces. This section provides a detailed examination of the process and methods following regarding the development and implementation of the design. According to the developed design framework, three fundamental principles flexibility, continuity, and balance were identified and translated into spatial design decisions. The principle of flexibility ensures that the space can accommodate works from different disciplines, allows for spatial transformations based on interdisciplinary scenarios, and can adapt to dynamic needs; The principle of continuity aims to ensure uninterrupted visitor circulation within the space, preserve spatial integrity by creating visual and functional flow between different exhibition units; and the principle of balance aims to distinguish walking and exhibition areas from one another through floor, ceiling, and lighting decisions, thereby establishing both visual balance and orientation for users within the space. The process was carried out in an iterative, cyclical, and phased manner, in which design proposals were evaluated and refined, rather than following a uniform design approach. Within this scope, user scenarios, functional diagrams, floor plans and sections, three-dimensional digital models, and construction details were developed. The resulting design was implemented on an actual scale.

2.2.1. Flexibility

Flexibility is a fundamental design characteristic that enables the design process to move away from rigid, unchangeable steps and adapt to changing conditions, user requirements, and different needs that arise over time (Molaei et al., 2021). Similarly, (Till & Schneider, 2005) define flexibility as the capacity to adapt to users' changing needs. (Kronenburg, 2007), on the other hand, describes flexible design as reusable, responsive to changing needs, and motivating rather than static. According to the author, the concept of flexible design extends the lifespan of the built environment while simultaneously increasing user satisfaction and spatial efficiency. In line with these theoretical approaches, based on liminal space theory, corridor designs should be considered as multifunctional spaces that can accommodate multiple usage scenarios without being limited to a single use, allow for long-term use, and can be adapted over time to meet the needs of different users.

Accordingly, a total of 8 perforated aluminum sliding panels, each measuring 120x210 cm, have been installed along both the right and left axes of the corridor under consideration. The sliding panels are positioned to close the window openings along the corridor axis on the horizontal plane. On the left axis, the panels are anchored from floor to ceiling, while on the right axis, they are anchored from the floor to the wall above the window. Thanks to the sliding track system installed at floor level, the panels serve as a display surface when closed and allow natural light to enter when open. The perforated structure, created by utilizing the aluminum surface properties of the panels, ensures the homogeneous distribution of natural light throughout the space and allows for controlled light intake. This linear and multifunctional design concept creates rhythmic pauses and visual focal points within the space, thereby encouraging users to pause and explore (Figure 3.).

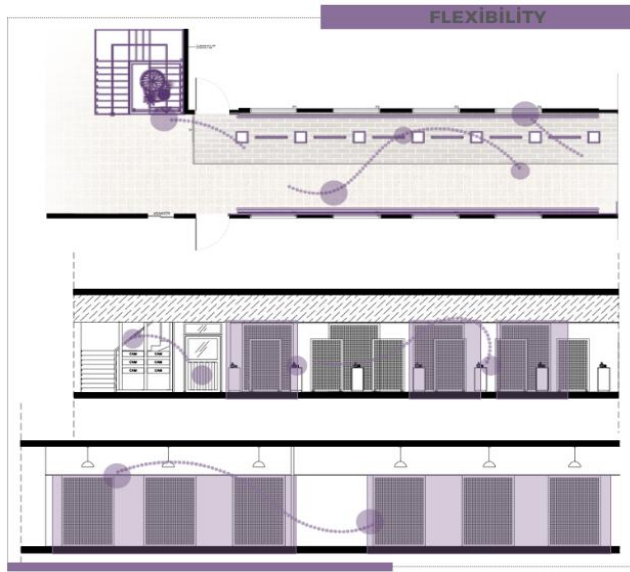


Figure 3. Floor Plan and Section Created in the Context of the Principle of Flexibility

The perforated structure of the aluminum panel system installed in front of the windows along the corridor provides a flexible infrastructure that allows for the display of student work of various scales and types. Thanks to the perforated surface of the panel system and its movable hanging elements, the display arrangement can accommodate two-dimensional drawings, three-dimensional models, textile products, shoe designs, and other student works, adapting to their respective dimensions and characteristics.

By adopting a flexible design approach, the corridor has transformed into a learning and exhibition environment that is not limited to a single-use scenario serving only as a circulation space. Instead of a fixed exhibition system, it allows works to be adapted to different exhibition scenarios, accommodates the needs of various disciplines and changes educational activities, and can be transformed to suit different usage scenarios while remaining continuously updatable (Figure 4.).

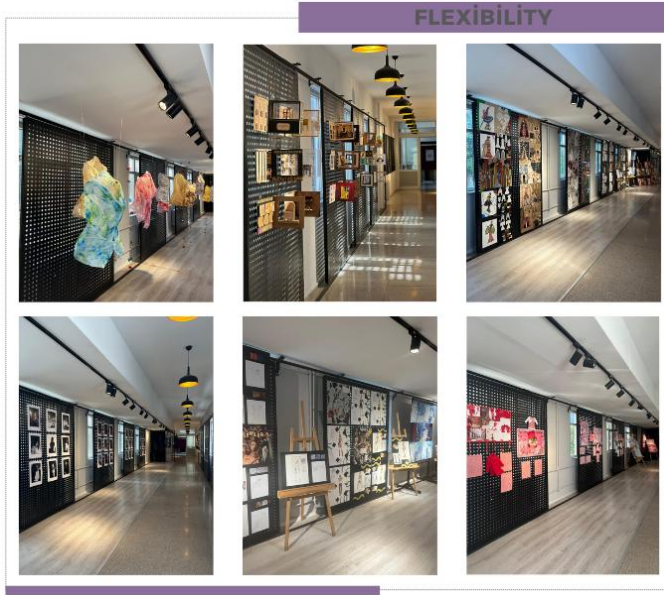


Figure 4. Display Images Based on Different Usage Scenarios

2.2.2. Continuity

Continuity is the eye's ability to follow a line, form, or texture without interruption. In design, continuity refers to the movement of lines in the same direction and their perception as a unified whole (Gezer, 2019). Continuity is a fundamental spatial organization that enables users to perceive a space holistically by establishing seamless relationships among the various components of an architectural space. According to (Kim, 2015), architectural form gains meaning by bringing together elements that belong together. This facilitates the functional and comfortable use of space and enables the establishment of geometric order. Visual continuity is one of the primary design principles that ensures the holistic perception of a design. When used in conjunction with the principles of similarity and repetition, it plays a unifying role by ensuring visual flow; when addressed through the principle of color, it ensures unity (H. Yıldırım & Büyükçam, 2026).

In the process of incorporating the principle of continuity into the design, the floor plane of the corridor was divided into two distinct sections: a 2.00 m wide display axis on the left and a 1.90 m wide walkway axis on the right. Wood look laminate flooring was installed in the exhibition axis, while a mottled anthracite gray 60×60 cm matte ceramic tile was used in the exhibition axis adjacent to the windows. The transition between the two materials was completed with an aluminum profile featuring a 10 mm brass joint (Figure 5).

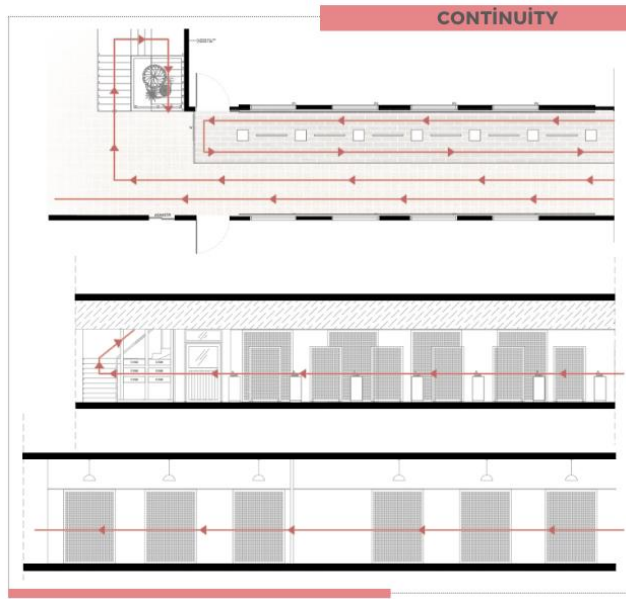


Figure 5. Floor Plan and Section Created in the Context of the Principle of Continuity

When evaluated in the context of the floor-to-ceiling relationship, the exhibition axis and the circulation axis are clearly separated, allowing users to intuitively perceive the act of pausing. This ensures that the exhibition axis does not interrupt traffic circulation, enabling the simultaneous operation of both functions and allowing it to serve as a functional wayfinding tool.

Similarly, the corridor's lighting design is resolved through a two-layered system comprising the exhibition and circulation axes. A suspended drywall ceiling was installed on the ceiling surface of the exhibition axis. In this area, the ceiling height was lowered from 3.40 m to 2.70 m, creating a 70 cm level difference. On the ceiling plain of the walkway axis, the structural floor level was maintained. Along the exhibition axis, 12 black pendant fixtures were positioned at 80 cm intervals, corresponding to the upper axis of each window opening. This continuous and rhythmic arrangement lends a sense of unity to the corridor axis and creates a balanced sense of depth. Furthermore, the sequential point-like appearance created by the fixtures forms a continuous line that guides visitors along the corridor axis. Linear track spotlights have been installed along the exhibition axis. This allows for a visual hierarchy by focusing on the exhibited products on the panels, thereby highlighting product details (Figure 6.).

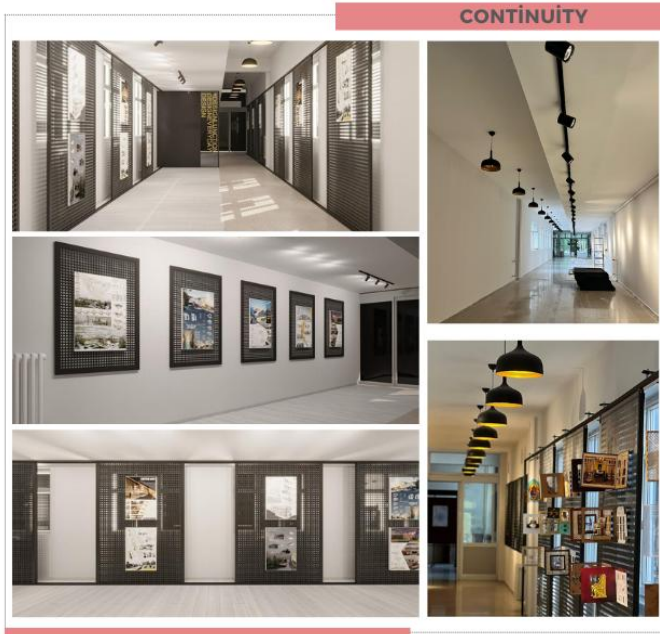


Figure 6. Corridor Images Reflecting the Principle of Continuity

2.2.3. Balance

The principle of balance is one of the fundamental design principles that ensures design elements are organized in an orderly and harmonious manner. This principle not only creates a symmetrical arrangement but also ensures that space is perceived as a whole through the principles of form, color, texture, light, and space. (Locher et al., 1998) treat the principle of balance as a fundamental organizational framework for the composition process. (Samuel & Kerzel, 2013) associate balance with aesthetic perception, stating that it ensures the composition is perceived as stable and holistic as a result of visual elements balancing one another. Furthermore, the author argues that balance can be achieved not only through symmetry but also through asymmetrical arrangements by properly distributing the visual center of gravity. In their study, (Han & Ishida, 2004) evaluate balance through the visual harmony created by natural and artificial light sources. The study emphasizes that, in addition to having sufficient lighting levels to enable users to perceive the space as balanced, this balance can also be achieved through the balanced distribution of lighting elements within the space. This approach highlights the importance of lighting elements and lighting design within the design components that constitute the principle of balance. (Odabaşıoğlu & Olguntürk, 2020) state that visual balance in interior design does not depend on a single design parameter; rather, color is integrated with the surface finish properties of the design, thereby enabling users to perceive the space as harmonious. According to the author, the balanced distribution of color within a space strengthens the design in terms of visual harmony and

compositional integrity. When the literature is considered as a whole, the principle of balance in design gains meaning not so much through orderly and symmetrical placement, but rather when considered in conjunction with other design parameters such as color, light, form, visual weight, and lighting elements.

In its current state, the corridor's linear spatial organization presents a fragmented appearance due to wayfinding elements, bulletin boards, and display areas added at different times; there is no consistent design language established among color, material, and form. Through the design intervention, this fragmented structure has been reorganized; by creating a unified compositional language using display panels, linear lighting, floor coverings, wayfinding signs, corporate identity elements, structural supports, and a neutral color palette along the corridor, the visual weight has been distributed evenly throughout space.

The modular display panels placed along the window axes on both sides of the corridor not only serve a display function but also, thanks to their reciprocal placement, reinforce the space's linear perspective and create a balanced arrangement approaching symmetry. This arrangement allows natural light to spread into the space in a controlled manner through the window openings while preventing visual weight from concentrating at single point (Figure 7.).



Figure 7. Floor Plan and Section Created in the Context of the Principle of Balance

The principle of balance was also applied in the selection of colors and materials. The wooden parquet flooring, added to the existing floor material planned for preservation, is balanced by black metal surfaces and light gray walls. This creates contrasting relationships that harmonize with the contemporary design language; the visual intensity created by the dark-colored surfaces is

balanced by the light-colored floor and wall surfaces, resulting in a legible spatial atmosphere.

The wayfinding area under the staircase has also been reimagined in line with the principle of balance. Wayfinding signs, previously perceived as independent signage elements, have been reimagined in a balanced manner as part of a single composition alongside the interior courtyard layout and structural elements. The color contrast between the black vertical structural elements and the white wayfinding panels enhances legibility, while the inner courtyard created with stone infill and landscaping balances the visual weight of the rigid geometric elements, establishing a harmonious reception area within the perceptual context (Figure 8.).



Figure 8. Images of the Corridor Reflecting the Principle of Balance

An information display has been added to one of the vertical metal panels used to define the boundaries of the exhibition area. The name of the space was inscribed on the transparent plexiglass panel next to it, with the aim of both identifying the space and establishing a visual connection through its transparency. The Atatürk Corner, located in front of this area, has been redesigned using materials and a color scheme that integrate with the space's design language. To highlight the Atatürk bust, the surrounding area was clad in anthracite MDF laminate, and strip LED lighting was installed on the interior.

In the venue's design, the principle of balance was treated as an element that ensures cohesion among color, texture, form, light, and functional components. In this regard, the design decisions made ensure that users perceive the space as more orderly, legible, and holistic. Thanks to the balanced relationship

established among the functions of display, wayfinding, and circulation, the venue's representational value within the educational structure has been strengthened.

2.3. Post-Occupancy Observation

The relationships established between users and the design decisions made from the outset of the process were evaluated using post-implementation observation techniques. In this regard, the experiential role of the space was examined in terms of users' circulation routes, dwell times in the exhibition area, points of encounter, and usage intensities. The various spatial scenarios enabled by modular systems and the contribution of the selected materials to these scenarios were addressed in terms of the space's technical performance. According to the results of the three-month observation period that began upon completion of the project:

- Users spontaneously gathered along the corridor, turning it into a focal point, and the average dwell time increased,
- Informal (natural and spontaneous) group discussions took place in front of the exhibition panels,
- Students from different disciplines examined each other's work, leading to increased interdisciplinary dialogue,
- Faculty and student project exhibitions, end-of-term presentations, and exhibition events took place regularly in the corridor space,
- Organizations such as project presentations and departmental events transformed the space from merely a circulation area into a social gathering point,
- The corridor began to be used for various academic activities such as guest lectures, short presentations, pre-jury briefings, and student club events,
- Informal learning processes are supported as the works on display foster an environment for feedback and critical evaluation among users,
- As the space began to be used by different user groups throughout the day, diversity of use and spatial vitality increased, it has been observed.

In summary, a transitional space that was previously passive has been transformed into an active, dynamic area of interaction that meets the needs of the building's users. As a welcoming space that reflects the faculty's creative

identity and supports the institutional infrastructure, it has also become an area that enhances the building's interaction with its users.

3. Conclusion

The study clearly demonstrates that intermediate spaces defined as circulation areas can transcend their role as mere transitional elements and, through appropriate design decisions, also assume educational, cultural, and institutional functions. The fact that these spaces can be redesigned as more layered environments without losing their primary function thereby increasing their utilization serves as strong evidence of the applicability of liminal space theory.

According to the findings of this study, the theory of liminal space not only explains the transformative potential of transitional spaces but also provides a foundation for the implementation of design decisions. Furthermore, the application of design principles in linear spaces such as corridors endows the space with qualities such as functionality, aesthetics, informal learning, social interaction, legibility, and focus. Consequently, design principles not only serve as a guide in making design decisions but can also be applied as a methodological tool.

For the further development of this study and future research, it is recommended to conduct survey based user evaluations to measure spatial legibility using quantitative data; to involve users in the design process to ensure user-centered management of design outcomes; and to examine similar spatial transformation projects within the scope of comparative case studies.

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CHAPTER 6

**Spatial and Digital Transformation in
Anatomy Education:
The Case of the Anatomy Laboratory
at Selçuk University School of Medicine**

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1. INTRODUCTION

Learning in higher education is associated not only with educational content but also with the physical spaces in which education takes place. Studies on learning spaces demonstrate that the relationship between space and learning has been addressed through different pedagogical approaches (Leijon et al., 2024). With technological advancements, the integration of space, pedagogical approaches, and information and communication technologies has gained increasing importance (Valtonen et al., 2021).

One of the fields in which the physical learning environment is particularly important is practical medical education. Anatomy, a fundamental discipline in medicine and health sciences, examines the form, location, and interrelationships of structures within the human body. Therefore, anatomy education encompasses a learning process in which theoretical knowledge and practical experience are integrated (Miller et al., 2002; Zhang et al., 2023).

Anatomy laboratories are active learning environments that enable students to establish relationships between structure and function in the human body and to integrate knowledge acquired from different disciplines (Allison et al., 2023). Therefore, educational materials, spatial organization, work areas, circulation, ergonomics, physical comfort, and technological infrastructure are of considerable importance in these laboratories.

The importance of the physical laboratory in anatomy education became particularly evident following the COVID-19 pandemic. Tatar et al. (2026) investigated online and face-to-face approaches to anatomy education. The study, conducted with students from the Faculties of Medicine and Dentistry at Selçuk University, revealed that students preferred practical anatomy education to be conducted face-to-face. The authors concluded that laboratory practices involving direct interaction with anatomical models and cadavers continue to maintain their importance (Tatar et al., 2026). Evans et al. (2020) examined approaches to how anatomy science curricula could be designed and implemented in the post-COVID-19 period. They regarded this situation as an opportunity and anticipated the development of innovative and pedagogically diverse approaches aimed at facilitating learning in education.

Technological developments have also diversified the tools used in anatomy education. Traditional tools include cadaveric dissection, prosection, anatomical models, and atlases. In addition to these methods, three-dimensional digital models, medical imaging technologies, VR systems, and virtual dissection tables have increasingly been incorporated into anatomy education. These developments have increased the importance of using digital tools as complementary resources alongside traditional methods (Chytas et al., 2023).

Students' learning preferences also support this integration. Özcan and Sevindik (2026) identified students' increasing tendency toward digital materials and recommended that anatomy education be enriched with interactive

applications and technology-supported tools to create flexible and continuous learning environments.

Accordingly, contemporary anatomy laboratories should be considered learning environments that integrate traditional and digital teaching methods while meeting the ergonomic and functional requirements of the space. In this context, interior architectural design plays an important role in integrating spatial organization, furnishings, ergonomics, physical environmental conditions, and technological infrastructure (Lorke et al., 2023; Trelease, 2006).

The aim of this study is to evaluate the existing spatial conditions of the anatomy laboratory at Selçuk University Faculty of Medicine and to present the interior architectural improvement project developed in accordance with the functional, ergonomic, and digital requirements of contemporary anatomy education.

2. METHOD

This study was conducted as a design- and implementation-based study in which an existing anatomy laboratory was reconsidered in accordance with physical and technological requirements. The study process consisted of reviewing the literature and contemporary anatomy laboratories, analyzing the existing conditions, identifying spatial problems, developing design decisions, obtaining feedback and making revisions, and implementing the final project.

2.1. Field of Study

The study focuses on the anatomy laboratory at Selçuk University Faculty of Medicine, which spans an area of 199 m² and has a capacity of approximately 150 students; this facility provides both theoretical and practical training for medical students.

The study began with an examination of current approaches to anatomy education and examples of modern anatomy laboratories. Subsequently, on-site observations, measurements, and photographic documentation of the existing laboratory were conducted. Finally, the current status and issues regarding spatial organization, functionality, ergonomics, comfort, hygiene, storage, and digital infrastructure were identified.

2.2. Design and Implementation Process

Interior design decisions were developed based on the problems identified during the analysis of the existing conditions. In this context, arrangements were made regarding spatial organization, workspaces and furnishings, circulation, visual connections, storage, and lighting. Additionally, digital education infrastructure was integrated into the interior space.

The design process was evaluated through meetings attended by representatives from the Rectorate, the Department of Anatomy, and the Department of Construction and Technical Affairs. The project was revised based on feedback received during two review meetings held following the initial

design proposal. The authors conducted the design process as a team-spanning from the assessment of existing conditions to the development of the final design and the approved final project was implemented. The study's methodology and design process are summarized in Figure 1.

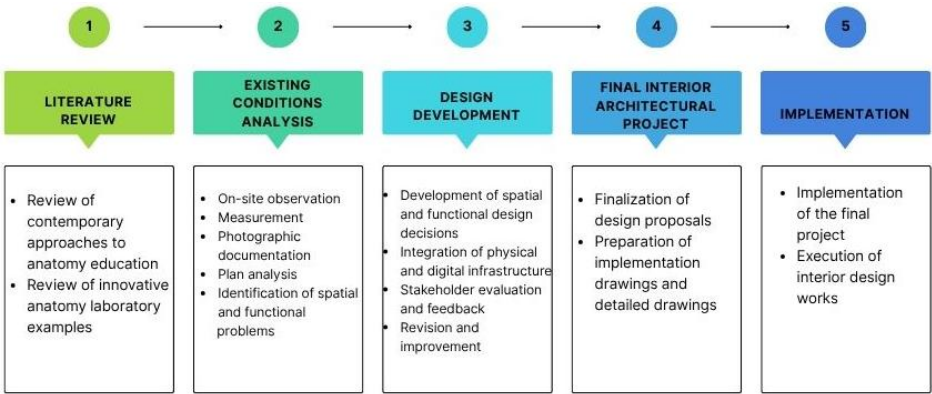


Figure 1. Working method and design process

3. FINDINGS

The current state of the laboratory was evaluated through on-site observation, measurement, and photography. The assessment identified issues regarding the spatial and technological infrastructure. It was observed that the laboratory currently contains fixed worktables that lack appropriate height adjustment, as well as heavy, stationary stools. The cabinets used for displaying and storing anatomical specimens, along with the sink areas, were found to be non-ergonomic. While the existing spatial layout accommodates traditional anatomy practices, it was determined that technological upgrades are required to meet the standards of modern anatomy education. The current physical condition of the laboratory is shown in Figure 2.



Figure 2.a.b.c.d. The current state of the anatomy laboratory

Following an assessment of the existing conditions and the laboratory's primary functions, the layout was redesigned to incorporate student workspaces, a cadaver practice area, sinks, storage units, and digital educational equipment. The spatial organization of the student workspaces was reconfigured in the developed plan. While the cadaver area, computer workstations, sink area, cabinets, and niches remained in their original locations, their designs were optimized for better ergonomics. Additionally, screen areas were designated to ensure visibility from every angle. Large screens were installed at various points to allow study groups to view digital imaging systems; these screens are mounted on structural metal profiles. The final plan is presented in Figure 3.

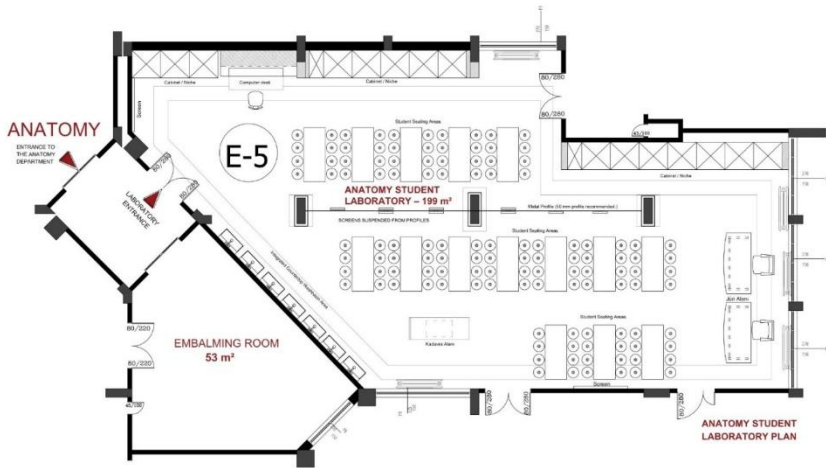


Figure 3. Revised interior layout plan for the anatomy laboratory

Wall, color, material, furnishing, and lighting decisions were also considered in the interior design. Due to hygiene requirements and the intensive use of the laboratory, light colors were selected for the floor and wall surfaces. The existing stainless-steel student worktables were retained. The overall design concept was defined by gray and beige tones. Furnishings and storage surfaces were complemented with wood textures within the space. In addition to general lighting, linear lighting fixtures were installed above the worktables. The material, color, furnishing, and lighting board used in the design is presented in Figure 4.

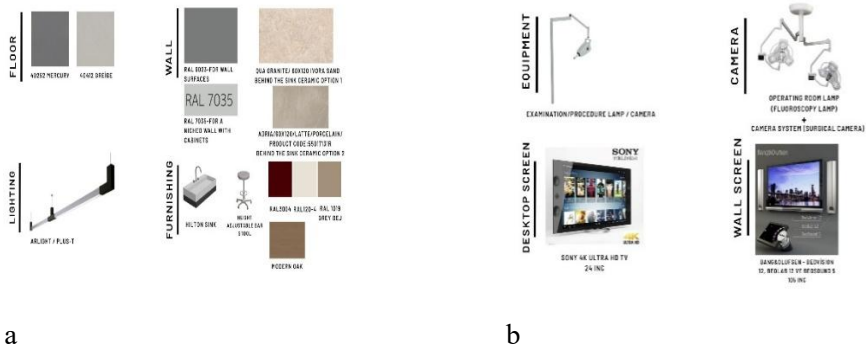


Figure 4.a. Materials, colors, fixtures, and lighting used in the anatomy laboratory, **b.** Digital systems used in the anatomy laboratory

The most significant change in the project was the integration of a digital educational infrastructure into the laboratory space. Digital infrastructure plays a crucial role in the educational systems of modern anatomy laboratories. Accordingly, in addition to a main display screen, multiple screens were positioned at various points throughout the space to ensure visual access for every student.

These screens were mounted on a metal support system and aligned with the different workstations. The metal profiles were framed around the existing columns in space. A camera system was also installed to enable the simultaneous transmission of procedures performed in the cadaver and embalming areas to the students, thereby displaying the footage from the embalming area on the screens within the laboratory (Figure 5).

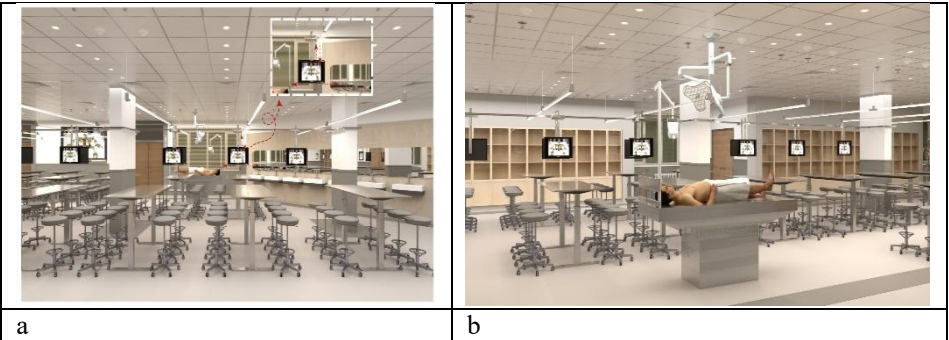
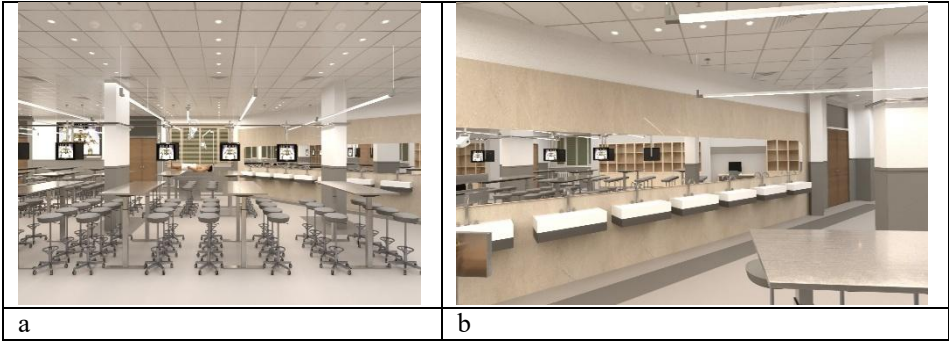


Figure 5.a.b. Digital imaging and camera systems in the laboratory

Three-dimensional visualizations have been prepared to observe the impact of design decisions within space. Using these visualizations, the layout of workstations, fixtures, the cadaver demonstration area, screen placement, storage units, sink areas, and the lighting arrangement were evaluated collectively. Through visualizations created from different viewpoints, sight lines, circulation areas, and the accessibility of digital screens within the space were specifically checked before the design was implemented.

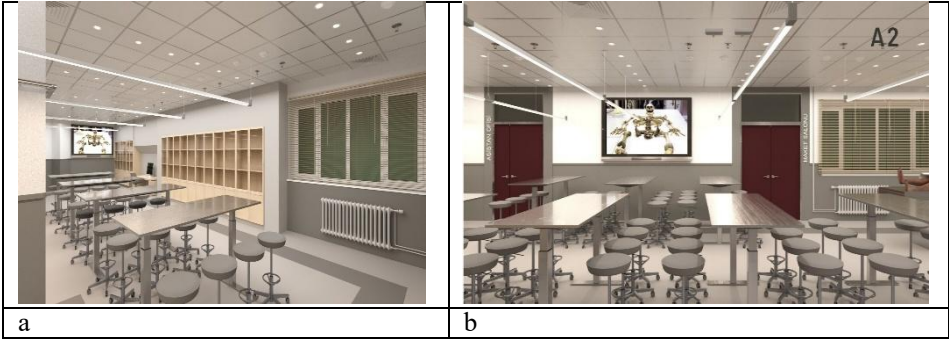
In the developed interior architectural design, the spatial character was addressed through a holistic approach. As shown in the three-dimensional visualizations in Figure 6, the steel-surfaced tables were retained, while only the table legs were raised to a height of 1 m to improve ergonomics. This adjustment provided students with a more comfortable posture during prolonged periods of study and enabled more effective use of the work surfaces. Similarly, the heights of the washbasins and the positions of the mirrors were redesigned in accordance with human ergonomic principles. In addition, Hilton-type washbasins were preferred for hygienic considerations.



Şekil 6.a.b. Table and washbasin area of the anatomy laboratory

The areas shown in Figure 7 illustrate the storage units designed for anatomical models along the wall surfaces and the large display screen areas. In the storage area, the dimensions of the existing human anatomical models were measured, and the shelf heights and internal partitions were designed accordingly. The lower sections of the cabinets were intentionally enclosed and allocated for the storage of documents and other materials. The area in front of the radiator was left unobstructed to maintain effective heating within the space.

In addition, the door located on the right side of this area allows students to exit from the other side without encountering or seeing other students during midterm and final examinations. This detail was deliberately considered as part of the spatial organization. The doors were finished in burgundy to create visual emphasis and make them more noticeable.



Şekil 7.a.b. Table and washbasin area of the anatomy laboratory

The design was finalized and implemented following two rounds of evaluation and revision based on feedback received from the relevant academic and administrative units. As a result, work desks and seating elements were rearranged, the laboratory's overall surface and color scheme were refreshed, a linear lighting system was installed, and digital display systems were placed in locations within the laboratory accessible to different user groups. Post-implementation photographs show that the spatial organization, as well as the

physical and digital components, envisioned during the design phase were largely implemented. Figure 7 presents the laboratory’s post-renovation condition.

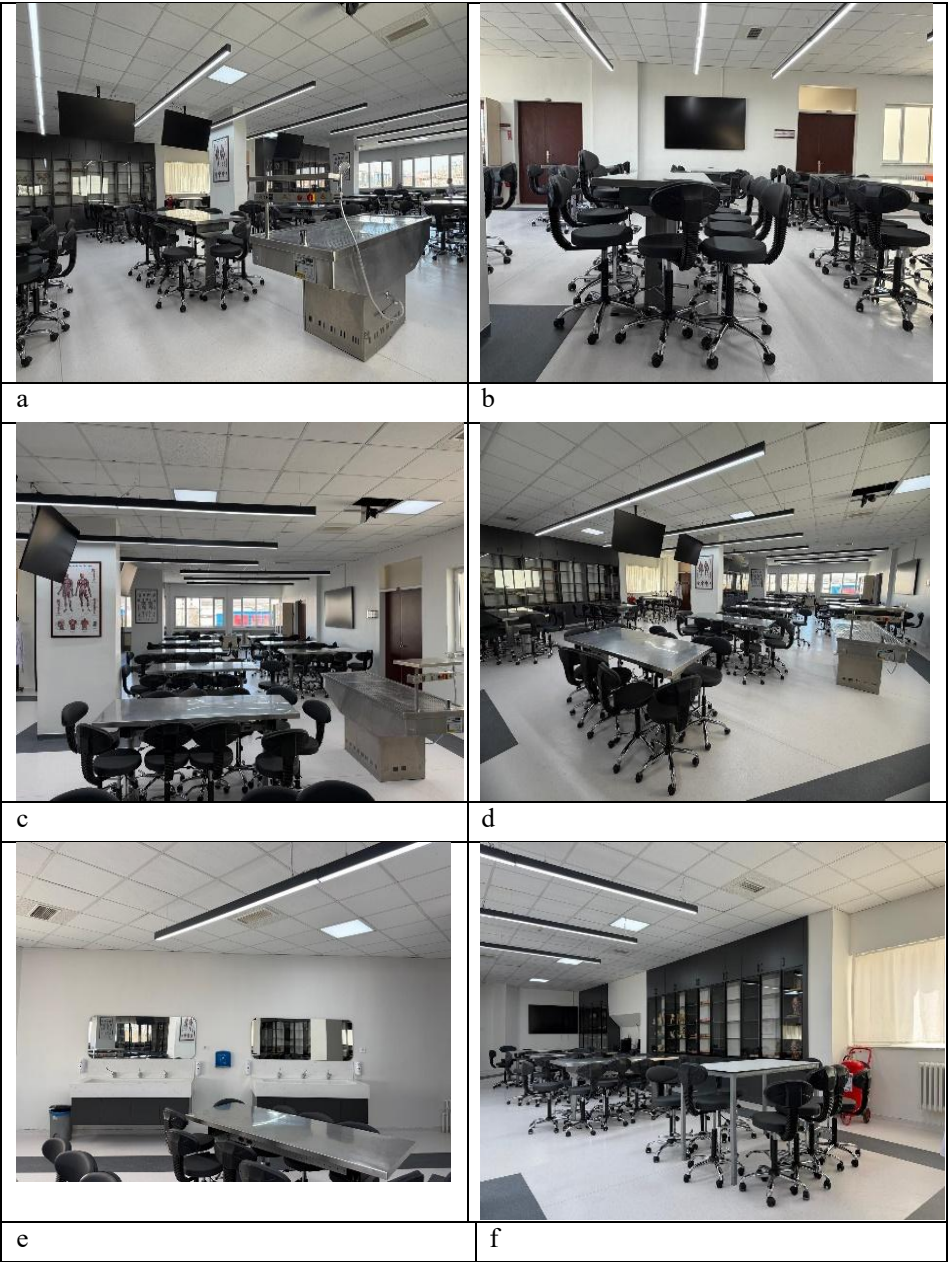


Figure 7.a.b.c.d.e.f. The anatomy lab after its interior renovation

The laboratory's post-renovation spatial organization, work and seating furnishings, circulation and sightlines, surface and material choices, lighting, storage, and digital education infrastructure were evaluated as interrelated design components. In particular, integrating camera and multi-screen systems with student work areas has created a learning environment that allows practical exercises in the dissection room and cadaver area to be observed from various points throughout the laboratory. Thus, while preserving the physical characteristics of traditional, hands-on education based on anatomical materials, an integrated anatomy learning environment has been developed that utilizes digital imaging and transmission capabilities within the same spatial system.

4. CONCLUSION

Thanks to advancing technology, digital transformation is taking place across almost every profession today. Digital infrastructure systems have become particularly prominent in medical education, a field that directly affects human life. The importance of the digital infrastructure of anatomy laboratories in medical education has been discussed from different perspectives in the literature. In particular, its effects on learning efficiency and ease of learning have been emphasized. Although traditional teaching methods continue to maintain their importance, the significance of supporting these methods with digital infrastructure has also been highlighted.

In medical education, the anatomy laboratory is one of the fundamental environments in which theoretical knowledge and practical training are integrated. In contemporary anatomy education, digital imaging and transmission technologies are increasingly incorporated into learning environments. Particularly in advanced medical laboratories abroad, the use of technology has made educational processes easier and faster. This transformation requires anatomy laboratories to be considered integrated learning environments in which different teaching tools can be used together.

Chytas et al. (2023), Allison et al. (2023), Tatar et al. (2026), Evans et al., and Özcan and Sevindik (2026) reported similar findings, emphasizing the need to integrate digital systems into anatomy laboratories to support traditional education.

In this study, steps were taken to improve the Anatomy Laboratory at Selçuk University Faculty of Medicine, which had become outdated in terms of contemporary learning requirements. One of the primary objectives in transforming the laboratory, whose existing physical conditions had become considerably outdated and worn, was to integrate digital systems into the educational process. Problems identified based on feedback from faculty members and students were evaluated, and the interior architectural transformation of the laboratory was carried out accordingly.

During the design process, the existing capacity and fundamental pattern of use were preserved. The main axis of spatial organization and circulation was maintained in accordance with the previous layout, while the capacity was

increased. Circulation areas, table arrangements, and display systems were designed to provide optimal viewing angles. The seating units were replaced with more ergonomic alternatives. In addition to the insufficient natural lighting, artificial linear lighting was installed above the tables to improve visual accessibility. The capacity of the storage units along the wall surfaces used for anatomical models and materials was increased, and the units were designed to create visual continuity along the walls. Appropriate equipment for the display systems and digital infrastructure was integrated into the interior environment.

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CHAPTER 7

User-Centred Building Performance Assessment: Integrating Indoor Environmental Quality and Occupant Feedback

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1. Introduction

Low energy use can coexist with uncomfortable rooms or inadequate ventilation. Occupants may also report satisfactory conditions after repeatedly adjusting blinds, windows or heating. These situations raise a question about how the building achieves its recorded performance. Energy records describe consumption, while environmental measurements and occupant accounts provide other information about conditions in use. Understanding their relationship requires examining the circumstances behind each result.

Post-occupancy evaluation (POE) investigates buildings in use, including environmental conditions and the consequences of design and operational decisions. P. Li, Froese, and Brager (2018) argue for continuing, detailed and integrated evaluation. In their later review of office studies, Dam-Krogh and colleagues identify considerable variation in POE methods and difficulties in implementing recommendations (Dam-Krogh, Rupp, Clausen, & Toftum, 2024). Collecting information about a building is therefore only part of the task. An assessment must also explain what that information means for a decision.

Established methods already combine several aspects of building performance. They include multidimensional POE, occupant-centric indicators and simulation (Azar et al., 2020; H. Li, Wang, & Hong, 2021; P. Li et al., 2018). Recent work also connects sensor-tracked actions with occupants' reported motivations (Barthelmes et al., 2026). This chapter considers how these methods support an architectural recommendation. The central question is how the assessor moves from an observed pattern to an explanation, and from that explanation to an appropriate response. The chapter focuses on how the reasoning from evidence to action can be recorded and examined, because POE reviews report weak implementation of recommendations (Dam-Krogh et al., 2024).

Here, user-centred assessment means assessing energy and indoor environmental quality (IEQ) with attention to occupants' activities, experiences and opportunities to adjust their surroundings. Their accounts help interpret a problem and evaluate the response. Alongside providing survey answers, occupants need opportunities to clarify their concern and understand the resulting decision. The term is used here for environmental performance assessment, rather than a comprehensive method of participatory design.

The chapter examines thermal, visual and acoustic conditions and indoor air quality (IAQ), alongside energy use. It first considers the meaning of physical and occupant indicators, then examines how the two can be compared. A literature-informed framework organises this reasoning into five assessment stages. The framework is intended to make the basis of a recommendation clear enough for designers, operators and affected occupants to examine it and, where necessary, question it.

2. Review approach

Literature was located through topic-focused web searches, publisher websites and institutional repositories. Sources were selected for their relevance to combining physical measurements with occupant feedback and informing building design or operation. Relevant full-text sections were examined to compare methods, findings and limitations.

The synthesis considered the meaning of indicators, the comparability of measurements and occupant reports, and the role of behaviour and environmental control. These comparisons informed the proposed assessment framework, with published findings distinguished from the chapter's interpretations. SANRA informed checks of clarity, referencing and scientific reasoning (Baethge, Goldbeck-Wood, & Mertens, 2019).

3. Building performance and the meaning of its indicators

3.1. Energy use and environmental service

Energy consumption needs to be considered alongside the service a building provides and how it is used. Comparisons require a defined boundary, period and basis of normalisation. An annual total cannot show whether heating runs unnecessarily in empty rooms or whether occupied rooms receive enough heat. Indicators that account for occupancy can help investigate these questions. H. Li, Wang, and Hong (2021) organise occupant-centric key performance indicators (KPIs) around resource use, IEQ and human–building interactions. They link indicator selection to the assessment purpose. This allows the assessor to consider occupancy and the service delivered when interpreting energy use.

An energy result can change meaning when the building's use changes. If consumption stays constant after occupancy falls, less service may be delivered per unit of energy. An increase during longer opening hours may have a different explanation and need not indicate lower efficiency. Energy reporting therefore needs an account of occupancy and operating conditions. Occupants can describe whether the service meets their needs, but those accounts cannot establish equipment efficiency or resolve an undefined metering boundary. **Table 1** summarises the physical and occupant evidence relevant to energy and environmental assessment.

Table 1. Physical and occupant evidence across performance domains

Domain	Physical evidence	Occupant evidence	Interpretation for assessment
Energy	Metered consumption; end uses; demand; occupancy and operating hours.	Adequacy of the service; unmet needs; operating practices.	Match the boundary and period. Check whether low use reflects efficiency, reduced occupancy or inadequate service.
Thermal	Air and radiant temperature; humidity; air speed; occupied position.	Sensation, satisfaction and preference; clothing, activity and adjustments.	Retain the response construct, local exposure and access to effective control. Spot readings may miss recurring episodes.
Visual	Task illuminance; view luminance; glare-source size and position; shading state.	Glare, visibility, views and lighting preference; screen and blind use.	Match the task and viewing direction. Adequate task illuminance does not establish freedom from glare.
Acoustic	Sound level, source and timing; speech and relevant room characteristics.	Disturbance, speech privacy and activity interference; adaptations.	Relate the exposure to the activity and operating state. An average sound level can miss disruptive events.
IAQ	Ventilation and occupancy records; CO ₂ with stated assumptions; relevant pollutants.	Perceived freshness, odour or irritation; window use and context.	CO ₂ is a limited proxy. Occupant reports guide investigation but cannot identify pollutants or establish a health diagnosis.

3.2. Measurements and environmental experience

The physical indicators needed for IEQ assessment vary between thermal, visual, acoustic and air-quality questions (H. Li et al., 2021; Park et al., 2018). **Table 1** pairs representative measures with the occupant information needed to interpret them. Location and timing matter as much as the recorded value. A sensor near a return-air grille may provide little information about conditions at a sunlit workstation. A short visit also offers limited coverage of discomfort that occurs only in a particular season.

Thermal conditions depend on the factors involved in bodily heat exchange, including more than air temperature. Park, Loftness, and Aziz (2018) combined workstation measurements, satisfaction surveys and building-system attributes in their office investigation. Thermal satisfaction was associated with factors including temperature, zoning, window quality and control. These findings support examining the physical setting together with the adjustments available to occupants. Its short spot measurements and observational design limit conclusions about recurring exposure and the effect of replacing a component.

For visual assessment, illuminance describes available light, whereas discomfort glare depends on the occupied view. Wienold and Christoffersen's daylight glare model considers vertical eye illuminance and the luminance, size and position of glare sources (Wienold & Christoffersen, 2006). A desk may have adequate illuminance while a bright window causes discomfort during screen work. The measurement and complaint can both be accurate because they concern different properties.

Kim and de Dear (2013) found that noise and privacy were associated with dissatisfaction in open-plan offices. Assessing a local complaint may require the sound source, timing and affected activity in addition to an average level, because their survey does not link complaints to specific acoustic measures.

Carbon dioxide (CO₂) requires particular care as an IAQ indicator. Persily (2022) explains that its use as a ventilation indicator depends on occupancy and assumptions about the space. It is not a comprehensive measure of IAQ. A low concentration cannot rule out pollutants unrelated to occupant emissions. Reports of freshness, odour or irritation can guide an investigation, but cannot identify a contaminant or establish a health diagnosis. The purpose of the physical measurements and the purpose of the occupant questions should therefore be stated separately.

3.3. Simulation and the performance gap

Simulation estimates performance from stated assumptions. Monitoring records what happens in the occupied building, within the coverage of the instruments used. A comparison needs equivalent boundaries, weather periods, schedules and system descriptions. When results differ, the assessor can examine the model assumptions, equipment operation and actual use (Azar et al., 2020; Hong, Chen, Belafi, & D'Oca, 2018). Differences in occupancy or control may contribute, but need to be checked against information from both the model and the building.

Hong and colleagues review the ways occupant behaviour is represented and implemented in simulation programs (Hong et al., 2018). Azar and colleagues organise the literature on simulation-aided occupant-centric design around metrics, modelling approaches, design methods and supporting practices, and identify barriers such as limited validation and weak integration of occupant behaviour models into simulation tools (Azar et al., 2020). Occupant-centric design is thus already addressed by these established approaches. In practice, survey and observation evidence can help define plausible operating scenarios. Simulation can then compare schedules or control assumptions, provided the predictions are interpreted within the conditions represented by the model.

4. Occupant evidence and its methodological limits

4.1. Perception, satisfaction and preference

Perception describes an experience, such as warmth, brightness or disturbance. Satisfaction concerns how that experience meets needs and expectations, whereas preference indicates a desired change. Someone can therefore feel warm, remain satisfied and still prefer slightly cooler conditions. Asking about these constructs separately preserves distinctions that matter when choosing an intervention.

Personal comfort models use individual responses to avoid assuming that a population average describes everyone (Kim, Schiavon, & Brager, 2018). In an office field study, Kim and colleagues used machine learning to relate personal heating and cooling actions, environmental records and reported thermal preference (Kim, Zhou, Schiavon, Raftery, & Brager, 2018). Model performance varied between individuals and depended on the training data and the range of observed conditions. Such models can support personalised prediction. Whether their predictions lead to better comfort or lower energy use must be assessed separately through operation and intervention outcomes.

The wording of a question defines the evidence it provides. A report about experience over several months cannot be treated as a response to the temperature when the questionnaire was completed. Mohammed, Luo, Walker, and Kramer (2025) identify inconsistencies in the design, deployment and calculation of subjective indicators in thermal and air-quality applications. Scores with the same name may consequently represent different questions or recall periods. Reporting how the score was produced allows the reader to judge whether a comparison is appropriate.

4.2. Behaviour and environmental control

Closing blinds, opening windows and moving to another seat can change both occupants' exposure and building energy demand. Hong and colleagues examine such actions in relation to building use and context (Hong, Yan, D'Oca, & Chen, 2017). Their meaning still needs interpretation. A closed blind, for example, could reflect glare, a wish for privacy or a preferred atmosphere. Assigning a reason requires an occupant's account or other supporting evidence beyond the observed action.

Having a control does not establish that occupants can use it effectively. Reach, authority and system response all matter: a switch may be inaccessible, a thermostat may govern a shared zone, or automation may undo a manual adjustment. Shared controls also bring different needs into the same decision. An adjustment that suits one person may make conditions worse for someone else. The assessment needs to distinguish a problem with the interface or equipment from a problem with how control is allocated.

Reported satisfaction may follow an adaptation that leaves the original problem unresolved. Someone who moves away from an uncomfortable seat can be satisfied with the new location while the first seat remains difficult to use. Yet frequent adjustment can also be a convenient, intended part of building operation. Interpreting it requires asking what the adjustment achieves and how often and with what effort occupants make it. This distinguishes useful control from a continuing difficulty that occupants manage themselves.

4.3. POE as an interpretative process

POE can use questionnaires, interviews, walkthroughs, measurements and building records (Dam-Krogh et al., 2024; P. Li et al., 2018). Park and colleagues link workstation measurements with survey responses and system attributes (Park et al., 2018). Kim and de Dear use the Center for the Built Environment survey database to compare experience across office layouts (Kim & de Dear, 2013). The studies address different assessment needs. One investigates conditions at occupied workstations; the other compares reported experience across buildings.

Participation determines whose experience appears in the results. Few complaints could reflect satisfaction, low response or a belief that reporting a problem will achieve little. An assessment should distinguish the invited population from respondents and identify the group to which its conclusions apply. Building means need particular care when small groups or local difficulties are poorly represented. Interviews can help explain these difficulties, but a selected account does not establish how common the problem is.

Altomonte and Schiavon (2013) found negligible overall differences in satisfaction between offices certified under Leadership in Energy and Environmental Design (LEED) and non-LEED offices, and they separated statistical significance from practical relevance. Non-random sampling and the absence of linked physical IEQ measurements limit causal explanation, although the findings do not rule out certification benefits in other settings. Within LEED-rated offices, neither the total IEQ points earned nor the rating level meaningfully predicted workspace satisfaction (Altomonte, Schiavon, Kent, & Brager, 2019), and voluntary participation and an imperfect match between credits and survey categories qualify this result. Certification, achieved credits and measured conditions therefore describe different aspects of performance, and an explanation of satisfaction needs to state which one was studied and how it relates to the relevant activity and exposure.

5. Integrating evidence through explicit comparison

5.1. Establishing comparable observations

Evidence can refer to different units within the same building. Annual energy use may describe the whole building, ventilation records a room, and thermal preference an individual. Combining them requires identifying how those units

relate in the occupied place and period. A record of environmental conditions, reported experience and relevant control actions can make the connection explicit. Sources that cannot be connected may still suggest what to investigate, although they support a more limited explanation.

Time matters beyond matching timestamps. An intermittent event may be absent during a monitoring visit or disappear within an average, while a retrospective survey records its importance to the respondent. A comparison must therefore specify whether it concerns an immediate perception, recurring episodes or overall experience. Bringing sources with different temporal resolutions to a common scale can be useful, provided the loss of detail is explained.

Spatial coverage poses the same problem. A cluster of complaints near a façade needs information about local exposure and desk position. A room mean may describe overall operation without representing those desks. Building-level aggregation remains useful for benchmarking. Investigation of a local problem, however, needs enough spatial detail to retain the pattern that prompted the enquiry.

5.2. Interpreting disagreement

Measurements and occupant reports should first be checked for comparability before treating their disagreement as a problem. Adequate illuminance and reported glare concern different properties. Satisfaction with temperature also says little about an IAQ concern. If both sources do address the same phenomenon, the assessor should examine measurement uncertainty, sampling and question interpretation before choosing a design explanation.

Dissatisfaction under apparently acceptable conditions has several possible explanations. The measurement may miss a local exposure, the criterion may be unsuitable for the activity, or occupants may have limited control. Each possibility calls for a different investigation. A walkthrough or short questionnaire during a reported episode can help locate the problem. Further monitoring should examine the suspected exposure; repeating the original room average may leave the uncertainty unchanged.

Occupants may also report satisfaction under conditions outside a selected criterion. Adaptation or personal preference may explain the response, or the criterion may have limited applicability. The assessor needs to establish whether it concerns comfort prediction, health protection or system function. User tolerance helps interpret comfort but cannot determine whether safety requirements are met. Persily (2022) explains why a favourable CO₂ reading cannot establish overall air quality. Similarly, a favourable occupant report does not establish compliance with health or safety requirements.

Agreement between independent sources gives stronger descriptive support when both cover the same context. Warmth reported at a hot perimeter, for example, narrows the investigation. Glazing, shading, equipment gains, occupancy and control operation may still contribute. The agreement can support a targeted investigation or reversible trial, while the contribution of each factor remains to be established.

5.3. Approach families and representative applications

Table 2 compares general approach families through representative studies. The cited publications illustrate the families rather than define their full scope, and a project may use several approaches together. POE examines buildings in use. Indicators organise outcomes for a stated purpose, while simulation compares alternatives under specified assumptions. Personal comfort models predict individual responses. Multidomain control and mixed-method assessment draw on several environmental or behavioural sources. The table identifies the output of each family and the judgement still needed to select an architectural response.

Table 2. Approach families and representative applications

Approach family	Representative studies	Evidence or output	Decision use and limits
Integrated POE	P. Li et al. (2018); Park et al. (2018)	Surveys, observations and physical evidence relating experience to buildings in use.	Locate concerns and investigate exposure. Coverage and observational design limit causal inference.
Purpose-specific indicators	H. Li et al. (2021); Mohammed et al. (2025)	Indicators selected for a stated goal; explicit survey design, deployment and computation.	Compare relevant outcomes. Preserve scale, resolution and group differences when aggregating.
Personal comfort modelling	Kim, Schiavon, and Brager (2018); Kim, Zhou, et al. (2018)	Individual response prediction from personal feedback, behaviour and environmental inputs.	Inform personalised operation. Training coverage and prediction quality do not establish intervention benefit.
Simulation-aided design	Azar et al. (2020); Hong et al. (2018)	Conditional performance estimates under alternative design, occupancy and control assumptions.	Examine alternatives and uncertainty. Check assumptions against use; predictions require follow-up.

Approach family	Representative studies	Evidence or output	Decision use and limits
Multidomain control	Martinez-Alcaraz, de la Barra, Andriotis, Knaack, and Luna-Navarro (2026)	Models and control objectives representing several occupant and environmental demands.	Coordinate competing outcomes. Make weights explicit and evaluate occupant outcomes independently.
Mixed-method assessment	Barthelmes et al. (2026), eCOMBINE	Environmental monitoring linked to reported perceptions, motivations and tracked control actions.	Investigate episode-level relationships. Retain participation gaps and distinguish associations from causes.

6. A literature-informed assessment framework

6.1. Stages and required outputs

Figure 1 shows the five stages of the proposed framework, and **Table 3** specifies the information and outputs to record. The record can accompany an existing POE instrument, KPI workflow or simulation comparison. It documents the basis of a recommendation, including the evidence that would lead the assessor to reconsider it.

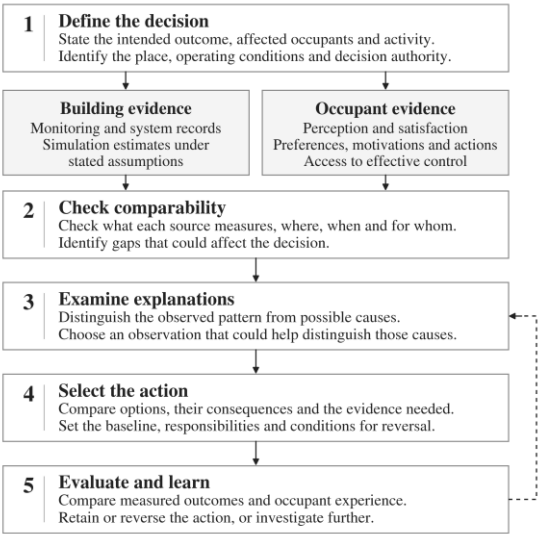


*Figure 1. Connecting evidence with action and follow-up.
The dashed arrow indicates that explanations may be reconsidered in light of follow-up findings.*

At the first stage, a reported concern is turned into a question about a particular decision. Defining the intended outcome establishes which occupants, activities and places the assessment needs to cover. An occasional or seasonal problem also needs an observation plan suited to when it occurs. The coordinator and the person authorised to approve a change are identified at this point.

The second stage examines comparability and coverage using the fields in **Table 3**. Evidence does not have to match at every level to be informative. A retrospective survey can guide monitoring of recurring discomfort even when it cannot be paired with a single sensor reading. Such a limitation belongs in the record. Missing evidence for a decisive place, period or group usually calls for targeted observation before a permanent intervention. The question is whether the available evidence supports the next step, rather than whether it reaches a universal sample-size threshold. A plausible explanation may justify a reversible trial with bounded, detectable consequences while remaining insufficient for a costly permanent alteration.

The third stage considers explanations for the observed pattern. For each one, the assessor states what would be expected if it were correct and what finding would weaken it. These expectations determine the next observation, rather than simply prompting more of the measurements already available. The record retains the conditions accompanying the concern and any unmatched observations. An investigation that supports another explanation, or leaves the concern unresolved, is reported on the same basis.

The fourth stage selects an action in proportion to its supporting evidence and consequences. A local reversible adjustment may be appropriate where a coherent pattern supports a plausible mechanism and the effects can be monitored. A permanent façade change needs stronger evidence and comparison with operational alternatives. Before implementation, the record identifies who will act and whose needs are affected, then defines the baseline and follow-up conditions. It also specifies grounds for retaining, reversing or extending the action. Safety and health questions require the relevant criteria and specialist expertise.

At the fifth stage, follow-up compares physical outcomes and occupant accounts with the baseline under reasonably similar conditions. Differences in activity, weather or operation are documented. An improvement may support continued use in those conditions, but its cause remains uncertain if other changes occurred at the same time. An unsuccessful action also stays in the record and prompts reconsideration of the alternatives. The account of exposure, activity and adjustment gives later designers the context needed to judge whether a finding applies to another project.

Table 3. Information and outputs at the five assessment stages

Stage	Information to record	Output for the next decision
Stage 1: Define the decision	Choice and intended outcome; affected place, people and activity; season and operating state.	A bounded question with an assessment coordinator and decision authority.
Stage 2: Check comparability	Construct, location, period, instrument and population represented for each source.	A justified relationship between evidence streams; decisive gaps identified for targeted investigation.
Stage 3: Examine explanations	Observed pattern; plausible mechanisms; expected evidence for and against each explanation.	The next observation that could distinguish explanations, including a finding that would revise the recommendation.
Stage 4: Select the action	Support for the mechanism; alternatives, reversibility and effects on other domains or groups.	A reasoned choice, implementer, baseline and follow-up plan, with conditions for retention, reversal or escalation.
Stage 5: Evaluate and learn	Physical and occupant outcomes; weather, activity and operational differences from the baseline.	Retain, reverse or investigate further; document a conditional finding for future design and operation.

6.2. Worked hypothetical glare example

Consider a hypothetical office with reports of afternoon visual discomfort at desks near a west-facing façade. Workplane measurements indicate adequate illuminance, leaving the assessor to consider whether a shading adjustment would help screen-based work. Adequate light on a desk does not rule out discomfort in the occupied view. The initial findings therefore establish a concern rather than a contradiction or a need for façade alteration. This example follows the assessment process and contains no intervention results.

The assessor would first locate the affected desks and occupants, establish the reported periods and identify who controls the blinds. Existing measurements would then be checked against those afternoons and viewing directions. People who moved away from the façade also matter when checking survey coverage, since their experience may be absent from the current responses. Without these checks, a permanent change has limited support.

Several explanations could be investigated. A bright window calls for an assessment from the occupied view during a reported episode. A suspected operating fault calls for checking whether the blind reaches and holds its requested position, including what happens under any automated override. Temporarily reorienting the screen under otherwise comparable conditions can test the contribution of reflections. These observations distinguish visual exposure, blind performance and workstation arrangement while allowing more than one contributor to be present.

Evidence pointing to shading could support a local reversible trial agreed with affected occupants and the operator. Its intended improvement would be stated before starting. Follow-up would cover glare in the occupied view alongside useful daylight, view availability, lighting operation and nearby occupants' experience. The operator would document settings and overrides. A substantial loss of useful daylight or a new difficulty for another group could be agreed as a reason to reverse the adjustment.

Suitable afternoon episodes would be compared with the baseline, allowing for documented differences in weather, tasks and operation. Better reported experience together with the expected visual change could justify retaining the adjustment if other consequences were acceptable. Persistent glare would prompt reassessment of the explanation. Improvement only after reorienting the screen would likewise change the recommendation. A capital intervention would still require a wider comparison of alternatives.

The choice of observation would also follow the explanation in other cases. Noise during window opening for cooling would need acoustic measurements and occupant accounts while the windows were open, with thermal and ventilation effects considered when comparing responses. Unusually low energy use would first raise questions about occupancy, opening hours and delivered service before supporting a claim of efficiency.

7. Discussion

7.1. What integration adds to established approaches

Integration involves interpreting outputs that have different meanings. Satisfaction results describe occupants' accounts of experience. A model estimates a response to specified inputs, while a control objective sets a priority. All can inform a decision, provided their role in answering the assessment question is explicit. Treating them as equivalent would lose the distinctions on which the recommendation depends.

In practice, a survey may identify a recurring concern, monitoring may investigate the exposure, and simulation may help compare design options. **Table 2** allows for this use of several approaches within one project. Their selection

depends on what remains uncertain about the decision. Collecting more data at another location or outside the affected period may increase the dataset while contributing little to the explanation.

The eCOMBINE study shows what detailed linkage can contribute. It combined environmental monitoring, reported perceptions and motivations, and sensor-tracked control actions in two Swiss offices (Barthelmes et al., 2026). Its findings indicate incomplete self-reporting of actions. Observing behaviour alongside asking about it can therefore help assess the coverage of occupant accounts. The study examines experience and actions in occupied settings, although its observational design leaves the effect of a proposed change to the building or controls unresolved.

The framework brings these established contributions together in a record of the recommendation. By documenting observations and possible explanations, it allows designers and operators to examine why an action was chosen and what evidence would change the decision. Occupants could also see how their concern was interpreted. This clearer account of the reasoning is the intended contribution.

7.2. From observed patterns to architectural action

An association can indicate where to investigate, but cannot establish the effect of replacing a building feature. Workstations with different windows may also differ in orientation, equipment gains or control arrangements. A large sample cannot correct a mismatch between the measured exposure and reported experience. An intervention needs a stated explanation and observations that could show it to be wrong.

The scale and reversibility of an action affect the support it needs. Recurring complaints at a few desks may justify local investigation despite a favourable building average. A plausible explanation may support a trial if it can be reversed and its effects monitored. Permanent façade alteration involves different costs and consequences for other occupants. The framework asks the assessor to make these considerations explicit when deciding whether to act, collect further information or compare alternatives.

Environmental outcomes can change together when an action is taken. A window opened for cooling affects ventilation and noise exposure; a closed blind can reduce discomfort at the expense of daylight or views. Martinez-Alcaraz and colleagues distinguish the use of multiple environmental inputs from coordination of competing demands (Martinez-Alcaraz et al., 2026). They identify limited acoustic representation and show how fixed weights or reward terms can make trade-offs difficult to interpret. This raises a difficulty for interpreting combined scores, since a favourable total can obscure an outcome

assigned little weight. Separate results and an explanation of the priorities allow the proposed compromise to be examined.

The distinction between a design constraint and an operating problem affects the intervention itself. Repairing a faulty blind, changing a viewing direction and improving access to a control respond to different difficulties. The hypothetical case shows why these possibilities need to remain distinguishable during investigation. More than one may contribute to the complaint, so the basis of a recommendation should make clear which explanation it addresses and what remains unresolved.

7.3. Participation, implementation and design learning

The people represented in an assessment can change its recommendation. A building mean may conceal difficulties among occupants whose tasks or access to controls differ from those of most respondents. People who moved to another location may no longer report the exposure that prompted the move. Relevant subgroup patterns should remain visible when the findings are summarised. Discussion with affected occupants can then distinguish disagreement about conditions from disagreement about which outcome to prioritise, and explain whose needs a compromise serves.

Participation requires time, and detailed linkage may involve repeated questions or identifiable records. The assessment purpose should determine the information collected and the arrangements for privacy. An anonymised comparison by location may answer the question without continuous individual tracking. Mohammed and colleagues organise subjective indicators around the application goal, survey design, deployment and computation (Mohammed et al., 2025). Their approach supports matching question frequency and detail to the intended use.

Implementation depends on who receives the recommendation and who can carry it out. Dam-Krogh and colleagues identify shortcomings in post-POE implementation and the selection of cost-effective solutions in the office studies reviewed (Dam-Krogh et al., 2024). Naming the recipient and the person responsible, together with a follow-up plan, makes the proposed action clear. Funding, access and organisational capacity may still limit what can be done. The record should explain the choice in enough detail to be useful without becoming burdensome to use.

To use a finding in another design, the designer needs to know the conditions in which it applies. A successful local adjustment may inform the assessment of orientation, viewing direction or control provision in a later project. It does not establish the same solution for every building. Simulation can examine the proposed explanation under other use conditions (Azar et al., 2020; Hong et al., 2018). Knowing whether the original problem involved an operating fault,

restricted control or a design constraint helps identify which assumption to revisit in the next brief.

7.4. Limits and priorities for evaluation

The review compares selected approaches and provides neither a complete account of the field nor an estimate of their prevalence or a pooled effect. English-language searches and access to full texts influenced the selection, and much of the empirical evidence comes from offices. Findings need to be reconsidered for the activities, populations and control arrangements of classrooms, homes or healthcare settings. In a classroom, for example, observing a lesson may be more relevant than monitoring a stable workstation.

Evaluation of the complete framework is still needed. The hypothetical example explains how the stages connect, without demonstrating better diagnosis, comfort, energy use or cost-effectiveness. Those outcomes require real decision cases with documented interventions. The framework addresses environmental service and experience, so actions affecting accessibility, structural or fire safety, or clinical risk also require the relevant specialist assessment.

A prospective study could compare an established POE protocol with the same protocol supplemented by the structured record. Before assigning comparable cases, the study would define the decision question and baseline, along with outcomes and the follow-up period. The assessment process could be examined through the completeness of the rationale, agreement between assessors and changes in recommendations after further observations. Staff time and the burden on occupants would also need to be recorded. Agreement indicates consistency without establishing that an explanation is correct. Judging whether a recommendation works requires observing physical changes and occupant outcomes in the conditions studied.

Changes in weather, occupancy or operation during follow-up should be documented, using comparison conditions or cases where feasible. The analysis needs to retain unsuccessful interventions and unresolved concerns alongside improvements. A clearer record might leave decision quality unchanged, so practical value must be judged from both the assessment process and its outcomes. This evaluation could also identify stages that need revision.

8. Conclusion

Physical measurements and occupant feedback can inform architectural decisions when their relationship to the affected activity, place and period is clear. POE, indicators, behavioural models and simulation offer complementary information, but their outputs need to be interpreted according to what they describe and whose experience they represent.

The proposed framework records the reasoning that connects a reported concern with an architectural recommendation. It combines checks of the evidence with investigation of possible explanations and a follow-up plan agreed before action begins. The hypothetical glare case illustrates how this reasoning can guide an investigation and reversible trial while considering other occupants and environmental outcomes. Its value for decisions and their results must now be examined in real cases.

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