THEORY, CONTEXT, AND PRACTICE IN ARCHITECTURE, PLANNING, AND DESIGN

Editor: Asst. Prof. Dr. Burçin SALTIK

DUVAR

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Editör

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Chapter 1

Comparative Visibility Graphic Analysis (VGA) in Educational Buildings

Beyza Nur ÇALIŞKAN [1]

ABSTRACT

The physical characteristics of educational buildings and circulation patterns directly affect the quality of the learning process. Architectural design plays a decisive role in student behavior. The concept of visible space allows for the analysis of how users interact visually and behaviorally with a space. This concept is an important tool for understanding how a space is perceived and experienced. In this context, this study aims to investigate spatial organizational forms that facilitate orientation behaviors in educational buildings. Using Visibility Graph Analysis (VGA), floor plans of university faculty buildings were analyzed in relation to user behaviors. The floor plans were transferred to DepthmapX software, and visibility analyses were performed. In these analyses, visibility and integration values were visualized on a color scale ranging from red to blue. The color scale was scored using a Likert scale (red = 5, blue = 1), and visual analyses of educational spaces were conducted using the obtained visibility impact scores. As a result, the structures' plan forms were comparatively evaluated based on users' movement and visual perception within the space, revealing the effects of physical layout on user experience. The obtained data were proposed as input for designs in the field of building information.

Keywords: Plan typologies, organisation, visibility, VGA, depthmapX

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INTRODUCTION

Universities are institutions of higher education that organise their educational, research, publication and production activities for the benefit of society, training qualified professionals in a variety of fields (Keleş, 1972). Quantitatively, the function of these institutions is to train the number of professionals needed by society. Qualitatively, they consider and question social values, criticise the system when necessary, propose new values, develop different perspectives and prepare a culture and knowledge environment suitable for technical or institutional innovations (Sönmez, 1972). The primary goal of universities is to generate knowledge, conduct research and educate scientists. Their secondary goal is to disseminate the scientific knowledge they produce (San, 1992). A university's success is measured by its capacity to produce scientific knowledge and its ability to transfer this knowledge to society (Tekeli, 1972).

To ensure an effective educational process, the physical environment in which educational activities take place is as important as the university's level of development and the quality of its academic staff. Physical characteristics such as space design, circulation, use of natural light, acoustic arrangements and flexible usage options affect the quality of educational processes. In line with the ongoing transformation of the education system, architectural elements should be evaluated as tools that support learning, and physical spaces should be redesigned to align with educational processes (Meek, 1995).

In short, the design of educational buildings should be approached holistically, considering their functional, pedagogical, and environmental aspects. In line with current educational approaches, faculty buildings should be designed to offer spatial solutions that support sustainability and functionality.

The architecture of educational buildings directly affects students' behaviour, achievements and learning potential (Maiden, 1998). Space is perceived as a geometric order in all its dimensions; however, what makes it habitable is its functional quality, which allows for human action. Just as people interact with each other, so too do spaces; the structuring of these interactions and their arrangement in a specific order form the basis of the architectural design process. The design process results in buildings taking shape with numerous interconnected spaces and a circulation network between them. At this stage, the programme requirements of the buildings and the physical conditions of the land on which they will be located play a critical role in determining the spatial organisation. The increasing complexity of educational structures, incorporating more diverse types of spaces, has led to the evolution of spatial organisation. This evolution has given rise to different types of spatial organisation, such as the division of combined classrooms into smaller spaces.

One example is Pasalar's (2003) corridor-type and central-type organisation. In the corridor type, classrooms are arranged along a corridor; in the central type, they are arranged around a central area. In the corridor type, the corridor serves as a circulation area, providing access to the classrooms for students and teaching staff. In the central type, the area at the centre of the classrooms serves not only the function of circulation, but also as a social space (Figure 1.1).

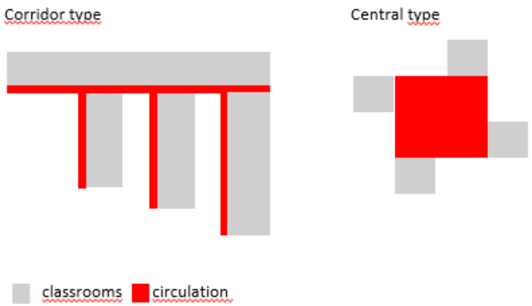


Figure 1.1. Plan diagrams based on the spatial organisation of Pasalar (2003)

Perkins (2001) emphasises that educational structures tend to be organised either in linear arrangements or in clustered groups. Linear arrangements are a layout format in which units are organised in one direction only. In this format, classrooms are usually situated alongside a corridor. This offers a simple, understandable flow. It facilitates directional guidance. However, interaction areas are limited and this layout may be insufficient for fostering social cohesion. This organisational type is typically preferred in traditional school buildings (Figure 1.2).

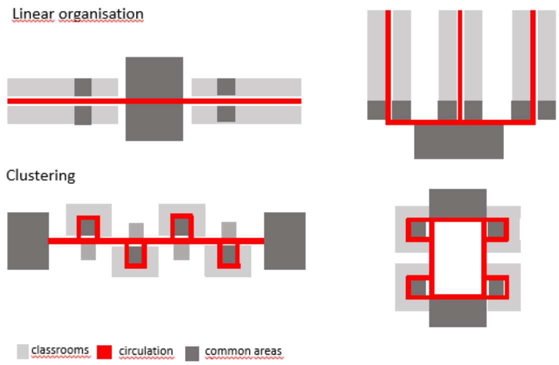


Figure 1.2. Plan diagrams based on the spatial organisation of Perkins (2001)

Rigolon (2010) argues that different design types should be evaluated according to specific educational and social requirements, and suggests four broad categories of educational building. The Courtyard Plan: This plan features a courtyard at its centre, surrounded by classrooms and other spaces. It provides a safe, peaceful open space. It provides a visual focal point and fosters a sense of belonging. The use of this design varies according to climate and settlement conditions; in rural areas, L- or U-shaped open courtyards are common. Circulation is usually provided by corridors surrounding the courtyard. Block Plan: Compact structures with linear or central circulation. Circulation areas open directly onto educational spaces. This offers spacious open areas suitable for socialising. It allows for flexible arrangement of educational and social spaces. Cluster Plan: A plan type in which educational units are grouped in independent volumes. Small learning communities are formed. This enhances a sense of belonging. Transition areas (buffer zones) support students' adaptation. Circulation areas can be transformed into active learning spaces. Complex Plan: This is an organic, village-like layout where various structures are combined freely. It consists of freely arranged independent volumes. The social centre is connected to the learning units (Figure 1.3).

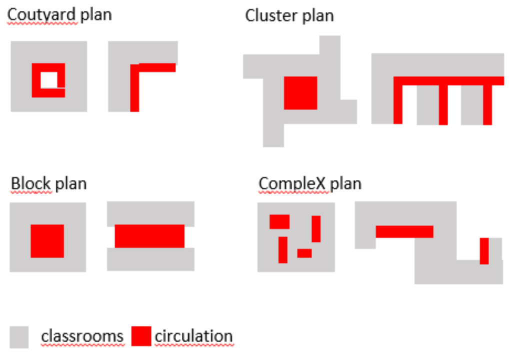


Figure 1.3. Plan diagrams based on the spatial organisation of Rigolon (2010)

Çalışkan (2021), on the other hand, limited his master's thesis research on the typological schemes of educational structures to faculty buildings, classifying them according to ten different schemes. These schemes were produced through various combinations of the simplest typology: the linear scheme. Typically, one branch of the scheme defines educational units, while another branch defines areas where academic staff rooms are located. The final scheme is referred to as 'chaotic' for structures whose boundaries and form cannot be clearly defined. In such buildings, it is impossible to predict which departments will be located where (Figure 1. 4).

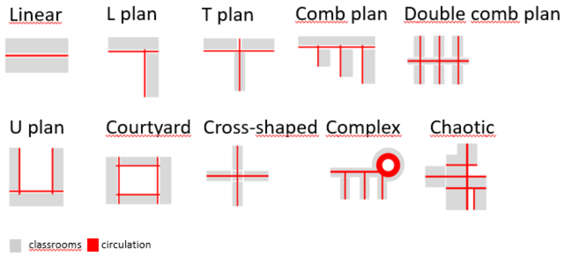


Figure 1.4. Plan diagrams based on the spatial organisation of Çalışkan (2021)

Circulation networks play a decisive role in the organisation of buildings; ease of access to the desired space for users directly affects the building's functional quality. As McCormick (1970) points out, accessibility and wayfinding are important criteria in determining the quality of the physical environment, and these criteria should be evaluated through the circulation system. Space usage depends not only on physical movement, but also on visual perception. Therefore, in order to understand how a space is designed, physical and visual accessibility must both be analysed (Şen and Ediz, 2016).

In this context, **the study aims** to investigate spatial organisation forms that facilitate wayfinding behaviours in educational structures, revealing how they create different spatial relationship patterns through morphological analysis. A comparative analysis method was applied to existing faculty buildings to evaluate educational structures at university level. The objective is to evaluate various organisational structures in terms of perceptual continuity, spatial guidance cues, and circulation networks.

Visible space analyses, as conceptualised by Benedikt (1979), are conducted to understand how human movement adapts to space. This approach involves measuring visible areas and investigating their relationship to human behaviour. To evaluate the accessibility of visible areas within a building, space syntax and visible area analyses were employed in conjunction. Combining these two methods resulted in Visibility Graph Analysis (VGA).

For this study, **VGA was chosen as the method** to evaluate the relationship between spatial organisation and social structures. The analyses were performed using DepthmapX 0.8.0 software. This method uses a graph-based approach to analyse the morphological structure of spatial systems and draw conclusions. How spaces are perceived by people determines how effectively and functionally those areas can be used. As people move through a space, their perceptions change;

therefore, visibility and movement-related perception should be considered in the design of educational structures.

2. MATERIALS AND METHODS

2.1. Materials

This study focuses on the faculty buildings located on the campus of Yozgat Bozok University. The presence of six different plan typologies on the same campus was a key factor in selecting the study area. In order to enable a sound analysis of the formal structure at plan level, faculties on the same campus were selected, bearing in mind that the buildings were designed under similar climatic, topographical and other environmental conditions. The architectural plans were obtained from the university's Directorate of Construction and Technical Affairs.

Each faculty building is identified by a code, such as P1, P2 or P3, according to the formal characteristics of the plan scheme. Accordingly: The P1 structure is linear; the P2 structure is L-shaped; the P3 structure is U-shaped; the P4 structure has a courtyard; the P5 structure is complex; and the P6 structure has a chaotic plan typology (Table 2.1). This classification enables comparative evaluations in the typological analysis process.

Buildings coded P1, P2, P3 and P4 have two floors above the ground floor. The entrances are located on the ground floor, with one wing designated for the education department and the other for academic staff. The P5 building has a complex plan formed by combining three different plan schemes: U-shaped, linear and open courtyard. Building P6 has a chaotic plan scheme, with student services and social areas on the ground floor, educational areas on the first floor and academic staff offices on the second floor.

The architectural floor plans of the selected faculty buildings are shown in Table 2.2. The analyses conducted in this study to draw conclusions about students' spatial perception are limited to first-floor plans where educational units are located.

Table 2.1. The typological representation and naming of faculty buildings.

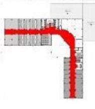
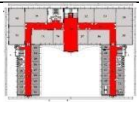
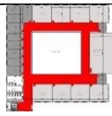
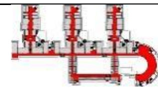
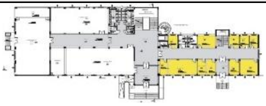
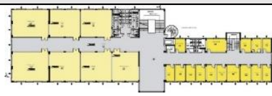
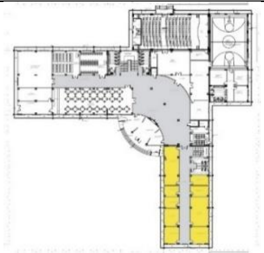
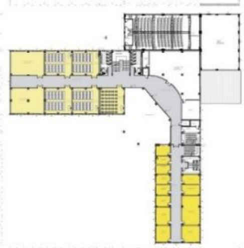
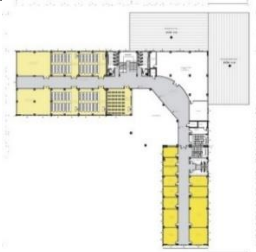
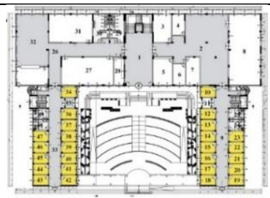
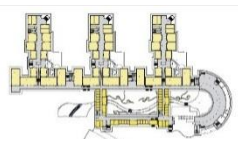
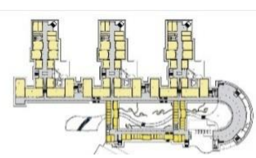
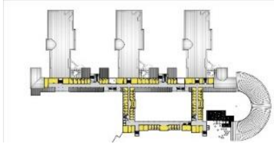
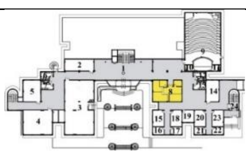
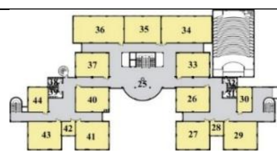
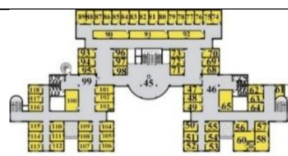
	P1	P2	P3	P4	P5	P6
PLAN						
TYPE	Linear plan	L plan	U plan	Courtyard plan	Complex plan	Chaotic plan

Table 2.2. Architectural floor plans of faculty buildings

	GROUND FLOOR PLAN	1st FLOOR PLAN	2 nd FLOOR PLAN
P1			
P2			
P3			
P4			
P5			
P6			
	common areas	educational units	academic staff offices

2.2. Method

Spatial syntax is an analytical technique that aims to reveal the relationship between the formal layout of a space and user behaviour. It does this by analysing floor plans of buildings (Hanson and Hillier, 1987). This method allows spatial patterns to be systematically examined for their influence on users' orientation, interaction and circulation behaviours, and defines spatial shaping characteristics using quantitative data (Keleş et al., 2025). While quantitatively measuring human behaviour, social patterns and psychological tendencies can be challenging, these behaviours can be analysed indirectly through the measurable characteristics of physical spaces (Bafna, 2003). In this context, the Spatial Syntax method focuses on the morphological and typological characteristics of spaces, examining the effects these characteristics have on user behaviour (Karimi, 2012).

The concept of visible space is an effective tool for understanding how a space is perceived, experienced and used. It helps us to understand how users see their surroundings from their positions within a space, and how this visual perception shapes their interaction with it. Thus, fields of view allow us to analyse physical layout as well as perceptual and behavioural dimensions (Turner, 2001).

Visibility Graph Analysis (VGA) is a method that combines spatial layout and visible area analysis to determine the perceptual qualities of a structure. It also examines the movement and interaction patterns of individuals within visible areas (Turner et al., 2001). DepthmapX software is used to convert two-dimensional (2D) drawings into an analysable format when creating VGA in spaces (URL-1). The software prepares the analysis infrastructure by covering open areas in the plan with grid points, using a grid system that is defined according to human scale. It then determines the visible areas by creating visual connections from each grid point to the others (URL-2). The graphics created by the software enable analyses of the spatial system from different perspectives (URL-3).

In the first phase of the study, spatial access analyses (SA) were conducted for both students and academic staff using stairs as a reference within the faculty buildings. The closest and furthest classrooms relative to the stairs were identified for students. The closest and furthest offices relative to the stairs were determined for academic staff. In terms of visual coding:

Closest distances → Displayed in red
Farthest distances → Displayed in blue

In the second stage of the study, the architectural plans of the faculty buildings, prepared using AutoCAD software, were converted to a DXF-extension graphic and transferred to DepthmapX 0.8.0. A grid was defined on the graphic and the grid areas were filled. Visibility graphic analyses (VGAs) were then performed. Visibility analysis options, including the global measurement radius, were then used to produce colour-coded graphics showing visibility in terms of syntactic values such as visual integration. The programme displays the analysis results on a colour scale ranging from red to blue. The integration value obtained in VGA shows the effect of the visible areas, decreasing from red to blue.

In the third stage of the study, colours were scored according to the Likert scale to determine the extent to which the visibility effect changed. Based on this, an evaluation table was created (Table 2.3). According to this, red was defined as 5 points, orange as 4 points, yellow as 3 points, green as 2 points and blue as 1 point. The visibility effect degree of circulation areas in the education section was calculated using the VGA plans of the faculty buildings and the evaluation table.

Finally, the analyses obtained were comparatively evaluated. Consideration was given to the spatial structure, the user's movement within the space, and visual perception, and these were interpreted.

Table 2.3. Evaluation table

VGA	COLOUR	SCORE	DEGREE
Visibility graphic	Red	5	high
	Orange	4	high
	Yellow	3	moderate
	Green	2	low
	Blue	1	low

4. FINDINGS

In Visibility Graph Analysis (VGA), each cell is analysed numerically with a specific connection value, and colour coding enables the data to be interpreted quickly and intuitively. In the software, a transition from red to blue indicates a decrease in visibility.

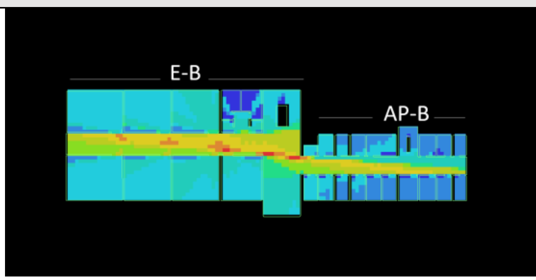
Areas with high visibility generally have higher integration values, indicating that these areas are highly accessible and perceptible. These areas can therefore be considered regions within the building that are more likely to be visited or used. Therefore, VGA contributes significantly to predicting user movements and understanding spatial organisation.

In this context, VGA plans for each faculty building were examined and evaluated according to colour coding. Scoring was performed based on the table showing the visibility impact levels in the education block (E-B).

On the plans, the blocks were coded according to their function: the education block was coded as E-B and the block containing the academic staff offices was coded as AP-B. The following findings were obtained as a result of the analyses:

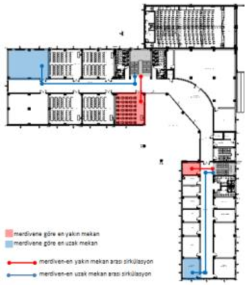
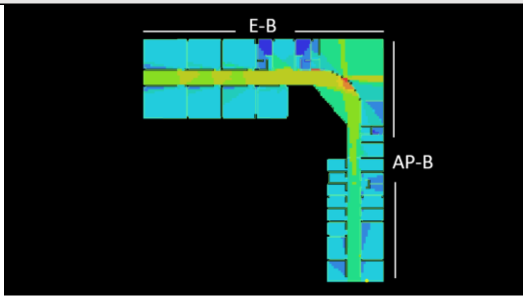
The structure coded as P1 has a linear circulation line and was designed with a linear plan scheme. In this structure, the closest classroom to the staircase is 9.9 metres away and the furthest is 32 metres. In terms of offices, the closest one to the staircase is 3.00 metres away and the furthest one is 18.60 metres away. According to the VGA results, the circulation areas in the education and office blocks are represented by red and orange colours respectively. This indicates that these areas have a high integration value. The education block's visibility impact rating was assessed as 9 points in total (Table 4.1).

Table 4.1. Spatial accessibility and visibility analysis of the structure coded P1

SA	DISTANCES		
	classrom	Min 9,90	
		Max 32,00	
	office	Min 3,00	
		Max 18,60	
VGA	**COLOUR**	**SCORE**	**DEGREE**
	Red	5	high
	Orange	4	high
	Yellow	3	moderate
	Green	2	low
	Blue	1	low
	Total: 9		

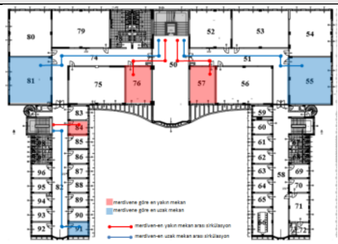
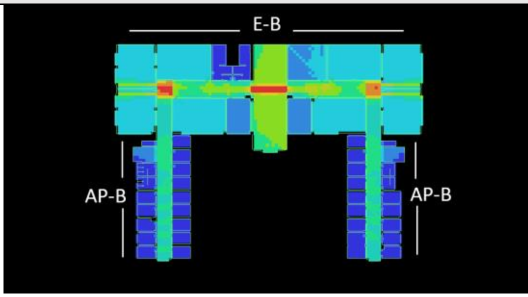
The P2-coded building has an L-shaped floor plan. The closest classroom to the staircase is 5.5 metres away and the furthest is 26 metres. In terms of offices, the closest one to the staircase is 5.7 metres away and the furthest one is 29.5 metres away. According to the VGA results, the circulation areas in the education block are coloured orange and yellow, indicating a high-to-medium level of integration value. The visibility impact level of the education block has been evaluated at 7 points in total. In contrast, the visibility level in the academic office block is generally low, predominantly represented by green in the VGA analysis (Table 4.2).

Table 4.2. Spatial accessibility and visibility analysis of the structure coded P2

SA	DISTANCES		
	classrom	Min 5,50	
		Max 26,00	
	office	Min 5,70	
		Max 29,50	
VGA	**COLOUR**	**SCORE**	**DEGREE**
	Red	5	high
	Orange	4	high
	Yellow	3	moderate
	Green	2	low
	Blue	1	low
	Total: 7		

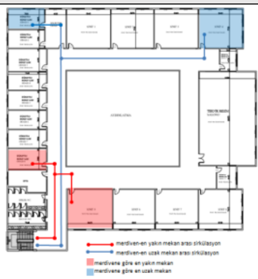
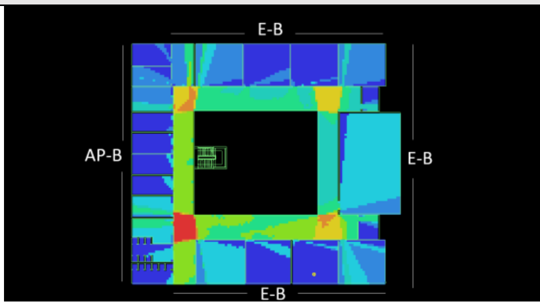
The P3-coded building has a U-shaped floor plan. The closest classroom to the staircase is 13.60 metres away and the furthest is 30.80 metres. In terms of offices, the closest one to the staircase is 4.3 metres away and the furthest one is 21.8 metres away. According to the VGA results, the circulation areas within this floor plan are generally represented by yellow and green, indicating moderate to low levels of integration. Due to the floor plan of the building, red colours stand out at the intersection points of the blocks, providing high visibility in these areas. As the staircase is located at the symmetry centre of the building, the hallway in front of it is also represented by red, indicating a high level of visibility. The visibility impact level of the education block was evaluated at 5 points in total. Conversely, visibility in the academic office blocks is generally low, predominantly represented by green tones in the VGA analysis (Table 4.3).

Table 4.3. Spatial accessibility and visibility analysis of the structure coded P3

SA	DISTANCES		
	classrom	Min 13,60	
		Max 30,80	
	office	Min 4,30	
		Max 21,80	
VGA	**COLOUR**	**SCORE**	**DEGREE**
	Red	5	high
	Orange	4	high
	Yellow	3	moderate
	Green	2	low
	Blue	1	low
	Total: 5		

The P4-coded building has a courtyard layout. The closest classroom to the staircase is 10.5 metres away and the furthest is 63 metres. In terms of offices, the closest one to the staircase is 16 metres away and the furthest one is 35 metres away. According to the VGA results, the integration values of the circulation areas in this layout are generally represented by yellow and green, indicating moderate to low levels of integration. Depending on the building's layout, red and orange colours stand out at the corners of the courtyard, providing high visibility in these areas. Office sections have a higher visibility level than education sections. The visibility impact level of the education block has been evaluated at 5 points in total. (Table 4.4).

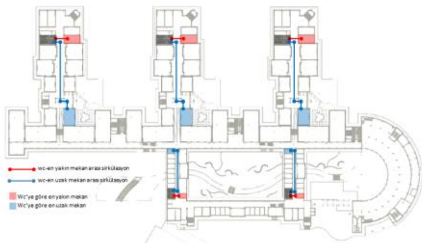
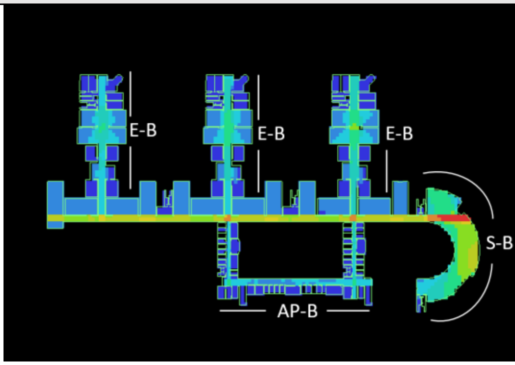
Table 4.4. Spatial accessibility and visibility analysis of the structure coded P4

<table>
<tr><th>SA</th><th colspan="3">DISTANCES</th></tr>
<tr><td rowspan="4"></td><td colspan="2" rowspan="2">classrom</td><td>Min 10,50</td></tr>
<tr><td>Max 63,00</td></tr>
<tr><td colspan="2" rowspan="2">office</td><td>Min 16,00</td></tr>
<tr><td>Max 35,00</td></tr>
<tr><th>VGA</th><th>COLOUR</th><th>SCORE</th><th>DEGREE</th></tr>
<tr><td rowspan="6">
</td><td>Red</td><td>5</td><td>high</td></tr>
<tr><td>Orange</td><td>4</td><td>high</td></tr>
<tr><td>Yellow</td><td>3</td><td>moderate</td></tr>
<tr><td>Green</td><td>2</td><td>low</td></tr>
<tr><td>Blue</td><td>1</td><td>low</td></tr>
<tr><td colspan="3">Total: 5</td></tr>
</table>

The P5-coded structure has a complex floor plan. The building is a multifunctional educational and administrative complex formed by combining three different floor plans. Each plan serves a different functional section of the building. 1. Office Section: This section is designed as a U-shaped floor plan around a closed courtyard, in which the academic offices are located. The closest office to the staircase is 11.00 metres away and the furthest is 118.00 metres. 2. Layout – Education Section: This section has a linear layout with classrooms and laboratories. The closest classroom to the staircase is 6.5 metres away and the furthest is 59.3 metres away. 3. Scheme – Social Section: This section is designed with an open courtyard circular plan and includes areas for student social interaction.

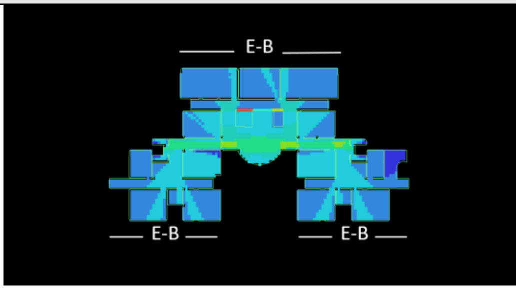
According to VGA results, the main circulation areas connecting the blocks within this plan scheme are generally represented by orange colours, indicating a high level of integration in these areas. Visibility is also high in areas of common use. In contrast, green and blue colours are prominent in the education and office sections. Low visibility was observed in these areas. The education block received a total visibility impact rating of 3 points. (Table 4.5).

Table 4.5. Spatial accessibility and visibility analysis of the structure coded P5

<table>
<tr><th>SA</th><th colspan="3">DISTANCES</th></tr>
<tr><td rowspan="4"></td><td rowspan="2" colspan="2">classrom</td><td>Min 6,50</td></tr>
<tr><td>Max 59,30</td></tr>
<tr><td rowspan="2" colspan="2">office</td><td>Min 11,00</td></tr>
<tr><td>Max 118,00</td></tr>
<tr><th>VGA</th><th>COLOUR</th><th>SCORE</th><th>DEGREE</th></tr>
<tr><td rowspan="6">
</td><td>Red</td><td>5</td><td>high</td></tr>
<tr><td>Orange</td><td>4</td><td>high</td></tr>
<tr><td>Yellow</td><td>3</td><td>moderate</td></tr>
<tr><td>Green</td><td>2</td><td>low</td></tr>
<tr><td>Blue</td><td>1</td><td>low</td></tr>
<tr><td colspan="3">Total: 3</td></tr>
</table>

The P6 building has a chaotic floor plan. The circulation route is irregular and organic. The closest classroom to the staircase is 14.90 metres away and the furthest is 42.50 metres. Educational units and academic staff offices are located on different floors. Therefore, only the floor on which the educational units are located was analysed. In the VGA results, circulation areas are generally represented by blue colours, indicating a low level of integration. The education block's visibility impact rating was assessed as 3 points in total.

Table 4.6. Spatial accessibility and visibility analysis of the structure coded P6

<table>
<tr><th>SA</th><th colspan="3">DISTANCES</th></tr>
<tr><td rowspan="4">
</td><td rowspan="2">classrom</td><td colspan="2">Min 14,90</td></tr>
<tr><td colspan="2">Max 42,50</td></tr>
<tr><td rowspan="2">office</td><td colspan="2">Min 6,20</td></tr>
<tr><td colspan="2">Max 107,40</td></tr>
<tr><th>VGA</th><th>COLOUR</th><th>SCORE</th><th>DEGREE</th></tr>
<tr><td rowspan="6">
</td><td>Red</td><td>5</td><td>high</td></tr>
<tr><td>Orange</td><td>4</td><td>high</td></tr>
<tr><td>Yellow</td><td>3</td><td>moderate</td></tr>
<tr><td>Green</td><td>2</td><td>low</td></tr>
<tr><td>Blue</td><td>1</td><td>low</td></tr>
<tr><td colspan="3">Total: 3</td></tr>
</table>

5. CONCLUSIONS AND RECOMMENDATIONS

The spatial organisation of buildings is shaped by programme requirements and the physical characteristics of the site. The increasing need for space has led to different types of spatial organisation emerging, with classrooms being divided into different spaces. These include corridor or central organisation, linear or cluster arrangements, and naming based on the geometric form of the structures. These differences in spatial organisation and circulation routes effectively impact accessibility, visual perception and the relationship established with the space.

Therefore, this study aims to analyse how users orient themselves, interact and circulate in relation to the formal arrangement of the space. A visibility analysis was conducted in the faculty buildings to evaluate users' visual perception of the space.

In the first phase of the study, the closest and furthest spaces (i.e. classrooms and offices) for both students and academic staff were determined using the stairs in the buildings as a reference. These distances were then visualised in red (close) and blue (far). In the second phase, faculty plans were imported into DepthmapX software from AutoCAD in DXF format, and visibility analyses were conducted. In these analyses, visibility and integration values were visualised on a colour scale ranging from red to blue. In the third stage, the colour scale was scored using a Likert scale (red = 5, blue = 1) and visual analyses of the educational areas were conducted using the visibility impact scores obtained. The plan forms of the structures were then comparatively evaluated based on users' movement and visual perception in the space, revealing the effects of physical layout on user experience.

This study analysed six different faculty building floor plans using spatial syntax methods. In particular, it evaluated users' orientation behaviours, circulation patterns and visibility levels comparatively. The effects of spatial configuration on user experience were examined numerically through Visibility Graph Analysis (VGA), based on integration values and visual accessibility of spaces.

The P1-coded structure has a linear floor plan and the highest visibility impact score (9 points). Circulation areas exhibited high integration values, indicated by red and orange colours, showing strong interconnectivity between spaces. The distances between offices, classrooms and the staircase are balanced, resulting in an effective structure in terms of user access.

The P2-coded structure has an L-shaped floor plan. Orange and yellow colours were observed in the circulation areas of the education block, indicating a medium-high level of integration. With a visibility impact rating of seven points, this structure is less visible in the office block. Overall, it is sufficient in terms of spatial orientation.

The P3-coded structure has demonstrated medium-to-low integration values, with a U-shaped plan scheme in yellow and green. However, the red areas stand out in terms of visibility in central areas, such as at the intersection of blocks and in front of staircases. The education block has a visibility score of 5, while the office blocks offer limited spatial legibility and a low visibility level.

The P4-coded structure stands out from the others thanks to its courtyard layout. The overall integration level is expressed in yellow and green, meaning it remains at a medium-low level. However, the prominence of red and orange at the corners of the courtyard indicates high visibility in these areas. Interestingly, the office sections have higher visibility values than the education sections. The visibility impact score for the education block is also 5.

The P5-coded structure has a complex plan scheme. This is formed by combining three different schemes: a U-shaped office section, a linear education section and a courtyard-style social section. While the main circulation areas exhibit high integration with orange colours, the dominance of green and blue colours in the education and office blocks indicates low visibility. The education block has a visibility score of 3, indicating insufficient spatial orientation.

The P6-coded structure has a chaotic and organic plan scheme. The circulation route is irregular. The educational and office units are spread across different floors; however, the analysis was conducted solely on the educational floor. VGA results indicate low integration in circulation areas, which are typically represented by blue colours. The education block has a visibility score of 3, indicating insufficient spatial orientation in this plan scheme.

Plan layout and visibility relationship: The formal layout of a structure has a direct impact on how users perceive and navigate the space. Structures with simpler, more linear layouts (e.g. P1 and P2) offer higher levels of integration and visibility, whereas complex or organic structures (P5 and P6) are more limited in this respect.

Circulation routes and integration: The integration values of circulation areas directly affect how easily users perceive the structure and experience transitions between spaces. P1 and P5 provide high integration along the main axes, whereas visibility in structures such as P3 and P4 is more limited to specific areas.

Visibility impact scores for educational areas: The ranking in terms of visibility is as follows:

P1 (9) > P2 (7) > P3 = P4 (5) > P5 = P6 (3).

This indicates that P1 has the most effective spatial design from a user-centred perspective, while P5 and P6 have the least effective.

The effects of complex spatial organisation: Multi-functional or scattered floor plans, such as those in P5 and P6, can make it difficult for users to understand the space. This has a negative impact on orientation behaviour and visual perception, consequently affecting the spatial experience.

Therefore, the impact of spatial organisation on the user experience is evident. Plan layouts that enhance visual accessibility and feature clear, readable circulation routes help users to orient themselves and improve the effectiveness of educational environments. In this context, analytical tools such as Spatial Syntax and VGA are valuable for evaluating user-centred design approaches.

The findings of this study emphasise the importance of planning decisions that influence users' orientation behaviours and spatial perceptions, particularly with regard to the concept of visible areas. Visible areas refer to the extent to which a user can see their surroundings from a specific point within a space and play a decisive role in orientation, decision-making and guidance processes. In this regard, the following design recommendations have been developed:

Stairs and elevators should be located not only with physical access in mind, but visual access too. A visual connection between these vertical circulation elements and the entrance hall enables users to naturally orient themselves. These transition points have high visibility and prevent disorientation within the interior space, supporting continuity of movement.

When positioning stairs, visual equality and distance optimisation should both be considered. In linear plans in particular, the position of the stairs should be designed to provide a similar visibility depth in both directions of the corridor extension. This gives users equal perception and decision-making advantages when turning in either direction.

The layout of corridors should provide clarity in terms of visibility. Highly fragmented, narrow or labyrinthine corridors divide the visible area, creating uncertainty for users. This makes it difficult to find one's way and increases the cognitive load of moving between spaces. In contrast, corridors with linear, open sightlines support continuity of visibility and facilitate spatial memory formation. Visible space is not only a tool that affects visual perception, but also directly influences users' spatial decision-making processes.

In this context, physical accessibility and visual access must be considered together when organising the interior of a building. This study highlights the need to support functional organisation and typological preferences with visibility-based analyses. It suggests that such analyses can serve as a powerful guide in the design of user-centred educational structures.

REFERENCES

Bafna, S. (2003). Space syntax: A brief introduction to its logic and analytic techniques. Environment and Behavior, 35(1), 17–29. https://doi.org/10.1177/0013916502238863

Benedikt, M. L. (1979). To take hold of space: Isovists and isovist fields. Environment and Planning B: Planning and Design, 6, 47–65.

Bradley, W. S. (1996). Perceptions about the role of architecture in education (Doctoral dissertation, University of Virginia). [ProQuest Dissertations Publishing].

Çalışkan, B. N. (2021). Fakülte binalarında plan şemalarındaki farklılığın mekânsal örgütlenmeye ve ulaşılabilirliğe etkisi (Yüksek lisans tezi, Gazi Üniversitesi, Fen Bilimleri Enstitüsü). Ankara.

Hanson, J., & Hillier, B. (1987). The architecture of community: Some new proposals on the social consequences of architectural and planning decisions. Architecture et Comportement / Architecture and Behaviour, 3(3), 251–273. https://discovery.ucl.ac.uk/id/eprint/5265/

Karimi, K. (2012). A configurational approach to analytical urban design: 'Space syntax' methodology. Urban Design International, 17(4), 297–318. https://doi.org/10.1057/udi.2012.19

Keleş, B. N., Takva, Ç., & Çakıcı, F. Z. (2025). Accessibility analysis of public buildings with graph theory and the space syntax method: Government houses. Journal of Asian Architecture and Building Engineering, 24(1), 199–213.

Keleş, R. (1972). Yerleşme kararları açısından büyük kent dışı üniversiteler sorunu. Mimarlık Dergisi, 12, 25–35.

Maiden, J., & Foreman, B. A. (1998). Cost, design and climate: Building a learning environment. School Business Affairs, 64(1), 40–44.

McCormick, J. E. (1970). Human factors engineering. McGraw-Hill Inc.

Meek, A. (Ed.). (1995). Designing places for learning. Association for Supervision and Curriculum Development.

Pasalar, C. (2003). The effects of spatial layouts on students' interactions in middle schools: Multiple case analysis (Doctoral dissertation, North Carolina State University). Dissertation Abstracts International, 19.

Perkins, B. (2001). Building type basics for elementary and secondary schools. John Wiley & Sons, Inc.

Rigolon, A. (2010). European design types for 21st century schools: An overview. Organisation for Economic Co-operation and Development Library, 3.

San, C. (1992). Bir toplumsal kurum olan üniversitede özerklik ve bilim özgürlüğü. Türk Sosyal Bilimler Derneği, 1, 149–153.

Şen, A. G. E., & Ediz, M. Ö. (2016). Sayısal teknolojilerle mimari doku analizi: Kayaköy (Levissi). In A. S. Döner & A. Akyüz (Eds.), Bilgi çağında inovasyon (ss. 217–240). Derin Yayınları.

Sönmez, A. (1972). Üniversitenin toplumdaki rolü. Mimarlık Dergisi, 12, 41–43.

Tekeli, İ. (1972). Büyükkent dışı üniversitelerin kuruluş yeri sorunları üzerine. Mimarlık Dergisi, 12, 36–40.

Turner, A. (2001). Depthmap: A program to perform visibility graph analysis. 3rd International Symposium on Space Syntax (pp. 31.1–31.9). Atlanta: Georgia Institute of Technology.

Turner, A., Doxa, M., O'Sullivan, D., & Penn, A. (2001). From isovists to visibility graphs: A methodology for the analysis of architectural space. Environment and Planning B: Planning and Design, 28, 103–121.

Web Resources

URL-1: UCL Bartlett School of Architecture. (n.d.). DepthmapX: Visual and spatial network analysis software. https://www.ucl.ac.uk/bartlett/architecture/research/computation-and-craft-technologies/depthmapx-visual-and-spatial-network-analysis-software

URL-2: Space Syntax Online. (n.d.). Building methods – Spatial form analysis. https://www.spacesyntax.online/applying-space-syntax/building-methods/spatial-form-analysis/

URL-3: Space Syntax Online. (n.d.). Building spatial model. https://www.spacesyntax.online/software-and-manuals/depthmap/building-spatial-model/

Chapter 2

Designing Modular Furniture for Urban Living

Burçin SALTIK [1]

ABSTRACT

As urbanization accelerates and living spaces shrink, the role of furniture is being redefined. No longer static or singular in purpose, furniture in urban environments must be compact, transformable, and responsive to dynamic user needs. This article examines the growing relevance of modular furniture design as a solution to the spatial, social, and ecological challenges of urban living. It explores how modularity enables adaptability, user empowerment, and sustainability—characteristics increasingly demanded in contemporary interior environments. Drawing from both historical precedents and contemporary design practice, the article outlines key principles in modular design, including adaptability, joinery logic, material efficiency, and compactness. A case study from an experimental design studio demonstrates how modular furniture can be conceived through hands-on prototyping and systems thinking. The article also emphasizes the pedagogical value of modular design in design education, highlighting how it fosters skills in iteration, material intelligence, and human-centered problem-solving. By connecting modular design to broader design ethics and sustainability imperatives, this article positions modular furniture not only as a spatial strategy but as a design philosophy for resilience. It advocates for an approach where furniture is seen as a system—evolving, engaging, and deeply integrated with the way we live today.

Keywords; Modular Furniture, Urban Living, Furniture Design

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1. INTRODUCTION

The Urban Space Challenge

Today's urban environments are in a state of rapid transformation. According to the United Nations (2019), more than 55% of the world's population now lives in cities, a figure expected to rise to 68% by 2050. This accelerating urbanization comes with a paradox: while cities offer economic opportunity and cultural vitality, they also present profound spatial challenges—smaller apartments, rising housing costs, and an increased demand for mobility and flexibility. In this context, the way we design our living spaces—and the furniture within them—must evolve.

Traditional furniture, with its fixed functions and large footprints, often clashes with the demands of compact urban living. Urban dwellers need furniture that does more than fill a room; they need it to adapt, transform, and respond to changing circumstances. This need has given rise to an exciting design frontier: modular furniture—an approach that emphasizes flexibility, scalability, and human-centered thinking.

Modular furniture is not a new concept, but it has never been more relevant. Rooted in 20th-century experiments in minimal living (Papanek & Hennessey, 1973), it now intersects with today's pressing concerns: sustainability, digital fabrication, the gig economy, and mobile lifestyles. It provides opportunities for users to reconfigure their environments, adjust to shifting needs, and maintain a sense of agency over their living space.

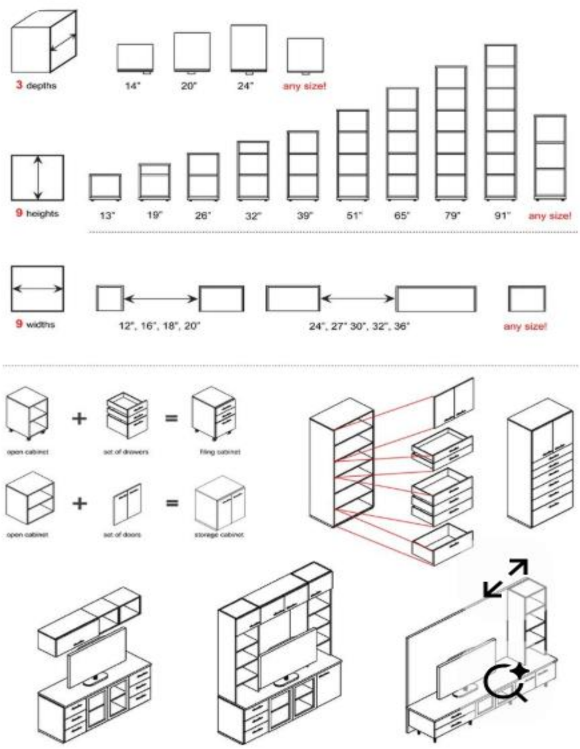
For designers, this paradigm presents both a creative challenge and a responsibility. It demands a reconsideration of how furniture is conceived—not merely as isolated objects but as systems of interdependent parts. These systems must accommodate modularity at multiple levels: structural, functional, aesthetic, and ecological. For educators, it offers a compelling framework through which to teach essential design skills—from material exploration to systems thinking and iterative prototyping.

This article explores the principles, practices, and potential of modular furniture design within the context of urban living. It investigates how adaptability, compactness, and sustainability converge in furniture that is both functional and flexible. Through analysis, a case study, and pedagogical insights, it makes the case for modularity not only as a technical strategy, but as a design philosophy attuned to the challenges of the 21st century.

What is Modular Furniture?

Modular furniture is based on repeatable components that can be rearranged, combined, or adapted over time. Unlike fixed furniture, modular designs enable interchangeability, expandability, and flexibility. These traits make modular furniture ideal for urban contexts, shared housing, and nomadic lifestyles (Papanek & Hennessey, 1973).

Beyond technical advantages, modular design encourages user participation and personal agency, aligning with contemporary values of customization and sustainability (Manzini, 2015).

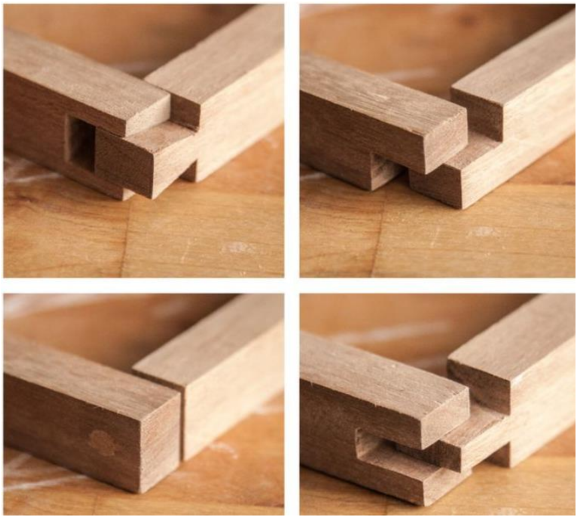


Fiqure 1. Guide to modular furniture

Design Principles for Modularity in Urban Furniture

- **Joinery & connection logic**

From traditional mortise and tenon to modern friction-fit and snap systems, joinery defines how modular parts connect. The logic must be intuitive and secure (Hoadley, 2000).

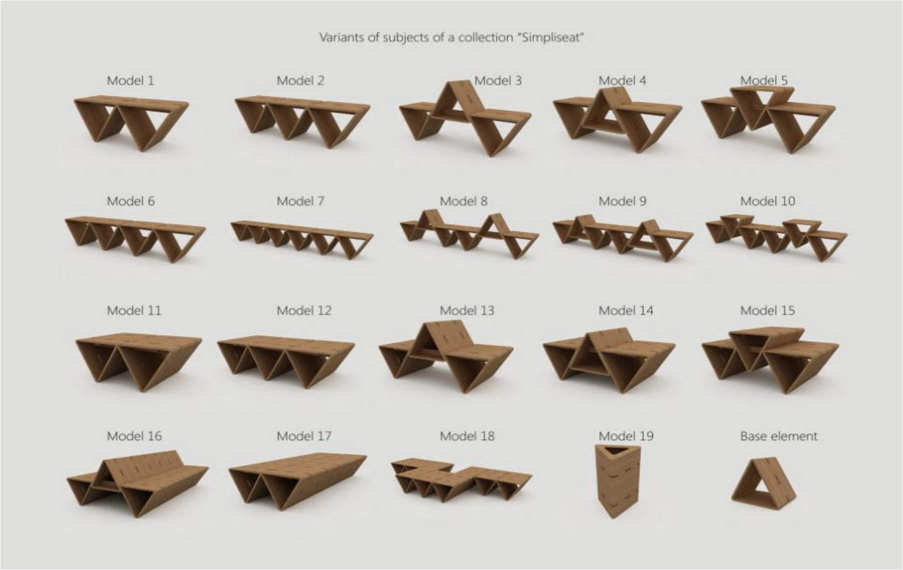


Fiqure 2. Wood joints

- **Adaptability**

Furniture in compact homes must transition between uses—e.g., a seat becomes a bed, or a shelf becomes a desk. Good modular design anticipates and enables such transitions without requiring extra space (Postell, 2012).

Fiqure 3. Hanna Dmitriieva design (a), Brennan Gudmundson design (b)



Fiqure 4. Maksim Shniak collection

- **Compactness and storage**

Modular furniture often emphasizes foldability and stackability. Designers must find ways to make pieces that are spatially efficient without compromising comfort or aesthetics.

Fiqure 5. Odu, by industrial designer Alberto Vasquez (a),(b)

- **Ease of assembly**

Influenced by flat-pack culture and digital fabrication, modular furniture is increasingly designed to be assembled without screws, glue, or tools (Papanek & Hennessey, 1973).

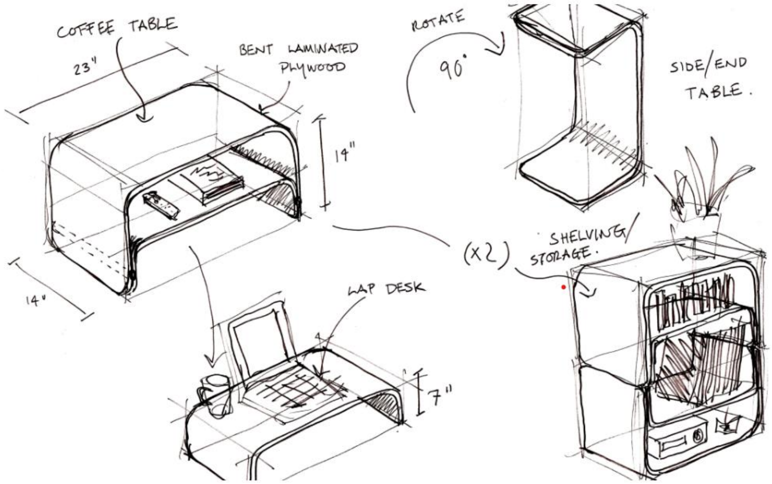
Fiqure 6. Easy assemble chair

- **Economic and eco-friendly**

The adaptability of modular furniture can translate into economic savings in the long run. Instead of investing in new furniture every few years, you can simply rearrange or add modules to your existing setup. Furthermore, the reduction in waste contributes to a more eco-friendly living, aligning with global efforts towards sustainability.

- **Space efficiency**

In the age of urban living, space is a luxury. Modular designs, such as FLEX, maximize the utilization of space. Whether you're in a studio apartment or a spacious home, modular pieces ensure that every square foot is used optimally.



Fiqure 7. “Flex” at Hoek Home

- **Material efficiency**

Sustainable design approaches such as designing for disassembly, using FSC-certified wood, or integrating recycled components are central to modern modular design (Manzini, 2015).

Fiqure 8. “Comfort Pure” Tatami Bed

2. CASE STUDY

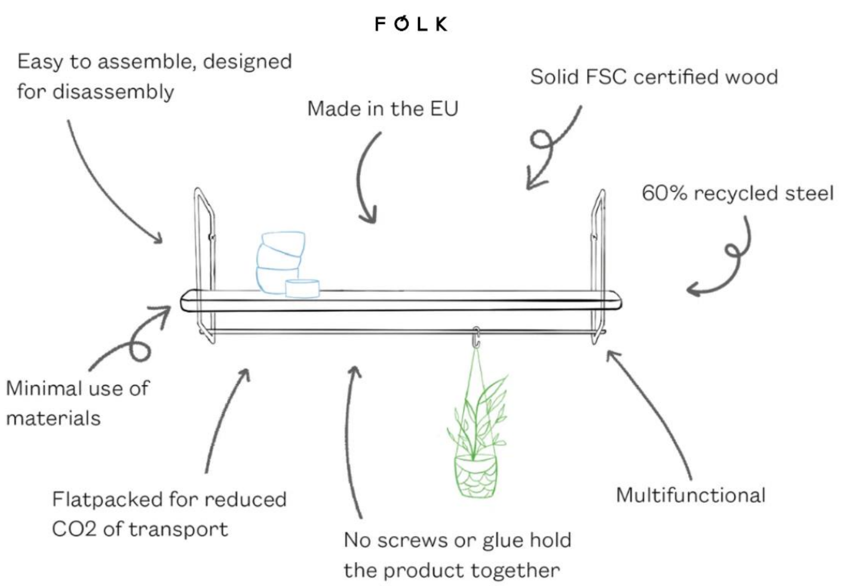
The Urban Nomad Shelf System

In an experimental studio course, students created the Urban Nomad Shelf System, a set of stackable wooden boxes that functioned interchangeably as:

- Bookshelves
- Tables
- Storage cubes
- Modular walls

Prototypes were constructed using plywood /wood and no-glue joinery, with laser-cut connections/basic joints and strap-lock mechanisms. The project emphasized tool-free transformation and material frugality, reflecting a sustainability-focused studio framework. Each unit was designed to serve multiple purposes across different living scenarios.

The case demonstrated how hands-on experimentation, user-centered design, and modular thinking can converge into highly functional, adaptable, and beautiful solutions.



Fiqure 9. "Fólk Reykjavík" Urban Nomad collection

Fiqure 10. Urban Nomad collection shelves (a), console table (b),

The Educational Power of Modular Design

Teaching modular furniture is about more than just building things—it's about thinking systemically. Students learn to:

- Design components that integrate into larger systems
- Understand how materials behave under different conditions
- Develop empathy by designing for evolving lifestyles
- Explore failures as part of an iterative learning process

Such studios align with the pedagogy of constructivist learning, where knowledge is built through doing and reflecting (Cane, 2012).

Looking Forward: Modularity as a Sustainable Strategy

Modularity fosters a circular design mindset. Furniture that is adaptable, repairable, and upgradable reduces waste and prolongs product lifespan (Manzini, 2015). It also reflects a shift in values—from ownership to function, permanence to transformation.

As environmental urgency increases, modularity is no longer just a style—it's a strategy for responsible design.

3. CONCLUSION

Modular furniture addresses today's pressing needs: limited space, fluid lifestyles, and sustainable choices. But more than just solving spatial challenges, it reshapes how we think about living, owning, and designing. In a world where change is constant—be it a shift in housing, work patterns, or environmental conditions—modular design offers a way to remain responsive and resilient.

For designers, this means embracing furniture not as static objects, but as systems that adapt, grow, and evolve alongside the user. For educators, modularity offers a rich platform to teach essential 21st-century design skills—systems thinking, material intelligence, problem-solving through iteration, and human-centered design.

In the hands of young designers and design educators, modular furniture becomes more than a product category; it becomes a design language that reflects our time. It promotes sustainability through longevity and reusability. It democratizes furniture by inviting users into the creative process. And it encourages designers to move beyond aesthetics into deeper ecological and social responsibility.

As cities become more compressed and resources more limited, furniture that is reconfigurable, efficient, and regenerative will not be a niche—it will be the norm. The future of design will not be fixed—it will be flexible, thoughtful, and modular.

REFERENCES

Burdek, B. E. (2005). Design: History, theory and practice of product design. Birkhäuser, ISBN-978-3764370299

Cane, K. (2012). Making and drawing. A&C Black, ISBN-978-1408134511

Ching, F. D. K. (2014). Interior design illustrated (3rd ed.). Wiley, ISBN-978-1118090718

Fry, T. (2009). Design futuring: Sustainability, ethics and new practice. Bloomsbury Publishing, ISBN: 9781350089952

Hoadley, R. B. (2000). Understanding wood: A craftsman's guide to wood technology. Taunton Press, ISBN: 9781561583584

Manzini, E. (2015). Design, when everybody designs: An introduction to design for social innovation. MIT Press, ISBN: 9780262028608

Miller, R. (2012). Design + environment: A global guide to designing greener goods. Fairchild Books, ISBN: 978-1874719434

Norman, D. A. (2013). The design of everyday things: Revised and expanded edition. Basic Books, ISBN: 978-0465050659

Papanek, V., & Hennessey, J. (1973). Nomadic furniture: D-I-Y projects that are lightweight & light on the environment. Pantheon, ISBN: 978-0764330247

Postell, J. (2012). Furniture design (2nd ed.). John Wiley & Sons, ISBN: 978-1118090787

Rawsthorn, A. (2018). Design as an attitude. MIT Press, ISBN: 978-3037645215

Rittel, H., & Webber, M. (1973). Dilemmas in a general theory of planning. Policy Sciences, 4(2), 155–169. DOI: 10.1007/BF01405730.

Sauer, M. (2020). Modular design: Flexible systems for a changing world. Journal of Contemporary Design, 18(4), 56–67, DOI:10.1007/978-3-642-35950-7_6460-4

United Nations. (2019). World urbanization prospects: The 2018 revision. UN Department of Economic and Social Affairs. https://population.un.org/wup/

Zeiger, M. (2010). Tiny houses. Rizzoli, ISBN: 978-0847832033

Chapter 3

The End, Crisis, and Transformation of Modern Architecture in the Context of Álvaro Siza's Architecture

Fazıl AKDAĞ[1]

INTRODUCTION

Since the mid-20th century, the universal principles and utopian social goals of modern architecture have entered a serious questioning and criticism process in the late 1960s and 1970s. Especially the demolition of the Pruitt-Igoe public housing blocks in America in 1972 was declared by architectural historian Charles Jencks as the symbolic death of modern architecture (Verebes, 2016). While the monotonous, context-free, and socially problematic aspects of modernism became the target of criticism, a period of crisis and transformation, which could be termed "postmodernism," began in the discipline of architecture. During this period of transformation, architectural theorists discussed the end of modern architecture, its causes, and new explorations; many thinkers, from Kenneth Frampton (1983) to Colin Rowe (1978), Manfredo Tafuri (1973;1976) to Alan Colquhoun (1988), approached the crisis of modernism from different perspectives.

This article aims to critically evaluate the architecture of Portuguese architect Álvaro Siza within the context of the death, crisis, and transformation of modern architecture, based on the aforementioned theoretical background. First, the theoretical approaches regarding the end of modernism are summarized, and then Álvaro Siza's unique position in the architectural environment, particularly after the 1970s, is examined. Through specific examples of Siza's works, it is analyzed how he reinterpreted traditional modernist principles in the post-modernist era and how he balanced continuity and transformation in architecture. In this context, Siza's significant projects, such as the Boa Nova Tea House, Leça Swimming Pools, SAAL/Bouça social housing, Malagueira housing complex, and the Portuguese Pavilion, are evaluated as representations of the transition from modern architecture to post-modern sensibilities. Throughout the study, the views of relevant architectural theorists are considered as a critical reference, and

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by emphasizing theoretical connections, the intellectual foundations of Siza's architectural approach are revealed.

Research Problem

The universal design principles proposed by modernism in architecture have been subject to serious criticism over time because they have distanced themselves from contextual sensitivity and homogenized space. These criticisms, especially in the 1970s, necessitated a re-examination of concepts such as historical continuity, local identity, and cultural context in architectural theory. In this context, the fundamental problem that arises is the question of how architecture can establish a balance between formal abstraction and historical and local context. Álvaro Siza's architecture provides a unique answer to this question; however, it appears that this answer has not been sufficiently analyzed as a theoretical position developed in response to the crisis of modernism. The research problem of this study is to reveal how Siza's architectural approach transforms modernist design principles through its relationships with context, memory, and history, and how this transformation should be interpreted as a critical, theoretical stance.

Purpose of the Study

The main aim of this research is to critically examine Álvaro Siza's architectural approach in the context of the theoretical and practical crises faced by modernism in the second half of the 20th century. The study aims to reveal how Siza transformed modernist design principles and integrated contextual elements such as place, history, and memory through the architectural projects he carried out in different periods and scales. In this context, the architect's place in architectural theory will be evaluated in light of theoretical backgrounds such as Kenneth Frampton's critical regionalism approach, Colin Rowe's formal analyses, and Manfredo Tafuri's emphasis on historical continuity. The aim is to interpret Siza's architecture not only at the formal aesthetic level but also in social, cultural, and historical contexts, and to reveal his critical contributions to the discipline of architecture.

Research Questions

This research examines Álvaro Siza's architectural practice in the context of the crisis of modernism, questioning the theoretical and contextual foundations of his architectural approach. In this context, the following research questions have been posed:

How does Álvaro Siza's architecture provide a critical response to the universalist and abstract principles of modernism?

How can Siza's designs be interpreted through concepts such as context, memory, history, and user interaction?

How can Siza's architectural production be positioned in light of theoretical approaches such as critical regionalism and historical continuity?

These questions are aimed not only at the formal analysis of specific structures but also at understanding Siza's contributions to architectural theory. The questions are related to theoretical discussions on the transformation of modernism and are significant in questioning the relationship architecture establishes with the site, social context, and historical continuity. In this respect, the research aims to make the place of critical thought production in architecture within contemporary discussions visible.

METHOD

This study is designed as a qualitative research aimed at theoretically examining Álvaro Siza's architectural approach within the context of the crisis of modernism. In the study, qualitative rather than quantitative analysis methods have been adopted; the focus has been on examining not only the physical outcomes of architectural production but also the underlying intellectual, historical, and contextual layers behind this production. Therefore, the study examines the relationship between theoretical approaches developed in the fields of architectural history, theory, and criticism and architectural practice from an interdisciplinary perspective.

The primary method of the research is interpretive analysis based on the examination of selected structures at formal, conceptual, and contextual levels. In this context, both early and mature period structures of Siza have been included; through projects with different scales and programmatic contents, the continuity of the architect's thought and the transformation in his architectural stance have been observed. In the selection of the buildings, not only examples that are significant in the history of architecture, but also projects that clearly demonstrate Siza's relationship with the context were preferred. In this context, the projects examined include the Boa Nova Tea House, Leça Swimming Pools, Bouça Social Housing Complex, Malagueira Housing in Évora, Serralves Museum, and the Portuguese Pavilion in Lisbon.

The analysis process was conducted through elements such as the period each structure was designed, its physical context, its relationship with the urban fabric, the layout, material selection, and user experience. While examining the relationship of the buildings with the site, the interaction with the natural landscape, the continuity established with topographic data, and the level of environmental harmony were taken into consideration. In formal analyses, architectural elements such as the geometric composition of buildings, spatial organization schemes, balance of voids and solids, and the use of light have been examined.

The theoretical framework is based on the intellectual approaches introduced in the field of architectural criticism after the 1970s. Especially Kenneth Frampton's theory of "critical regionalism," Manfredo Tafuri's emphasis on "historical continuity," and Colin Rowe's method of "formal analogy" constitute the main theoretical foundations referenced in the analysis of Siza's architecture.

Frampton's approach, which highlights contextual sensitivity and seeks to merge the local with the universal, directly aligns with Siza's architectural practice. Similarly, Rowe's comparative reading methods of classical and modern architecture have provided the opportunity to analyze how Siza draws from both traditional architecture and modernist abstraction. Tafuri's critical approach to architectural history has laid the groundwork for unraveling the historical layers of meaning behind Siza's formal choices. As a result, this methodological approach allows us to consider Álvaro Siza's architectural practice not only as a formal aesthetic issue but also as a multidimensional field of production related to place, memory, social conditions, and architectural theory.

THE END OF MODERN ARCHITECTURE: THEORETICAL BACKGROUND

The Disintegration of Modernism and Postmodern Pursuits

By the late 1960s, the modern architecture movement began to face intense criticism for failing to realize many of the ideals it had embraced when it first emerged. Architectural historian Alan Colquhoun notes that the criticism of modernism that developed in the 1960s focused on the failure of modern architecture to fulfill its utopian promises regarding the renewal of urban environments (Colquhoun, 1988). The large-scale housing projects and "new city" models implemented in urban planning after World War II have destroyed the existing urban fabric in many places, but they have not provided the expected quality of social life. This situation has led to criticism that modernism's principle of "form follows function" and its attitude of purging historical elements ignored the historical fabric and sense of context that people were familiar with (Sullivan, 1896). The postmodern architecture movement that emerged in the 1970s, as a reaction, adopted a more historicist and diversity-embracing approach, making references to past architectural styles. Robert Venturi's emphasis on "complexity and contradiction" (1966) and his opposition to formal functionalism, along with

Charles Jencks' declaration of the death of modernism (1977), heralded a new eclectic period in architecture. However, postmodernism was also criticized by some theorists for reducing superficial historical references to the level of "decoration" (Verebes, 2016).

Another significant work that identifies the process of modernism's dissolution is Colin Rowe and Fred Koetter's book, Collage City (Figure 1) (1978). Rowe and Koetter argue in the introduction of their book that the world of architecture and urban planning is in a "crisis," and that the holistic utopian city design of modern architecture has disintegrated. According to them, modernist urban planning ideals have almost "raped" the urban environment; many parts of cities have fallen into a "tragically ridiculous" state due to modern projects built after large-scale demolitions that became unworkable.

Figure 1. ‘Collage City’ by Colin Rowe and Fred Koetter
(Rowe & Koetter, 1978)

The social housing developments that failed one after another in the early 1970s (the Pruitt-Igoe in the USA is a striking example) showed that the holistic planning approach of modern architecture was in crisis (Figure 2). Rowe, instead of the rigid rules of modernism, proposed an urban approach based on the "collage" principle, harmonious with fragmented and historical fabric, thereby laying the theoretical groundwork for the quest for context in the postmodern era.

Figure 2: The Pruitt-Igoe public housing project, located in the city of St. Louis, Missouri, USA, was designed in the 1950s according to modernist planning principles. The project was demolished in a controlled manner in 1972 due to social problems and administrative challenges, and this demolition is considered the symbolic end of modern architecture (St. Louis Post-Dispatch, 1972).

On the other hand, architectural theorist Kenneth Frampton (1983) drew attention to the phenomenon of placelessness created by the universalist language of modernism and proposed the concept of "critical regionalism" as a response to it. According to Frampton, late 20th-century architecture should neither be trapped by the context-disconnected universality of modernism nor by the superficial historical imitations of postmodernism. Instead, architecture should draw strength from elements such as local topography, climate, light, and construction tectonics, filtering the influences of universal civilization through the lens of local authenticity. Frampton particularly emphasizes in his work Modern Architecture: A Critical History and the 1983 article "Critical Regionalism" that some contemporary examples from different geographies have begun to establish this balance. For example, it is noted that architects such as Alvar Aalto, Jørn Utzon, Carlo Scarpa, Tadao Ando, and Álvaro Siza have managed to reinvent their local architectural cultures within the language of modern architecture (Hartoonian, 2014). This approach is considered a critical stance blended with local culture against the uniformity of modernism.

Manfredo Tafuri: The End of Utopia and the Limits of Architecture

Italian architectural historian Manfredo Tafuri approached the crisis of modern architecture from a sharper and more Marxist perspective. In his works, particularly in Architecture and Utopia (1973), Tafuri ruthlessly analyzes the role architecture plays within the capitalist order. According to him, modern architects, even if they sincerely wanted to serve social progress, have no possibility of architecture being revolutionary in the face of market forces and political realities. The modern architecture movement, while trying to quickly respond to the housing crisis that emerged after industrialization, produced "patch" solutions and ignored the social values of the past in the process (Nesbitt, 1996). Tafuri (1973) emphasizes that the acceleration of mass housing production after World War II, driven by capitalist demands, has distanced architecture from the human scale and social values, rendering it de-humanizing.

According to Tafuri's argument (1973), the intrinsic utopian claims of architecture have failed; architects should no longer indulge in the dream of engineering society. He presents a view that can be summarized as "we must rid ourselves of the delusion that architecture can transform society" – architecture can neither change society from top to bottom nor fundamentally critique the existing economic-political reality. This idea is synonymous with Tafuri's famous judgment that "architecture cannot change society" (1973). According to his observation, every radical leap by pioneering architects throughout the modern movement has melted within the existing power relations of the system and ultimately nourished the status quo. This pessimistic analysis has created a sense of "closure" in the discipline of architecture. However, Tafuri's harsh criticism helped establish more realistic goals by encouraging skepticism towards superficial claims of innovation in architecture in the 1980s and 90s. So, accepting the limits of architecture should not lead to seeing it as entirely meaningless; rather, by focusing on the "achievable," the aspects of architecture that contribute to everyday life can be developed. Tafuri's diagnoses of the end of modernism (1973, 1976) have provided a significant warning to post-1970s architectural thought by demonstrating that architecture cannot progress without considering its ideological and economic context.

Alan Colquhoun: Modernism and Historical Continuity

British architectural theorist Alan Colquhoun, when evaluating the transformation of modern architecture, is neither as pessimistic as Tafuri nor as eclectic as the postmodernists; he exhibits a more balanced critical stance (Lee, 1998). Colquhoun argues that the connection modern architecture has severed with historicist architecture needs to be re-evaluated, but he also opposes the idea of this being understood as a simple return to the past. In his view, modernist principles have not been entirely invalidated; however, it has become necessary to revise these principles from a historical and contextual perspective. In texts like Colquhoun's "Postmodernism and Structuralism" written in the 1980s, he interprets the emergence of postmodern architecture as a result of the inconsistencies within modernism itself. Modern architecture, in the name of functionality and innovation, has failed to create a coherent environment on an urban scale while rejecting traditional forms (Colquhoun, 1988). As a natural consequence, in the 1970s, the architectural community turned towards a new approach that respects the existing urban fabric, considers the human scale, and values layers of meaning. Colquhoun views the search for historical continuity in architecture during the postmodern period positively, but he criticizes the direct imitation of historical forms. According to him, the main issue is to be able to establish a critical dialogue with the accumulation of the past without completely abandoning the intrinsic language of architecture and the achievements of modernism. This idea actually overlaps with Frampton's emphasis on critical regionalism: Both argue that modern architecture should undergo an evolutionary transformation rather than a radical rejection (Frampton, 1983; Colquhoun, 1988). Colquhoun's approach reflects the stance of "moderate postmodernism" or "late modernism" adopted by many architects in the 1980s. This stance neither embodies pure historical imitation nor rigid functionalism; instead, it seeks to establish a balanced relationship between context, typology, and architectural language (Klotz, 1988; Kelbaugh, 1996).

In light of the theoretical perspectives summarized above, a common point is emerging regarding the end and transformation of modern architecture: Architecture can no longer progress with a single universal dogma; a pluralistic understanding sensitive to local and historical conditions must be adopted. Álvaro Siza emerges as an important figure precisely at such a historical crossroads, nourishing his unique architectural style with these discussions. In the following section, Siza's position within the postmodern architectural context will be examined in relation to the theoretical framework outlined above.

ÁLVARO SIZA: A UNIQUE BRIDGE FROM MODERNISM TO POSTMODERNISM

Context and Continuity: Siza's Architectural Approach

Álvaro Siza began his career in the late 1950s and has been active in a wide span of time extending to the present day. His architectural approach, while rooted in the modernist tradition, has never fallen into the trap of rigid stylistic dogmatism. Siza exhibits an attitude that places great importance on the relationship architecture has with place and time, addressing each of his projects within its own context. In a famous statement, he said, "I do not have a predetermined language as an architect, nor do I create a language." He emphasizes that each of his designs develops unique solutions suitable for specific conditions, stating, "It is a response to a concrete problem I am involved in, a situation in transformation" (Siza, 2016, cited in Belogolovsky, 2016). Indeed, Siza's works are recognized for using a common formal language while responding differently to the environment, topography, cultural context, and user needs of each design. In this respect, Siza maintains an internationally renowned modernist architect identity on one hand, while reflecting local characteristics in his design with a sensitivity that can be described as critical regionalism on the other (Mota, 2011; Sampaio 2015; Amirjani, 2018).

As noted by the Britannica encyclopedia, Siza's buildings are generally characterized by "a quiet clarity of form and function, an environmentally sensitive harmony, and a deliberate dialogue with cultural/architectural traditions" (Cruz, Ferreira, & Freitas, 2024). In other words, in Siza's architecture, the clear structural order and understanding of function of modernism continue, but this order is reinterpreted each time specifically for the context of that project. The buildings exhibit sensitive integration with their surroundings; they adapt to the physical environment (nature, topography, climate) and establish a connection with the cultural heritage of the location. Siza's works never directly copy historical forms, but they make the architectural tradition perceptible at an abstract level. This approach has placed him in a unique position within the postmodernism that was debated worldwide throughout the 1980s. Indeed, some critics argue that Siza can actually be described as "postmodernist," as he reinterpreted modernism and created a unique compositional method (Amirjani, 2018). In a text evaluating Siza's works in Portugal, it is emphasized that he consistently reviews and summarizes different styles and movements, but while doing so, he deeply interprets the "place, program, and time" of each project, transforming them into his own method (UNESCO World Heritage Centre, 2015). Siza has almost internalized the historical process extending from the modernist heritage between the two world wars to the postmodern diversity of the 1980s, transforming it into a subjective synthesis (Samovich, 2024).

Álvaro Siza's response to a question about "postmodernism" in an interview also clarifies his stance: "We are all postmodernists, not just architects," says Siza, "But this does not mean we use pediments, Doric columns, and lilac color in our buildings." It means recognizing that a certain era has passed, that the search for innovation has come to an end; [post-modernism] had been reduced to a style, and that is over now" (Fala, 2022). This statement shows that Siza does not see himself as merely a modernist or a populist postmodernist, but rather as an architect who understands the spirit of his time and interprets it in his own language. He accepted the diversity and the atmosphere of revisiting the past brought by the postmodern era, but he distanced himself from the understanding that caricatured this by adopting historical motifs, preserving his own unique language.

Early Period Works: Modern Ideal and Contextual Harmony

Álvaro Siza's first significant projects in the 1960s can be seen as examples where he tested the principles derived from his modernist education in a local context. During this period, Siza, influenced by his teacher Fernando Távora, adopted a philosophy that aimed to combine respect for local architectural traditions with contemporary forms. The modernist training he received at the Porto School of Fine Arts developed in dialogue with Portugal's vernacular architecture through Távora. One of the first buildings designed by Siza before graduating, the Boa Nova Tea House (Casa de Chá da Boa Nova) and Restaurant (Matosinhos, 1958-63), serves as an early manifesto of this approach (Figure 3).

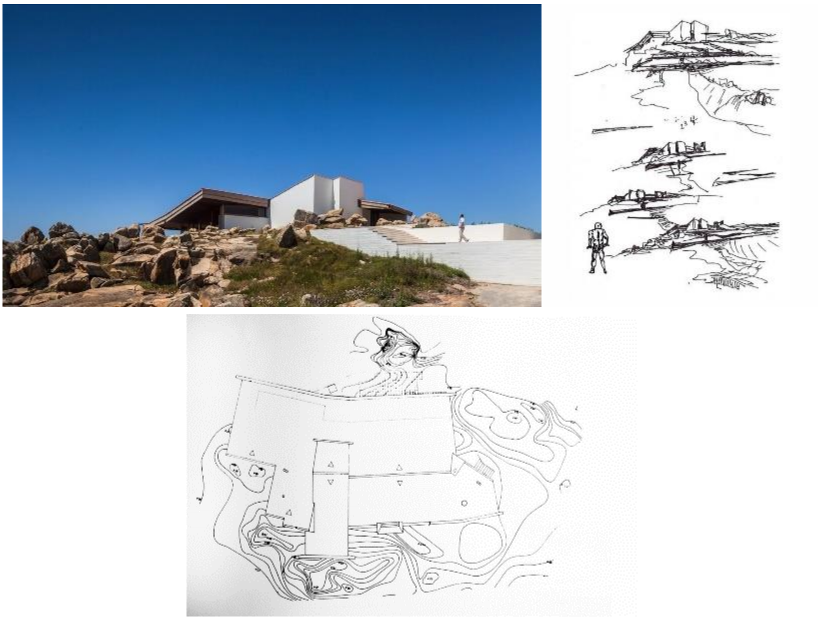

Figure 3. Photograph (by Joao Morgado), sketches and site plan (by Siza) of Boa Nova Tea House
https://www.metalocus.es/en/news/renovated-boa-nova-casa-de-cha-siza-now-restaurant-chef-rui-paula

Boa Nova Tea House (1958-63) is located on a rocky coastline, and the form of the building almost merges with the terrain. Siza has made the existing rock formations and the ocean view an inseparable part of the structure in his design. The building's flooring and terrace extend towards the sea in steps over the rocks, while large rocks have been left in the interior as an extension of the wall. In this way, an uninterrupted dialogue has been established between the building and nature; architecture has become a medium that complements and respects nature. In Siza's design at Boa Nova, the building provides a fluid transition with the landscape instead of "sticking" to the terrain. Siza incorporates rock formations, the ocean, and the surrounding greenery into the structure in this design, vividly reflecting the qualities of the local landscape in the architecture. Indeed, very close by, Siza's Swimming Pools (1961-66) project, also designed in the 1960s, features concrete swimming pools shaped by the natural rock formations of the coast with a similar approach (Figure 4).

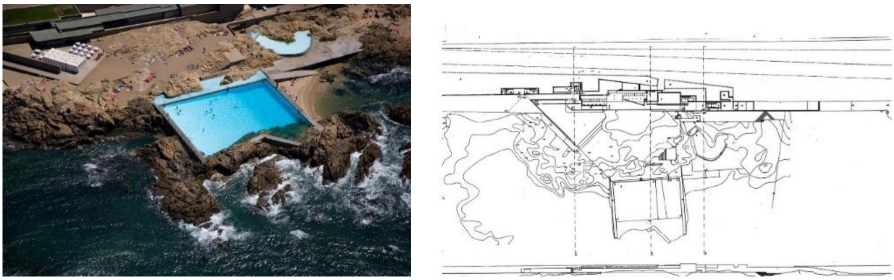

Figure 4. Photograph (by Fernando Guerra) and plan (with site plan) drawings of Pools of Marés https://www.metalocus.es/en/news/sizas-pools-das-mares-turn-50

These two early works form the foundation of Siza's architectural career and showcase his ability to integrate the abstract geometry of modern architecture with the organic elements of nature. The fact that a young architect, emerging from the international style of modernism, displayed such contextual sensitivity at the very beginning of his career sets him apart from the orthodox modernists of the time. Siza, while designing clean and rational spaces in the footsteps of Le Corbusier or Mies van der Rohe, has also continued the pursuit of being close to materials and nature, as his predecessors like Alvar Aalto did. Vittorio Gregotti appreciates Siza's early works for capturing such a "quiet and simple aesthetic" in a poor and peripheral country; he notes that it is possible to see the traces of the Portuguese people's "quiet humanity" and geography in his architecture (Gregotti, cited in UNESCO World Heritage Centre, 2015).

Social Participation and Housing: The SAAL and Malagueira Experience

The mid-1970s marked a significant social engagement in Álvaro Siza's architectural practice. Immediately after the Carnation Revolution in 1974, when dictatorship was overthrown and democracy was established in Portugal, large-scale social housing projects aimed at improving impoverished slum areas were initiated under a program called SAAL (Serviço de Apoio Ambulatório Local). Siza led the teams designing SAAL projects such as the Bouça Housing (1973-77) and São Victor Housing in the city of Porto during this period (Rodrigues, 2018; Pimenta do Vale, 2018). The Bouça social housing project consisted of four-story stacked maisonette (duplex) apartment blocks, shaped by the enthusiasm of the revolution and the participation of the neighborhood residents. Siza's design here featured a layout that, reminiscent of the human scale in 1920s Dutch and German social housing, included limited-height structures opening onto open communal courtyards (Figure 5).

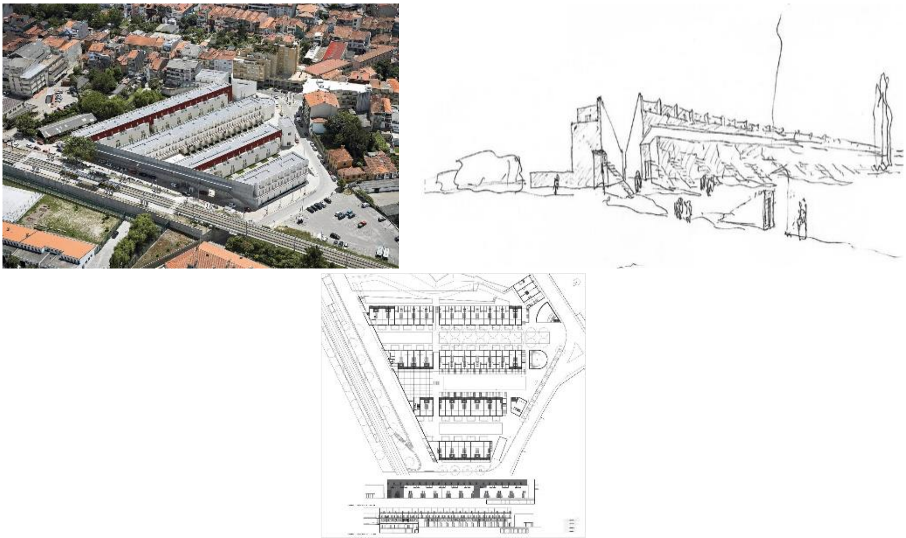

Figure 5. Photograph (by Joao Ferrand), Sketch, plan and elevation drawings of

Bouça Social Housing https://www.area-arch.it/en/social-housing-in-bouca/

This approach aimed to create lower-rise housing units that were compatible with the neighborhood fabric, instead of the monotonous high-rise blocks commonly seen in the late period of modernism. In the Bouça and similar SAAL projects, Siza developed housing types flexibly according to the needs of the users by directly interacting with them. This was an example of a bottom-up participatory approach against the top-down design understanding of modern architecture. This new attitude emerging in architecture in response to the crisis of modernism, as Tafuri (1973) also pointed out, was bringing the architect's role in society to a more "realistic" level: The architect should no longer be a prophet of utopia, but rather a facilitator who listens to the real needs of users and works with them. Siza's SAAL experience sharpened the social dimension of his architecture and gave it a sensitivity that would reflect in his later large-scale projects.

In 1977, Álvaro Siza began designing a large residential complex called Quinta da Malagueira in the city of Évora, east of Lisbon. The Malagueira Project is a large neighborhood design consisting of courtyard row houses, designed to accommodate approximately 1200 single-family homes, built in phases over a period of more than 20 years. This project is considered one of the most remarkable social housing implementations of the postmodern era, both in terms of its scale and approach. Siza created a fabric of two-story white plastered houses on the ground in this vacant lot next to the historic city of Évora in Malagueira, at a height that would not compete with the city's traditional texture. By proposing modest clusters of houses opening onto narrow streets instead of high blocks, he sought to address the issue of human scale that was lacking in modernist urbanism. The design is tiered to adapt to the conditions of the sloped terrain; thus, the distribution of the houses creates streets parallel to the slope, in accordance with the undulating topography of the land (Figure 6).

Figure 6. Photograph (by Estefanía Cruz), sketch (by Siza) and plan drawings of Quinta da Malagueira https://www.studiovarela.com/arquiruta-por-portugal/

The most striking feature that makes Malagueira unique is the network of elevated concrete infrastructure spanning over the settlement, in other words, a mini "aqueduct" system. Siza designed an elevated channel network instead of traditional underground pipes to deliver infrastructure services like water and electricity to this area. This network is a brilliant solution that adds a historical reference to the project due to its visual similarity to the ancient aqueducts left by the Romans. In photographs taken fifty years apart, it is seen that these concrete arches extending through the streets of Malagueira govern the space as a third layer. Critic Ellis Woodman describes this arched infrastructure as a "third layer," suggesting that Malagueira should be understood not merely as a static architectural work but as part of an evolving process over time (Woodman, 2015). Indeed, Siza's approach in

Malagueira shows that he considers architecture not as a finished object but as a living fabric. On one hand, this infrastructure solution developed for economic and technical reasons, on the other hand, makes a poetic reference to the region's cultural landscape: the infrastructure of the new settlement resonates with the historical aqueduct in Évora (Figure 7).

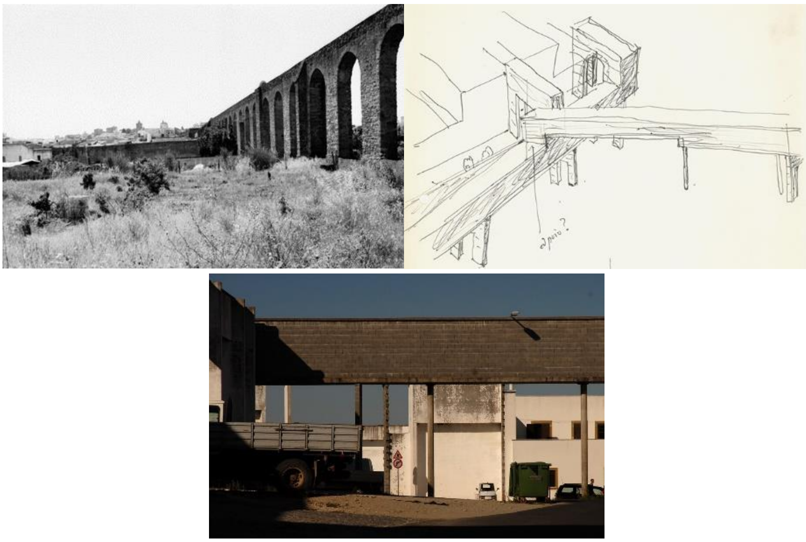

Figure 7. The historical aqueduct (LEFT) and the aqueduct developed by Siza
https://www.architectural-review.com/essays/revisiting-siza-an-archaeology-of-the-future

The Malagueira housing project brought international recognition to Siza in the early 1980s; the project was awarded the first European Mies van der Rohe Architecture Prize in 1988. This success has also been interpreted as a hope that modern architecture could return to its social mission. Indeed, Malagueira has been described as "perhaps the last great social housing project," marking a kind of pinnacle of architecture's contribution to social issues (Aureli, 2023). In the following years, as neoliberal policies gained prominence in urban housing production and such extensive social housing initiatives diminished, the model Siza developed in Malagueira became a source of inspiration for many architects. In the project, narrow streets, courtyards, white walls, and human scale reminiscent of traditional Mediterranean urban fabric offer a third way between modernism and traditional urbanism. Therefore, Siza's approach in Malagueira has been described as "a third way between populism and dogmatism" (Mota, 2011).

Metamorphoses from Modernism: Mature Works of Siza

Álvaro Siza began taking on projects outside his country from the 1980s, and his fame gradually spread across Europe. This period is notable for his works, where his architectural language matured and he creatively transformed modernist principles. Between 1985 and 1994, Siza designed the new campus of the Faculty of Architecture at the University of Porto, his alma mater. The buildings of the Porto School of Architecture (FAUP) consist of white modern blocks scattered in the garden of an old villa on a hill overlooking the Douro River. Here, Siza combined circulation elements reminiscent of Le Corbusier's ramps in Villa Savoye with the light-colored facades of traditional Porto houses that lean towards a terracotta hue; the faculty buildings are positioned within a scale and order that respects the silhouette of the historic city of Porto. The campus design is functional as a modern educational structure on one hand, while on the other hand, it reinterprets spaces like terraced gardens and courtyards that are embedded in the city's memory. This project is a beautiful example of how Siza addressed the nuanced relationship between the city and the building in his mature period. Even while using the principles of modern architecture such as open plans and free facades, Siza equips his buildings with elements that "speak" to the surrounding texture. The courtyards and transition spaces of Porto FAUP are like urban fragments designed as meeting places for students.

One of Siza's most notable works in the 1990s is the Pavilion of Portugal (Pavilhão de Portugal), which he designed for the 1998 Lisbon Expo. This project has become an iconic work in terms of the evolution of Siza's architectural style (Figure 8).

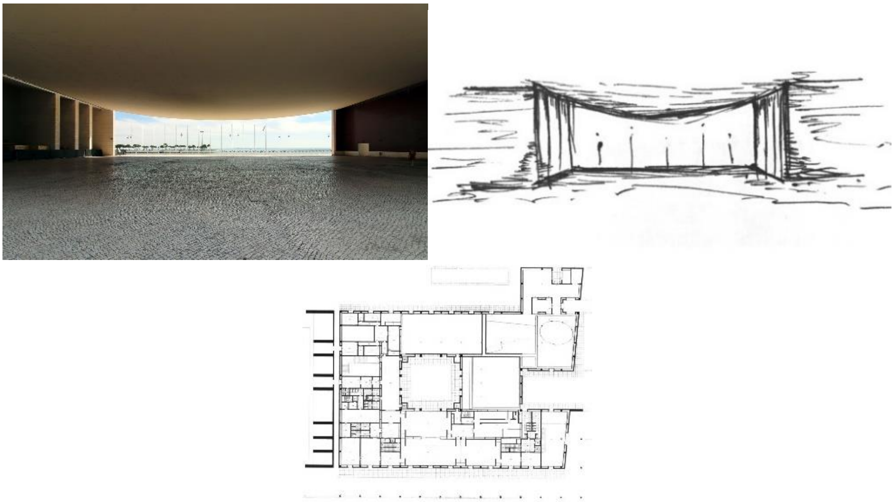

Figure 8. Portuguese Pavilion (Expo '98, Lisbon), one of the designs where Siza's monumental understanding of simplicity is most visible. https://archeyes.com/the-portuguese-pavilion-of-1998-by-alvaro-siza-a-modern-symbol-of-lisbons-expo-98/

The structure consists of a massive public canopy and two colonnades that support it, along with exhibition halls on the sides. The heavy concrete columns on the facade facing the shore, as seen in the photograph, serve as a city gate welcoming incoming visitors. The thin concrete shell, which gently curves towards the sky, is stretched like a sail between the two colonnades. This striking structural gesture provides a wide shaded courtyard to the space while creating a scene that frames the view towards the river. In this project, Siza has combined physical forces and architectural form in a theatrical harmony, creating a poetic space that pushes the boundaries of modern engineering with simple and clear elements.

Siza has combined physical forces with architectural form in a theatrical harmony in this project; he has created a poetic space that pushes the boundaries of modern engineering with simple and clear elements. The Portuguese Pavilion has secured its place in the architectural literature as an iconic design that creates tension between monumentality and the delicate requirements of the site.

The Portugal Pavilion has secured its place in architectural literature as an iconic design that creates tension between monumentality and the delicate requirements of the site. Siza, in this pavilion, on one hand, made references to the ocean and the history of discoveries in accordance with the country's Expo theme (the draped shell is designed to resemble a giant ship's sail), while on the other hand, he pushed the boundaries of modern reinforced concrete with a delicate shell structure. The result is a monumental architecture that simultaneously winks at both history and modern technology, with a paradoxical simplicity. The reflection of the massive arched colonnade on the pavilion's facade in the water can be considered a subtle interpretation of the "palace" theme from Siza's earlier school project in Setúbal. The thin concrete shell is described as an "anti-dome" – like an inverted dome that seems to shake off its supports, making them invisible. This structure embodies an innovation reminiscent of Oscar Niemeyer's modernist concrete forms; it appears fragile from the outside but is actually extremely strong, stretching like a light veil over the space to define a vast open area. The pavilion is a transformative interpretation of modern architecture: Monumental yet never ostentatious, innovative yet not rootless.

Another important work designed by Siza in the 1990s is the Serralves Museum in his hometown of Porto (1997). The Serralves Museum of Contemporary Art was built within an art center complex, alongside the Art Deco-style Serralves Villa and a large landscaped park. Siza has placed the white, minimalist box-shaped structures on the site in an orderly manner, keeping their heights at a level that does not exceed the height of the surrounding trees (Figure 9). In the museum's interiors, he used courtyards and skylights to spread natural light and illuminate the spaces, while on the exteriors, he created elegant planes that did not draw excessive attention, in a manner respectful of the neoclassical villa. The Serralves Museum is considered one of the peaks of Siza's "silent" architectural philosophy: While creating neutral spaces that highlight the artworks, it offers spatial sequences that enrich the visitors' tour experience. While fulfilling the conditions of modern museum typology, it establishes a modest dialogue with the historical garden and building it is situated in. Siza completed the Serralves Museum in 1999, and later, in addition to the museum, he completed the Manoel de Oliveira Cinema House in 2019 and a gardener's house along with the restoration of the Serralves art deco building in 2021.

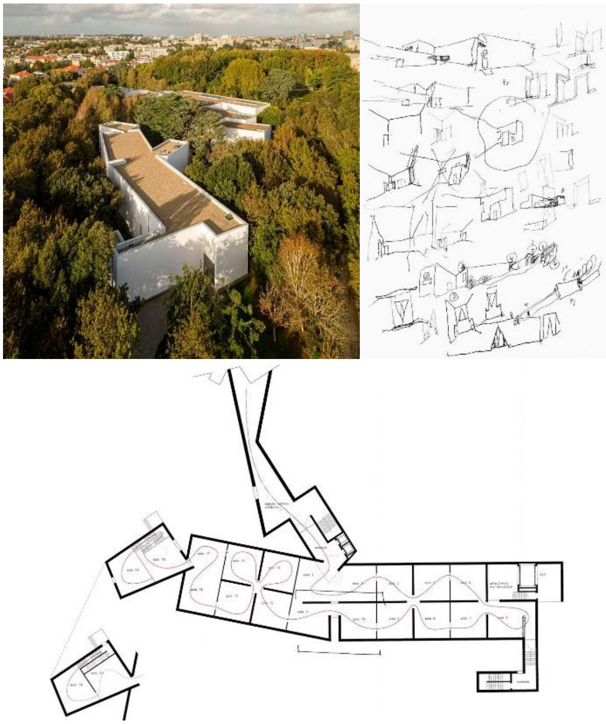

Figure 8. Photograph (by Nelson Garrido) Sketch (by Siza) and Plan drawing of Serralves Museum https://www.archdaily.com/1015907/serralves-museum-alvaro-siza-wing-alvaro-siza-vieira

By the 2000s, Siza continued to design significant structures in regions extending from Brazil to Korea. The Iberê Camargo Foundation Museum (2008) in Porto Alegre, Brazil, is situated on a riverbank slope and stands out with its white concrete mass. Here, Siza has used his signature fluid ramps as a sculptural facade element, while also paying a subtle homage to the legacy of Brazilian modernists (especially Oscar Niemeyer). This structure demonstrates that Siza's architectural language is universally comprehensible yet always open to local references. Indeed, in the 2010s, Siza diversified his palette of materials and forms according to the context while producing buildings in various cultures from China to Spain (for example, using bright ceramic tiles on the facade of a public building in Spain or cladding a museum in China with red sandstone). In this respect, Siza's architecture has become a point of resistance against the homogenizing effect of global architecture: In different geographies, he has been able to leave works that penetrate the local identity while still bearing Siza's signature.

Álvaro Siza's architectural journey, spanning from the 1960s to the present, exemplifies the quest for continuity within change that emerged during the crisis and transformation period of modern architecture. Siza's works, on one hand, embrace and continue the aesthetic and philosophical principles of modernism, while on the other hand, they reveal the metamorphoses these principles undergo under different social and regional conditions. In his buildings, the foundational principles of modern architecture (clarity of structure, functionality, innovation) uniquely blend with the material and technical knowledge of the local Portuguese building tradition. Therefore, while Siza is regarded as a "master" by his followers, his works have served as a school for many young architects: countless designs imitating Siza have emerged without leaving their own mark, and the Siza style has become a school of thought.

CONCLUSION

The relationship established between the theoretical framework discussing the death, crisis, and transformation of modern architecture and Álvaro Siza's architecture provides us with important clues about the continuity of architectural history. While many theorists declared the end of modernism in the 1970s, figures like Siza proved that it was possible to keep the essence of modernism alive by adapting it to new conditions. The balance between locality and universality, as pointed out by Kenneth Frampton, has been embodied in many of Siza's works; the principles of contextual harmony and collage, advocated by Colin Rowe, have manifested themselves in Siza's urban projects. Manfredo Tafuri's warning about the limits of architecture in social change has found its counterpart in Siza's participatory social housing projects; the architect's role has been redefined more as a mediator than an activist. Alan Colquhoun's proposal for a balance between modernism and history has become one of the fundamental principles applied by Siza in each of his projects: The dialogue between the historical fabric and new structures emerges as a natural balance in Siza's architecture.

Álvaro Siza, during a period when the "end of modernism" was being discussed, offered original approaches that evolved modern architecture without abandoning its intrinsic principles. His architecture neither completely imitates the past nor contains contextually disconnected innovation; on the contrary, it skillfully blends the new with the old, the local with the universal. Therefore, Siza's architecture has gained a unique position in the postmodern era; it deserves to be referred to as "a living continuation of the modernist legacy." Vittorio Gregotti, while evaluating Siza's works, states that his architecture is not simply a reflection of Portugal's deficiencies, but rather carries a subjective consistency shaped by the history of his relationships with the world. Siza has been an active subject of global architectural culture, but in doing so, he has not severed the bond with his inner voice and the voices of his own geography.

The 1970s debates, which began with the rhetoric of the death of modern architecture, were, when we look back today, a sign that pluralism and different paths were possible in architecture. Álvaro Siza's works, produced over more than half a century, have been examples of how these discussions found their practical dimension. Siza has proven with his works that modernism has not died and can continue to exist by transforming. His architecture is a creative response to the crisis, a kind of critical transformation. Indeed, Kenneth Frampton has described his works as "architecture as critical transformation." The theoretical discourse produced on the end of modern architecture has found life in the works of architects like Álvaro Siza; Siza, by creating a new synthesis from the crisis of modernism, has carried the continuity line of 20th-century architecture into the future.

References

Amirjani, R. (2018). Alvaro Siza's Design Strategy: An Insight into Critical Regionalism. *International Journal of Architectural and Environmental Engineering*, 12(10), 930–934.

Aureli, P. V. (2023). *Quinta da Malagueira*. Drawing Matter. Accessed April 25, 2025, from https://drawingmatter.org/on-malagueira/

Belogolovsky, V. (2016). *Interview with Álvaro Siza: "Beauty is the Peak of Functionality"*. ArchDaily. Accessed March 16, 2025, from https://www.archdaily.com/803250/interview-with-alvaro-siza-beauty-is-the-peak-of-functionality

Colquhoun, A. (1988). Postmodernism and structuralism: A retrospective glance. *Assemblage, (5)*, 6-15. Retrieved March 27, 2025, from https://www.jstor.org/stable/3171022.

Cruz, T. T., Ferreira, T. C., & Freitas, P. M. G. de. (2024). *Álvaro Siza's Lessons on Contextual Design in Historic Areas. Projects for the Historic Centre of Porto (1968-2000)*. In D. Fiorani, G. Franco, L. Kealy, R. Crișan, S. Mussó & T. C. Ferreira (Eds.), Conservation / Sustainable Design – Heritage Challenges in Historic Urban Landscapes (pp. 287–308). EAAE.

Fala. (2022). *Fala meets Siza*. Daidalos. Accessed April 22, 2025, from https://www.daidalos.org/en/articles/falameetssiza/

Frampton, K. (1983). *Towards a critical regionalism: Six points for an architecture of resistance*. In H. Foster (Ed.), *The Anti-Aesthetic: Essays on Postmodern Culture* (pp. 16–30). Bay Press.

Hartoonian, G. (2014). Critical regionalism: Whatever happened to autonomy? *Fusion Journal*, (4). Retrieved April 15, 2025, from https://fusion-journal.com/issue/004-fusion-the-town-and-the-city/critical-regionalism-whatever-happened-to-autonomy/

Kelbaugh, D. (1996). Typology — An architecture of limits. *Architectural Theory Review,* 1 (2), 33–52. https://doi.org/10.1080/13264829609478288

Klotz, H. (1988). *The history of postmodern architecture*. MIT Press.

Lee, D. (1998). The reactivating of Allan Colquhoun's architectural theory – 'Figure', 'Form' and 'Image'. *Journal of the Architectural Institute of Korea Planning & Design*, 14(11), 81–92. Retrieved April 11, 2025, from https://db.koreascholar.com/Article/Detail/373899

Mota, N. (2011). *Between Populism and Dogma: Álvaro Siza's Third Way*. Footprint (Issue 8), 35–58.

Nesbitt, K. (Ed.). (1996). *Theorizing a new agenda for architecture: An anthology of architectural theory 1965–1995*. Princeton Architectural Press.

Pimenta do Vale, C. (2018). *The social rise of a housing intervention: Álvaro Siza project for Bouça neighbourhood*. Faculdade de Arquitectura da Universidade do Porto. Retrieved April 23, 2025, from https://repositorio-aberto.up.pt/handle/10216/111685

Rodrigues, A. L. (2018). *In pursuit of a healthy city: Bouça Housing Complex by Álvaro Siza (1977), a lesson to retain*. AMPS, Architecture_MPS; University of the West of England. Retrieved April 24, 2025, from https://repositorium.sdum.uminho.pt/handle/1822/51184

Rowe, C., & Koetter, F. (1978). *Collage city* (p. 79). MIT Press.

Samovich, V. (2024). *The mischievous elements: On the architecture of cut-off columns, misaligned walls, and exaggerated windows built between 1966 and 2014* (Doctoral dissertation). Faculty of Architecture, University of Porto.

Sampaio, C. G. (2015). Alvar Aalto and Álvaro Siza: The Link between Architecture and Nature in the Construction of Place. *Athens Journal of Architecture*, 1(3), 207–220. https://doi.org/10.30958/aja.1-3-3

St. Louis Post-Dispatch. (1972). *Pruitt-Igoe housing project in St. Louis* [Photograph].

Sullivan, L. H. (1896). The tall office building artistically considered. *Lippincott's Monthly Magazine, 57*(3), 403-409.

Tafuri, M. (1973). *Architecture and utopia: Design and capitalist development* (B. Luigia La Penta, Trans.). MIT Press.

Tafuri, M. (1976). Toward a critique of architectural ideology. In K. M. Hays (Ed.), *Architecture theory since 1968 (pp. 2–35)*. MIT Press.

UNESCO World Heritage Centre. (2015). *Ensemble of Álvaro Siza's architecture works in Portugal*. Accessed April 20, 2025, from https://whc.unesco.org/en/tentativelists/6224/

Venturi, R. (1966). *Complexity and contradiction in architecture.* Museum of Modern Art.

Verebes, T. (2016). The interactive urban model: Histories and legacies related to prototyping the twenty-first century city. *Frontiers in Digital Humanities, 3*(1). https://doi.org/10.3389/fdigh.2016.00001

Chapter 4

The Conceptual Foundation of Passive Solar Design in Architecture: Effect on Thermal Comfort and Energy Consumption

Salar Salah Muhy Al-Din [1]

1.1 Introduction

Passive solar design (PSD) embodies a perennial methodology for constructing sustainable and energy-efficient edifices that integrate with the surrounding nature. Utilizing the sun's plentiful and sustainable energy, passive solar solutions diminish dependence on fossil fuels, decrease energy consumption, and improve thermal comfort without mechanical devices. This chapter examines the principles of PSD, assesses the latest advancements in passive heating and cooling methods, and investigates their impact on energy efficiency and thermal comfort in structures. It emphasizes tactics specifically designed for harsh climates, including both hot and cold environments, where severe temperatures and high solar intensity necessitate unique solutions, particularly for hot and arid conditions. Its relevance lies in its ability to address urgent global concerns, such as climate change and energy constraints, while creating healthier and more economical living areas.

This chapter provides researchers, architects, and students with a thorough understanding of how passive solar principles can be smoothly incorporated into building design. The chapter gives professionals useful tools to maximize energy efficiency by exploring the mechanisms of heat flow—radiation, convection, and conduction—and how they are applied through building orientation, form, thermal mass, and natural ventilation. Additionally, it looks at climatic and microclimatic elements, providing information on how environmental circumstances influence design choices.

This research is especially useful for people looking to design climate-responsive architecture. Architects will receive advice on how to design buildings that balance aesthetic, functional, and environmental objectives, while

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students will obtain a basic understanding of sustainable design principles. Researchers can use the precise classifications of passive solar heating and cooling systems. This chapter provides a roadmap and actionable insights for designing buildings that minimize energy needs while maximizing occupant comfort, with an emphasis on solutions specific to hot and arid areas. Finally, it emphasizes the vital role of PSD in crafting a sustainable future and empowers its readers to contribute to ecologically responsible architecture, especially in hot and arid areas.

1.1.1 The Principles of Passive Solar Design PSD for Heating and Cooling

Passive Solar Design (PSD) refers to harnessing the sun’s energy for heating, cooling, and illuminating living areas (Ozsen, 2010). According to Brawm and Dekay (2001), the idea of passive solar design is often dependent on the heat flow path, which is managed by building design in a trend that maintains (heating/cooling) according to the thermal performance of the buildings and interior space requirements. The principles of natural processes that are used in passive solar energy solutions include conduction, convection, and radiation-related thermal energy transfer.

Solar design in architecture refers to lowering the need for fossil fuels and replacing them with solar energy systems in order to conserve energy.

Grasping the principles of PSD involves comprehending how heat is transferred and stored. Heat naturally moves from hotter materials to cooler ones until thermal equilibrium is reached between them. Therefore, PSD facilitates the movement of heat from warmer areas to cooler ones within the structure, utilizing the principles of heat movement and storage. In passive design, heat transfer occurs through natural or physical methods: radiation, convection, and conduction (Kamal, 2012).

Radiation refers to heat transfer through space, exemplified by the sun's rays warming a person's cold face on a chilly day. Additionally, heat can travel through the air from warmer surfaces to cooler ones. In regions with hot climates, PSD can utilize light-colored materials to reflect incoming solar heat and to deflect it away from a building. Conversely, in colder climates, dark materials are employed to absorb solar heat and retain it within the building. For instance, clear glass allows nearly 90% of the sun's heat to enter the structure, effectively introducing warmth.

Convection pertains to heat transfer via flowing gases or liquids, such as air or water. Warmer gases and liquids rise, while cooler ones sink within an enclosed space. Warm air rises due to its lower density compared to cooler air, which descends. This explains why warmer air accumulates in the upper sections of a building near the ceiling or second floor, while cooler air settles in the basement. Some PSDs exploit air convection to distribute solar heat gained from southern walls to other areas of the building.

Conduction is the most common mode of heat transfer, occurring through direct contact between objects, like touching a hot surface. PSD harnesses this principle by utilizing various materials that can store heat. Materials such as stone, brick, concrete, and tile are often incorporated into PSD as thermal mass, particularly in roofs and walls (Wilson, 2014), as seen in Figure 1.

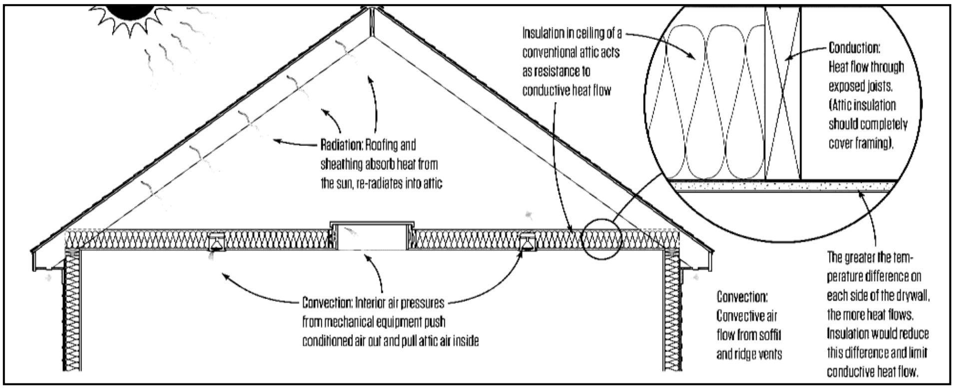


Figure 1. Modes of heat transfer include convection, conduction, and radiation (DeKorne, 2019).

1.2 PSD with Climate Response

The primary goal of PSD is to minimize energy use for heating, cooling, and lighting while ensuring good indoor air quality and thermal comfort (Athienitis and Santamouris 2013, pp.1-10).

Since the dawn of humanity, as people began constructing shelters for protection, there has been an ongoing effort to adapt designs and strategies to address climatic impacts. By incorporating considerations such as natural ventilation and solar radiation in the building design process, it is possible to cut operational costs associated with heating and cooling systems, thereby lowering overall energy consumption. Hence, architecture that responds to climate conditions tends to be energy-efficient.

It is crucial to adapt buildings so they serve as natural selective barriers between indoor and outdoor environments, allowing beneficial factors like natural summer ventilation, daylight, and winter sunlight while minimizing unwanted elements, such as overheating from direct sunlight in summer or glare during winter (Szokolay 2001). Consequently, climatic influences directly shape building design; variations in architectural approaches arise from differences in climatic conditions influenced by factors like local geography, climate characteristics, and the sun's path throughout the year, all of which must be considered in the creation of climate-responsive buildings.

1.2.1 Climatic Elements Influencing PSD

There exists a significant connection between climate and architectural design, which is evident in historical architecture since such designs typically respond well to climate conditions. As a result, these structures remained comfortable without relying on modern technologies for either construction materials or active thermal comfort systems (Markus and Morris, 1980). PSD incorporates strategies applicable to nearly every climate, though these strategies vary according to specific climatic needs. The fundamental principles of climate-responsive design are essential for achieving thermal comfort within any interior space by utilizing local materials and energy-efficient design strategies tailored to the unique climatic context (Carter and Villiers, 1987).

Baruch Givoni (1998) identifies four primary climatic effects, each with associated criteria for passive building design. In hot-dry climates, characterized by aridity, high daytime temperatures, and significant temperature variations between day and night, these regions usually lie between latitudes of 30° and 15°. The appropriate PSD techniques for this climate include compact building forms that ensure high insulation, incorporating interior or adjacent courtyards for shaded areas. Windows tend to be small to protect against intense solar radiation during summer, while outer walls are painted light colors to reduce heat absorption from the sun. Additionally, planting vegetation around the building helps regulate the local climate.

Cold climates, on the other hand, offer comfort during summer but can be uncomfortable in winter. Therefore, passive solar heating strategies are essential to reduce the need for heating energy. Proper building insulation is crucial in these climates and can be achieved through a compact design approach. It is also important to block the wind effectively to mitigate its adverse effects and thermal impacts during the winter months. Creating buffer zones on the northern-facing facades is necessary to adapt to external environmental influences.

In a hot-humid climate, these regions experience high humidity levels and elevated temperatures in summer, with minimal diurnal temperature fluctuation. The key PSD strategies for this climate include elongated building designs to enhance natural ventilation and maximizing nighttime cooling to maintain a comfortable indoor temperature during the day. Furthermore, integrating a courtyard (either fully enclosed or semi-enclosed) and providing shading for openings are essential to minimize direct solar exposure and reduce heat gain during summer. The two primary elements for ensuring thermal comfort in such climates are shading and natural ventilation.

Finally, regions marked by hot-humid summers and cold winters, typically found between latitudes of 30° and 45°, present challenges for PSD. In winter, buildings must capture passive solar energy, while in summer, they need protection from solar radiation. Therefore, it is necessary to implement all passive strategies to optimize the thermal performance of these buildings (Givoni, 1998).

It is critical to emphasize the importance of site-specific features as key considerations for passive solar building design and how the components of climate assessment interact with passive solar energy strategies combined with energy-efficient planning. This approach aims to provide a more suitable construction option for the specific site by taking into account climatic factors, topography, and landscaping to support the effectiveness of a passive solar building.

1.2.1.1 Temperature of the surrounding air

Ambient air temperature can be recorded in either degrees Celsius (°C) or Fahrenheit (F), typically using a mercury thermometer. The dry-bulb temperature, referred to as 'true air temperature', is obtained from a shaded location by placing the temperature gauge inside a box made of wood with louvers, also known as the 'Stevenson's screen'., elevated between 12 cm and 180 cm above the ground (Koenigsberger, et al., 2010), as illustrated in Figure 2.

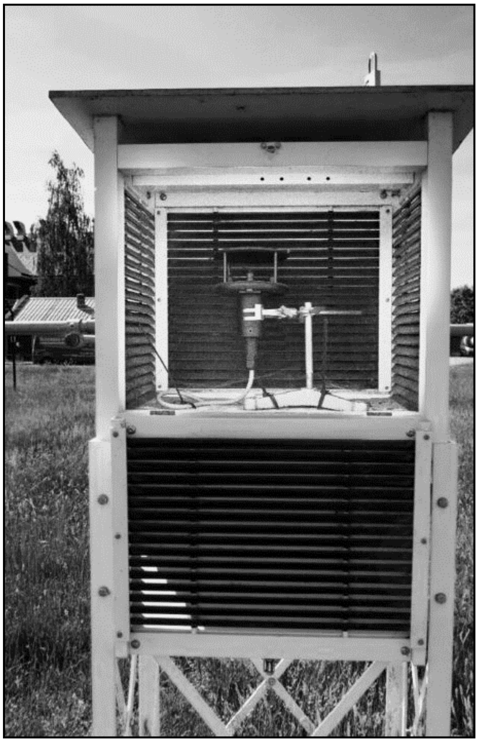


Figure 2. Stevenson's screen (Burt, 2022).

The temperature of the air is a crucial environmental factor that influences the climate characteristics of any area, and it is one of the key variables that guides the PSD approach in building architecture. Regions with low ambient temperatures are characterized by cold conditions, whereas areas with high temperatures exhibit hot characteristics. The temperature in a specific region is affected by various factors, including wind and humidity, as well as local conditions such as sunlight exposure, shading, and the presence of nearby water bodies. (Brawm and Dekay, 2001).

1.2.1.2 Solar Irradiance

Solar irradiance refers to the radiant energy that the sun emits and that reaches various surfaces; it is also described as the sun's power output. It indicates the intensity of solar radiation hitting a unit area over a specific period, typically measured in Watts per square meter (W/m^2) or kilowatts per square meter (kW/m^2). The Earth primarily derives its energy from the sun in the form of sunlight. The spectrum of solar irradiance ranges from 290 to 2300 nm (nanometers). The amount of irradiance that reaches the upper atmosphere is considered to be constant at 1395 W/m^2, although it can vary by ±3.5% due to variations in the distance between the sun and Earth. Additionally, it can fluctuate by ±2% due to changes in the sun’s output itself (Koenigsberger et al., 2010). Solar irradiance is a crucial meteorological factor that helps define the climatic traits of a region, affecting whether it has high or predominantly low temperatures; thus, it influences PSD strategies. The level of solar irradiance that strikes the surfaces of a building varies with the season and the time of day. Furthermore, Latitude and longitude, which directly affect the sun's route and height, have an impact on it (Ben Othman et al., 2018). See figure 3.

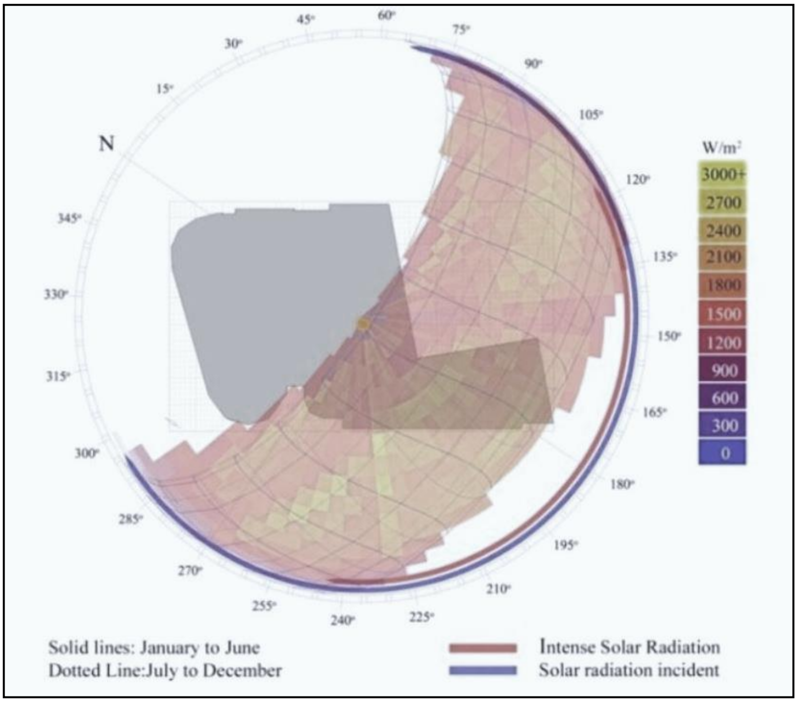


Figure 3. The incidence of solar irradiance and Sun path (Graiz and Al-Azhari, 2019).

1.2.1.3 Direction of the Wind

Wind is a crucial factor for designers, as it influences thermal comfort levels within the structure by affecting the heat exchange through convection at the building's exterior; additionally, it leads to air infiltration inside the building. Air movement plays a significant role in the perceived temperature or thermal sensation. The cooling effect of wind becomes more pronounced with lower temperatures and higher wind speeds. Moreover, increased wind speed can still enhance thermal comfort in hotter conditions, provided it does not fall below drought levels. However, with high humidity levels reaching around 85 percent, evaporation is restricted; thus, at this humidity level, even air movement may not effectively improve cooling and enhance thermal comfort (Szokolay, 2008). The direction of the wind impacts the shape and design of the building based on specific needs, either obstructing or allowing wind flow, as illustrated in Figure 4.

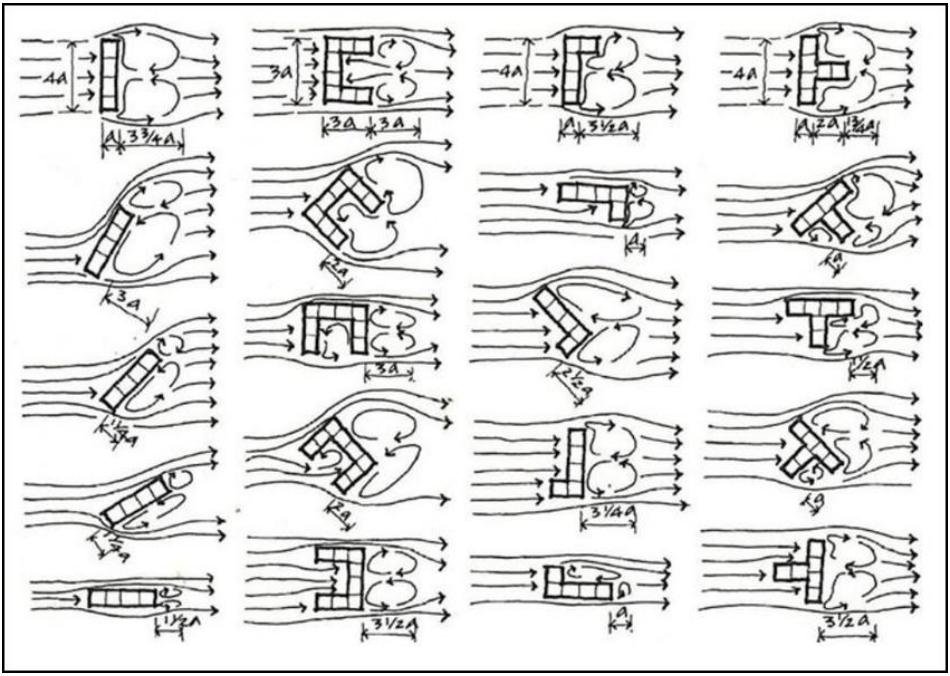


Figure 4. The impact of wind direction and the shape of buildings on wind shadow (Du and Zhu, 2023).

This figure shows various forms and geometries that interact with the wind to create a wind shadow. Natural ventilation, which includes cross-ventilation and stack ventilation, is a passive solar strategy that designers use to improve air flow within buildings, as illustrated in Figure 5.

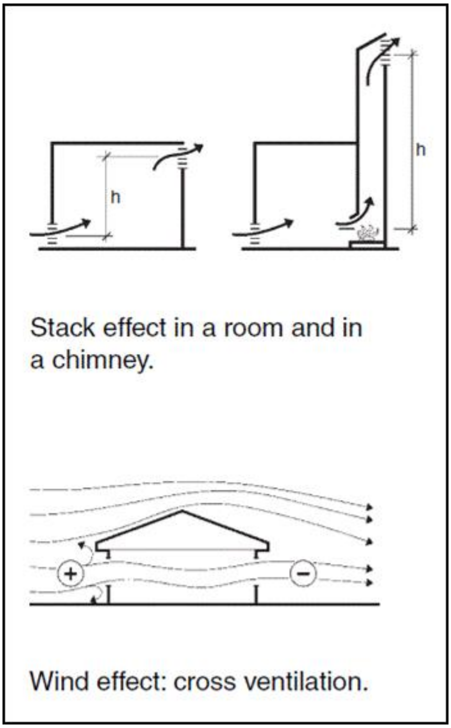


Figure 5. Strategies for PSD to improve airflow. Source: (Szokolay, 2008).

1.2.1.4 Precipitation

Precipitation is a collective term that includes all types of water, such as rain, snow, hail, frost, or dew. It is quantified by measuring rainfall in millimetres over a specified time period, such as millimetres per day (mm/day) or millimetres per month (mm/month) (Landsberg, 1947). Precipitation influences thermal comfort by creating an insulating layer on roofs during snowfall, which helps retain indoor heat. Additionally, rainfall cools both the building and its surroundings; in warmer areas, this can enhance thermal comfort, while in colder climates, it can increase humidity, particularly affecting the dampness of clothing, which negatively impacts thermal comfort (Hoppe, 1998). Assessing indoor dampness during heavy rain or snowfall, and identifying solutions through PSD, is a crucial factor for architects to take into account.

1.2.1.5 Wetness or humidity of weather

The level of humidity is influenced largely by the surrounding temperature and the amount of water vapour in the atmosphere. Humidity can be assessed by calculating the average monthly maximum relative humidity, which is derived from the highest readings over thirty days. Additionally, the average monthly minimum relative humidity is determined from the lowest readings over the same thirty days (Koenigsberger et al., 2010, p. 15). In areas characterized by high humidity or damp conditions, the transmission of solar radiation is reduced because of the atmosphere's absorption and scattering. Elevated humidity or dampness hampers the evaporation of water and sweat, leading to feelings of thermal discomfort. According to the National Bureau of Codes (NBC), the ideal range for indoor relative humidity is between 30% and 70% (National Building Code of India, 2005). Therefore, in these climates, PSD strategies often focus on enhancing natural ventilation and permeability within buildings, particularly in warm and humid climates (Subramanian et al., 2017).

1.2.1.6 Condition of the Sky

Sky conditions are typically defined by the presence or absence of clouds. Generally, two measurements are taken each day to calculate the percentage of the sky obscured by clouds, which can be expressed as a fraction, such as 50%, five-tenths, or four-eighths, indicating that half of the hemisphere is covered by clouds. There are also records for night-time sky observations (Cunliffe and Muncey, 1965). Clear skies enhance the intensity of solar irradiance, whereas an overcast sky reduces it. Additionally, when clear skies are present, the reflection from the external surfaces of buildings increases. Therefore, designers must understand the periods and seasons when skies are clear or cloudy, even within a single day, such as the differences between morning and afternoon conditions, which can influence the design of roofs and overhangs to effectively manage shading systems (Koenigsberger et al., 2010, p. 15-17).

1.2.2 Factors Influencing PSD at the Micro-Climatic Level

One of the key considerations for PSD is the effective use of the site in relation to suitable solar and wind patterns. The ideal location for a passive solar building is oriented to capture the maximum amount of sunlight during winter while minimizing exposure to icy winds (Carter and Villiers, 1987). A site's micro-climate is shaped by various factors, including its topography, the presence of vegetation, its orientation, the availability of water bodies, the width of surrounding streets, and the built environment nearby. Understanding these elements will enable designers to create an effective site layout plan. The characteristics of these factors should be examined and evaluated to make informed decisions regarding energy-efficient design (Brawm and Dekay, 2001), as illustrated in Figure 6.

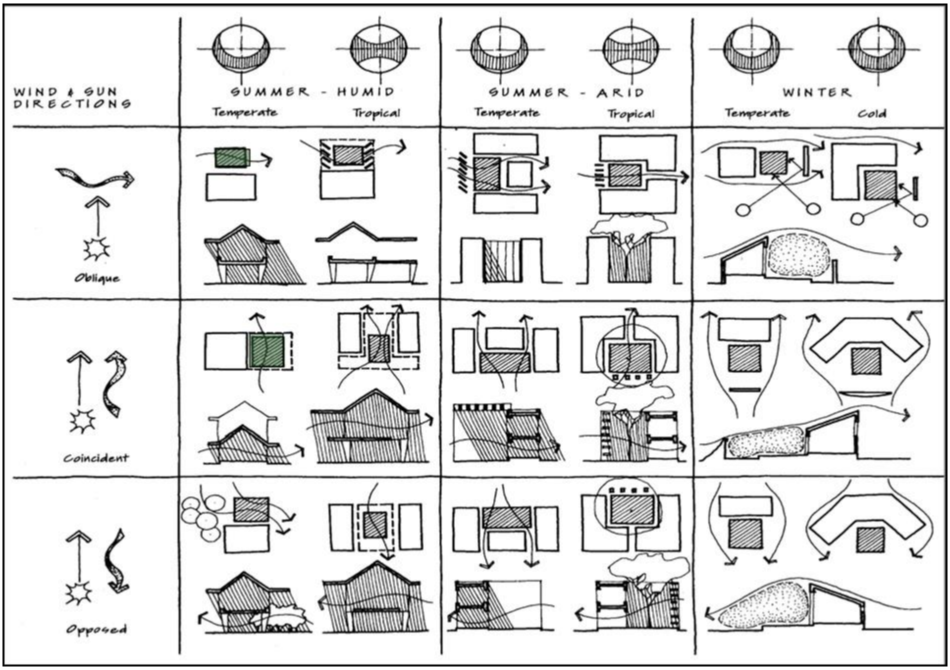


Figure 6. The framework of passive design is based on microclimate. (Brawm and Dekay, 2001)

1.2.2.1 Vegetation and Topography

Vegetation plays a crucial role in influencing the climate. The cooling effect is primarily due to the evaporation that occurs through the transpiration of plant leaves. This process converts solar energy into latent heat rather than sensible heat. Studies conducted in Mediterranean cities have demonstrated that vegetation significantly impacts thermal comfort. Trees with expansive canopies provide a cooling effect during the day, which can lead to a temperature reduction of over 3°C. However, at night, these trees can create uncomfortable conditions by raising humidity levels and decreasing wind speed (Muhy Al-Din et al., 2017; Potcher et al., 2006). When strategically planted around buildings, plants can play an essential role in lowering energy consumption. They provide shade to the building's exterior and help cool the air surrounding the structure. Additionally, ground vegetation reduces the sunlight reflection around buildings. Planting vegetation on the eastern and western sides of a building can offer substantial shade in the summer. Using deciduous trees on the southern side of a building is an effective approach for PSD since they can block solar radiation during warm months and allow sunlight to enter during colder months when they shed their leaves (Givoni, 1998). The site's topography and land shape are crucial considerations for designers aiming to maximize passive design benefits. For instance, in the northern hemisphere, a location facing south or north in the southern hemisphere is ideal for implementing effective PSD that minimizes energy consumption in buildings. Moreover, elevation above sea level affects ambient temperature, with a decrease of 0.8 °C for every 100 meters increase in height (Givoni and Reinhold, 1994).

1.2.2.2 The Interaction with the Adjacent Built Environment

The surrounding constructed environment will alter the micro-climatic properties of the area, so influencing the thermal comfort conditions of the building, either favorably or unfavorably. The neighboring horizontal surfaces and buildings reflect 20% of the incident radiation or shading effects on the structure (Brawm and Dekay, 2001). Therefore, establishing interaction with the surrounding built environment or as part of a building ensemble is crucial during the design process for passive solar architecture, and will render the evaluation more realistic for assessing energy usage in the building.

1.3 Classification of PSD in Buildings

As shown in the following graphic, the study will divide PSD into two primary categories: passive solar cooling systems and passive solar heating systems. See Figure 7.

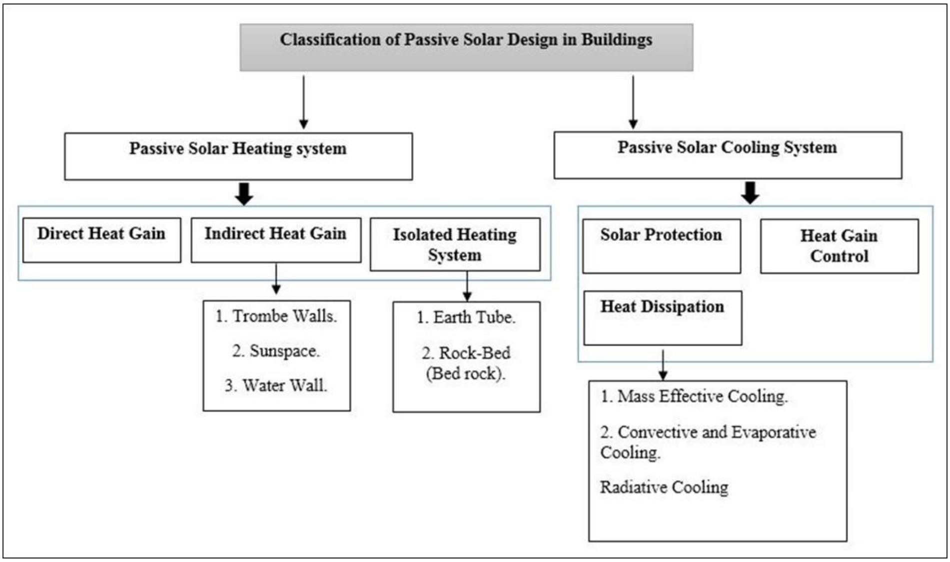


Figure 7. Buildings' classification for PSD. (By Author).

1.3.1 Passive Solar Heating System

According to the U.S. Department of Energy (2001), there are three primary categories of PSD:

1) Direct heat gain (DHG): This refers to the method of capturing and storing heat directly within the living area.

2) Indirect heat gain (IDHG): This indicates that heat is collected and held near the living spaces and thermally connected to them but is not visible; examples include thermal storage wall systems and roof pond systems.

3) Isolated gain: This process involves gathering heat (which may be linked to or separate from external weather) and storing it either separately or within the living areas, such as in a solar greenhouse. Later, Roaf et al. (2002) and Evans (2007) distinguished two more categories:

4) Combined: This refers to the use of multiple types in the same design.

5) Composite: This describes how active and passive systems are combined.

Key factors to explore in any given type include: solar collection orientations, the thermal retention ability of materials, heat distribution, and control methods.

1.3.1.1 Direct Heat Gain (DHG)

The simplest method of PSD involves direct sunlight entering the building through windows or openings, referred to as collectors, which are typically south-facing and made of transparent glazing material (Paul, 1979). The sunlight strikes the masonry floors or walls, which absorb the solar heat and retain it. For effective heat collection, surfaces are generally painted in dark colors, as they have a higher absorption capacity compared to lighter tones. At night, when indoor temperatures drop, Convection and radiation cause the thermal mass's stored heat to start reradiating into the dwelling area (U.S. Department of Energy, 2001). Key requirements for a direct gain approach include a broad aperture oriented to the south that connects directly to a living area, along with exposed solar thermal mass within the building's structure. While many modern buildings incorporate large south-facing openings, they often struggle with adequate thermal conservation. In commercial properties with extensive glass surfaces, excessive solar gain may arise from insufficient shading systems, leading to increased cooling requirements to ensure thermal comfort (Moore, 1993).

To mitigate these challenges, the scale, quantity, and placement of the fenestration, alongside the thermal mass, must be meticulously planned in accordance with passive solar principles, which will be elaborated on later in this chapter. Additionally, modern solutions, like double glazing, can help address these issues. Ultimately, strategies for achieving DHG rely exclusively on the fenestration. A larger aperture necessitates an increase in thermal mass to manage temperature fluctuations, which can become expensive if solely relying on mass for this thermal function. Conversely, this approach can be effective for buildings that already have load-bearing structures, as it is closely related to the building fabric and structure, the arrangement of the interior space, the materials used, and the fenestration system. These factors are crucial during the conceptual phase of architectural design for optimizing passive direct gain systems.

1.3.1.2 Indirect Heat Gain (IDHG)

Indirect gain differs from direct gain by employing a buffer that prevents solar irradiance from directly entering the living area. Several components of indirect gain mechanisms were established by Paul (1979) to include sunspaces, Trombe walls, thermal mass, and water walls that are divided from the main living area by roof basins, air circulation systems, and thermal walls. These systems act as IDHG mechanisms that capture, store, and redistribute solar energy within the building's exterior, influencing the area that needs heating (Goulding et al., 1992). This section will provide a brief overview of Trombe walls, water walls, and sunspaces, while a more detailed explanation of thermal mass will follow later in this chapter. In this approach, solar radiation is initially collected and then absorbed by a thermal mass. Subsequently, some of this stored energy is transferred through convection to warm the interior space, while another portion radiates heat during nighttime. The integration of such systems within the building will depend on the thermo-physical properties of the construction materials. Some IDHG systems are situated within the living area, while others are placed at a distance where natural convection can occur.

1.3.1.2.1 Trombe Walls

A Trombe wall is a sun-facing, glazed, heavyweight, external wall that suck the heat of the sun's radiation in the day to release it to the inner space during night-time. The difference between a Trombe wall and Thermal mass is that the former is opened from the upper and lower sides for venting up and down to enable air to circulate through the living area quickly. The first inventor of the classic Trombe wall was Edward Morse, an American engineer who patented his design in 1881, which contains a simple Trombe wall in which glass and an air space separate the wall from the outside ambient (Birkeland, 2008). Later, the idea was developed in the 1960s by French architect Jacques Michel and engineer Félix Trombe, and has been used around the world. Commonly, a Trombe wall involves a darkly coloured, southern-oriented masonry external wall covered by glazing on the outside (Thumann and Mehta, 2008). See Figure 8.

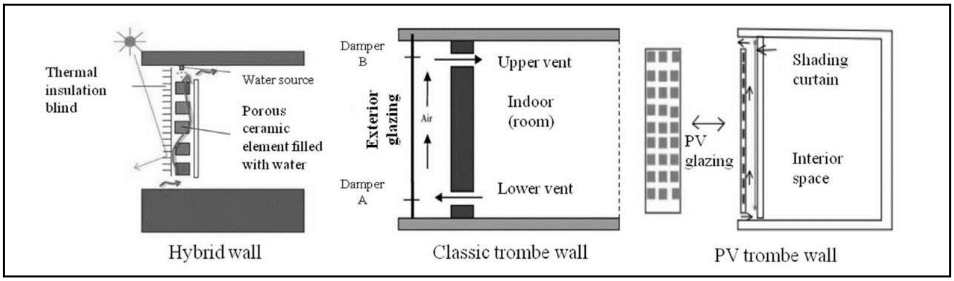


Figure 8. Section in 'Trombe Wall' (Bhamare et al., 2019).

The mechanism of the 'Trombe' wall is that solar irradiance is transferred through the glazing and heats the external surface of the wall. This heat slowly conducts through the wall to be reradiated out many hours later into the living space, reducing the amount of conventional space heating needed. During summer, Trombe walls need to be shaded carefully by shading devices to prevent overheating inside the living space, and the upper openings will be exposed to the outside ambient. Trombe walls are particularly well-suited to homes in sunny climates that have less cloud and great fluctuation in temperature between day and night in the cooler months (Hu *et al.,* 2017). A 'Trombe Wall' working mechanism in summer and winter is shown in Figure 9.

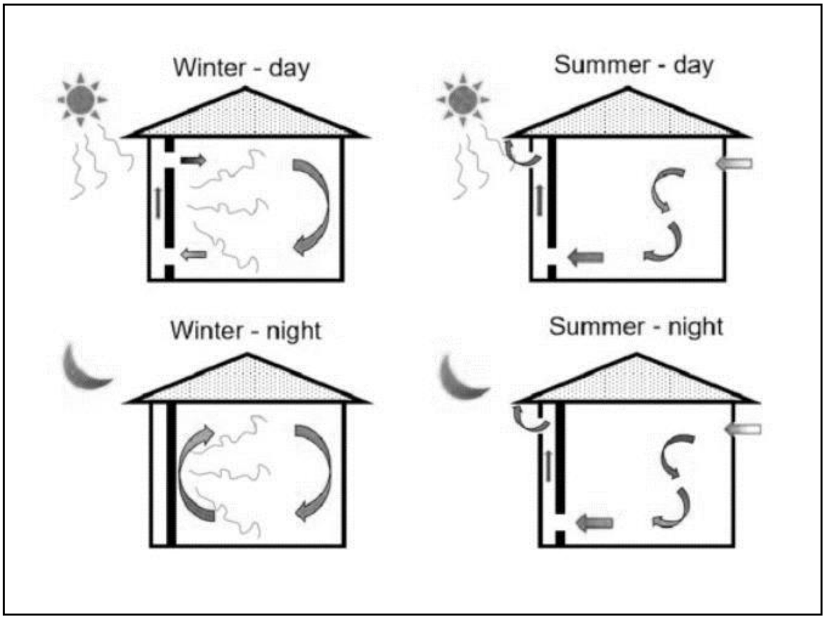


Figure 9. Trobe Wall mechanism in cold and hot seasons (Xu, 2023).

This strategy has some negative architectural impacts, which prevent sun rays from penetrating the inner living space directly, and the wall blocks the visual relation between inside and outside. Therefore, the walls can be designed as partly opened to moderate that (Moore, 2013).

1.3.1.2.2 Sunspace

A sun space is a glass enclosure on the side of a building facing the sun. Cofaigh *et al.* (1996) elucidate that the sunspace system appears with different names in architecture, such as glazed balcony, winter garden, summer room, etc. It is a prevalent system in the direct and IDHG techniques for the passive design of buildings. The system is recognized as an indirect heating system if there is a wall for thermal conservation capability, and there is no visual connection between the sunspace and primary space. If it doesn't have any wall obstacles, then the vision will be known as a direct one.

The mechanism of the sunspace is that sun irradiance passes through transparent glazing and warms the sunspace. To maintain inner space warming and temperature fluctuations, a masonry wall is built between the sunspace and living space to absorb the heat and store the sun's irradiance energy. At night or during the absence of sunny weather, the thermal mass releases the heat to warm the inner side of the sunspace. The envelope of the sunspace, ceiling, wall, floor, and window in the sunspace delays heat loss at night and during cold weather. Some features include operable windows, doors, vents, and fans that are used to control the sunspace from overheating by managing the ventilation for removing excess heat outside. Interior aperture (doors and windows) move warm air and distribute it to other parts inside the building when it is required. Through these inner apertures, the rest of the time, the sunspace can be isolated from the building when it is not required (Passerini, 2012). See Figure 10.

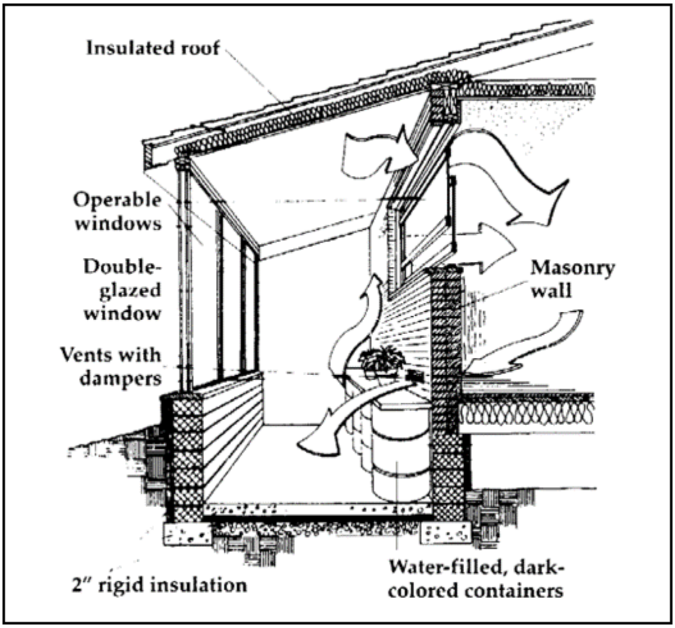


Figure 10. The Sunspace working mechanism and its incorporation with thermal mass to absorb solar heat. U.S. Department of Energy, and National Renewable Energy Laboratory, 1994).

1.3.1.2.3 Water Wall

The water wall is like Trombe wall systems except that the walls consist of water instead of a solid wall. The first water wall in the world was built in 1947 by Hoyt Hottel and his students at the Massachusetts Institute of Technology. This water wall used a full height array of one-and five-gallon cans, painted black and set behind double pane glass. These water walls provided 38-48% of the heating demand (Bainbridge, 2005). Water walls may be a preferable system because it has low-mass construction. The working mechanism of the system, as water walls transfer heat via the walls as a consequence of convective water circulation, while the Trombe wall transfers heat through conduction. The capacity of water to conserve heat per unit volume is higher than bricks, concrete blocks, and stones. Therefore, the efficiency of thermal performance of the system can be achieved at the highest levels with this material, because convection flow in water leads to the transfer of heat by means of convection and conduction (Moore, 1993). Furthermore, they can be easily installed in new construction, and it is cheaper than a Trombe wall. See Figure 11.

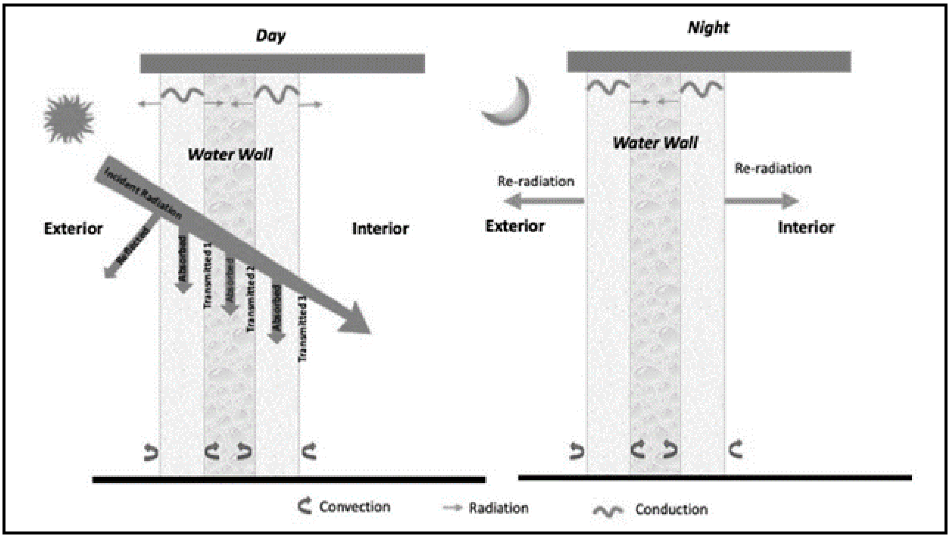


Figure 11. Water Wall IDHG system as part of a PSD (Rathnayake et al., 2020).

1.3.1.3 Isolated solar system

In systems with isolated gains, the gathering and storing of solar energy are kept separate from the living areas, which means that residents cannot observe the solar heating process. There is essentially no heat radiation from within the collection wall to the living space, although there is potential for the conservation wall to emit heat into the occupied area. Typically, the mechanism in these systems involves air being heated in the collector first, which then rises from the bottom upward (Holubec, 2008). The warmer air transfers its energy into the space. These solutions may serve as a valuable addition in retrofit projects. However, implementing this type of system can be challenging in existing buildings, as it requires specific components for heat conservation, in contrast to direct or indirect heating systems (Goulding et al., 1992). This system promotes architectural complementarity in contrast to DHG/IDHG systems, which necessitate more strictly defined architectural elements. In isolated systems, only the storage device needs to be located near the living areas to meet the heat inflow requirements of passive design. This allows for all operations to occur naturally without relying on any active systems (Bilgic, 2003). Examples of isolated solar systems include earth tube systems and the 'Rock-Bed' system.

1.3.1.3.1 Earth Tube

Earth tubes are long tubes buried in a selected region near the living space (1.5 m to 4 m). The temperature of the earth at a depth of 1.5 to 2 m stays constant throughout the year (Bisoniya *et al.,* 2013). The temperature difference between the outside air and that of the ground results in a cooling or heating effect, depending on the time of day or year. Earth tubes are effective at mitigating large fluctuations in daily temperature in climates that experience such temperature swings as the temperature on hot days and the temperature on cool nights. In addition, earth tubes provide a low-tech alternative for moderating significant seasonal temperature extremes. Design factors for earth tubes can be divided into fixed and free parameters. Fixed parameters are known as those that cannot be changed or can be changed relatively easily. Weather, location, ground and backfill material, groundwater content, and the building heating or cooling load are fixed parameters. While free parameters depend on the designer, such as air flow rate, length of the tube, and the diameter, tube material, and depth of installation (George and Kimba, 2010). See Figure 12.

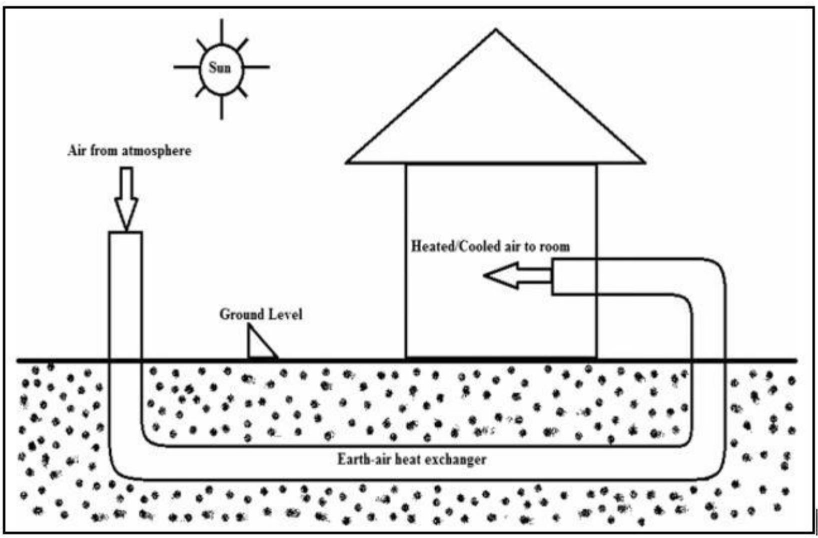


Figure 12. Model of Earth–tube heat exchanger system.
(Bisoniya, et al., 2013, p.2)

Earth tubes can be installed on its own to reduce energy consumption in building conditioning or could be coupled with conventional heating or cooling systems to reduce overall power requirements, or the system.

1.3.1.3.2 Rock- Bed (Bedrock)

The Bedrock system is a heating strategy used in cold climates. It is useful to use a heat storage, in the form of a rock bin, under the building or living space as a PSD strategy. It would work as thermal storage of heat collected in the daytime.

Heat transfer happens by convection if the building is terraced up a slope, or by the use of a fan, which would transfer heat to a rock bed located in a space under the floor of the building. See Figure 13.

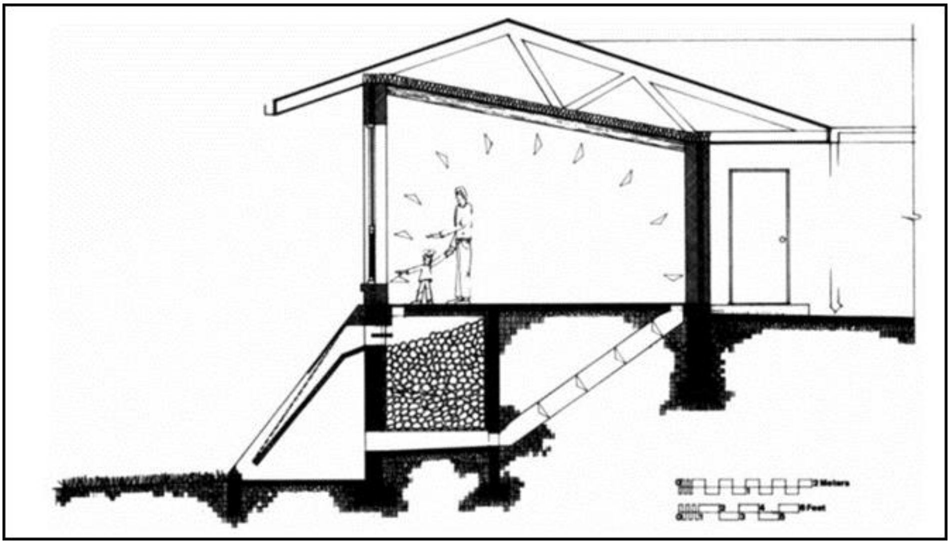


Figure 13. Rock-bed (Bedrock) heat storage strategy (Cook, 1983).

The rock bed should spread across 50 to 75% of the floor area in moderate climates, and 75 to 100% of the structure's floor area in cold climates. The heat from the greenhouse or sunspace should be steered over the rock bed, and a tool for returning cold air from the bottom of the rock bed to the greenhouse should be provided. If a terraced design is applied, colder air will naturally separate because of the convective loop cycle. The rock size is important for implementing effective results. About 0.05 to 0.10 cubic meters of grip-sized rock is required in cold climates, and almost up to 0.03 cubic meters in temperate climates. In warm climates, Rock bin storage could also be used as a cooling system to mitigate cooling load in the buildings (Mazria, 1979).

1.3.2 Passive Solar Cooling System

Structures, in general, should ensure thermal comfort for their occupants. Achieving thermal comfort involves processes such as cooling, heating, humidification, dehumidification, and ventilation. As a result, cooling plays an essential role in maintaining thermal comfort and contributes significantly to a building's load and energy usage for air conditioning, leading to peaks in electricity consumption during the summer months (Taleb, 2014). Therefore, it is vital to implement passive cooling technologies to reduce cooling load demands in buildings. In many instances, combining solar heating with passive cooling is more cost-effective than relying solely on active cooling or heating systems. Additionally, this approach enhances architectural design in terms of both logic and aesthetics (Bilgiç, 2003). There are three primary categories of passive cooling for buildings: Solar protection, Heat gain control, and Heat dissipation (Ahmed, 2012).

1.3.2.1 Solar protection

Shielding from direct exposure to sunlight may include: site planning (placement and orientation), architectural design and style, as well as sun shading for the exterior of the building. These aspects will be elaborated on later in this section.

1.3.2.2 Heat Gain Control

Managing heat gain involves the insulation characteristics and thermal storage capabilities of the building materials and design. Insulation not only reduces heat loss during the winter but also slows down heat absorption in the summer. Many principles and techniques used for passive heating can also be modified for passive cooling.

The key to effectively controlling heat gain lies in integrating two or more passive systems, such as using thermal mass in conjunction with heat dissipation methods like natural ventilation (refer to section 1.4.6). For instance, thermal masses incorporated into the construction, including materials like masonry, cement, or brick walls and floors, serve as heat sinks, resulting in a drop in internal temperatures on hot days. When positioned correctly, these thermal masses can be exposed to cooler night air, allowing for the expulsion of the heat accumulated during the day (see section 1.4.3).

Managing and minimizing the impact of direct solar radiation is achieved through strategic plantation; for example, deciduous trees can obstruct the direct rays of the sun during warmer months. Additionally, vegetated ground cover can lower the reflection of solar energy from the ground, keeping it cooler and diminishing re-radiation (see section 1.4.5).

Adjusting the size and configuration of openings helps to align with climatic conditions, effectively reducing heat gain during the summer while maximizing heat absorption in the winter and minimizing heat loss (see section 1.4.4).

1.3.2.3 Heat Dissipation

The strategy for heat dissipation focuses on removing excess heat from a building to the surrounding environment that has a lower temperature. The effectiveness of heat dissipation hinges on two primary factors: the presence of a suitable environmental medium to absorb the heat and the establishment of an effective thermal connection between the building and the heat-absorbing environment. Additionally, it is essential to have a sufficient temperature difference to facilitate the transfer of heat. The primary methods for heat dissipation include: utilizing the thermal properties of the ground soil as a heat sink for mass-effective cooling, where stable thermal conditions are maintained; employing convective and evaporative cooling by using air and/or water as the heat-absorbing media; and radiative cooling, which involves releasing heat to the sky as the environmental medium. The effectiveness of these heat dissipation techniques is heavily influenced by climatic conditions (Santamouris, 2005).

1.3.2.3.1 Mass effective cooling

The earth berm passive design, or the strategy of earth sheltering, is a time-honored approach to construction. This method leverages the earth's properties to maintain the thermal efficiency of buildings, a practice that dates back to ancient civilizations. Historical societies have crafted their environments by harnessing the stable thermal conditions inherent in the earth to achieve thermal comfort (Cook and Santos, 2000). In contemporary discussions, this technique has gained renewed definitions, focusing on its thermal properties to conserve energy for heating and cooling by utilizing the thermo-physical characteristics of the earth as a structural mass. Thus, earth berms or earth shelters are understood as structures that incorporate earth mass, providing protection against adverse external conditions while managing heat retention and stabilizing indoor temperatures throughout the seasons. Bisoniya et al. (2013) note that the earth's temperature remains steady year-round at a depth of 1.5 to 2 meters. According to various studies, constructing buildings that are in contact with the earth or partially underground can lower energy consumption by diminishing heating and cooling demands throughout the entire year when compared to traditional buildings. These constructions benefit from being shielded from direct sunlight; furthermore, the temperature variation between the exterior and interior of the building is minimized, which subsequently reduces heat gain and loss (Carpenter, 1994).

1.3.2.3.2 Convective and Evaporative Cooling

1. Cooling through convective

The contrast in density between cooler air and warmer air causes the lighter warm air to rise due to its lower density. This upward movement of air, referred to as convection, can lead to a buoyancy-driven stack effect (Tavakolinia, 2011).

One of the most efficient methods for dissipating heat is through convective cooling via ventilation, which is an effective approach to enhancing thermal comfort within buildings and lowering energy usage. Daytime ventilation can occur when the temperature outside is cooler than that inside. As a result, this is especially effective during the night (Santamouris, 2005). Examples of strategies for convective cooling include wind catchers and solar chimneys.

"Wind-catchers," or 'Badgeer' were originally used in hot-arid climate regions, where there are prevailing winds and drier air, which is free from moisture. In these regions, a wind catcher is built above the building, facing the prevailing wind, to catch and promote the cool air inside the building. In hot-dry areas, the windows cannot supply ventilation and lighting at the same time. Where small opening windows are required with small sizes to create sufficient air velocity and consequently reduce the natural day lighting. Hence, a wind catcher as a separate ventilation system has been employed and designed to provide air movement, while windows were designed to serve just the purpose of natural daylighting. Based on the geographic location, wind catchers come with different designs and styles. They are designed in different heights and numbers of openings, from one-sided to eight-sided, in some cases related to the outside wind directions. The wind catchers were mounted at a high level sometime to catch free wind and avoid dusty wind in some regions (Kalantar, 2005; Bahadori, 1978). See Figure 14.

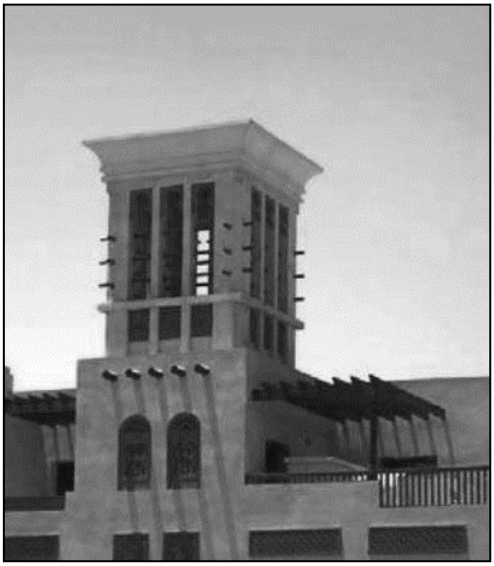


Figure 14. Wind catcher in hot and dry climate regions (Sarihi, 2015).

The mechanism of wind catcher as cooling strategy in summer is; flow of air from upper opining of wind catcher to down inside the building in day time, while air will flow opposite in the night time without wind by stack effect and this promote the ventilation and increase thermal comfort, and as a result reduce energy consumption for cooling in the buildings (Sayigh, 1979). See Figure 15.

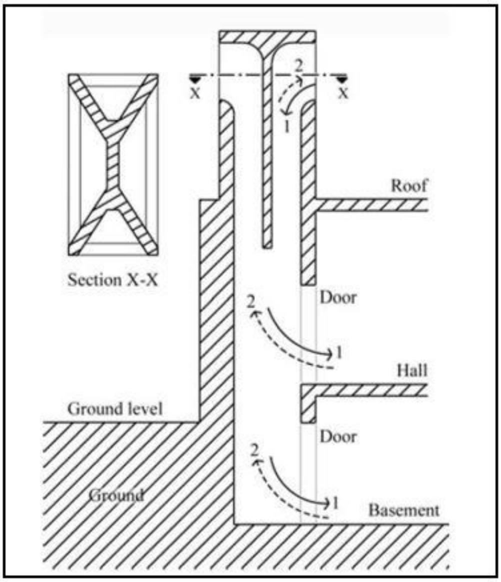


Figure15. Wind catcher mechanism at Day as demonstrated with wind movement as shown by number '1', and Night mechanism of wind movement as shown by number '2'. (Sayigh, 1979).

A solar chimney is another PSD technology used to boost air movement everywhere inside the building by using solar energy to obtain ventilation. The stack effect principle depends on the moving hot air to higher places inside the building and remove them out of the building through high-level windows to be replaced with cooler air from the outer ambient (see section 4.5.6.2 from this chapter). A solar chimney follows the same principle, but in this system, the air is designed to be heated through sun radiation to create an exhausting effect (Ahmad, 2012). A solar chimney basically has two parts: the solar air heater and the chimney, as shown in Figure 16.

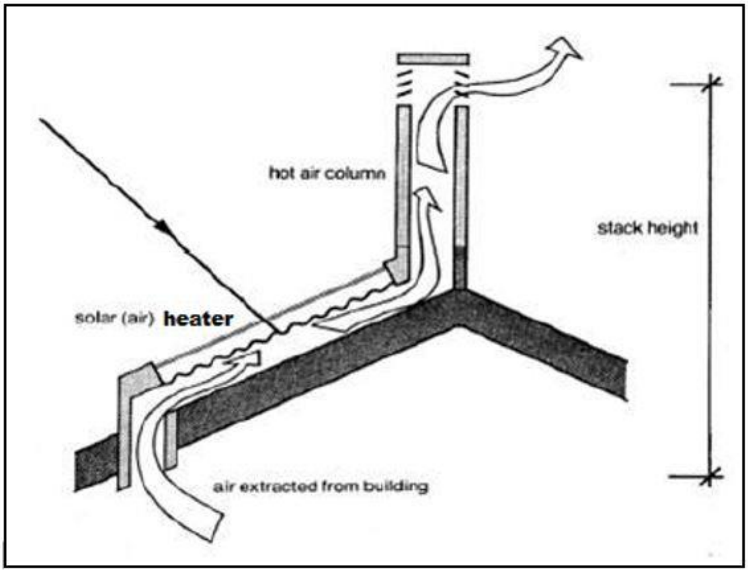


Figure 16. Solar Chimney System Principles. (Baker, 1987, p.126)

The system is designed to gain maximum solar radiation and, through that and based on stack system principles, will promote the ventilation effect. The criteria for the design are the stack height, the cross-sectional area of the chimney, and the difference in temperature between inside and outside of the solar heating system. During the day, air in a solar heater is heated, thereby expanding and rising. Consequently, it starts to withdraw the indoor air and remove it from the building. The advantages of this system are its ability to control itself based on the temperature outside. Where the hotter outside during the day, the hotter the solar air heat, and then the increased air movement occurs (Santamouris, 2009, p.22). The phenomenon of 'Buoyancy' effect takes place because of a difference in the density of indoor and outdoor air as a result of the difference in temperature and moisture. A chimney which, heated by solar energy, could be provided to drive the chimney effect without rising indoor temperature (Ahmad, 2012).

2. Cooling through Evaporation

Evaporation occurs when the vapor pressure of water exceeds the partial vapor pressure of water in the surrounding environment. The efficiency of the evaporative cooling process is influenced by the temperatures of both the water and air, the amount of vapor present in the air, and the rate of airflow over the water's surface. There are two types of evaporation systems: the direct system and the indirect system. In the direct system, moisture cools the air and increases, which leads to a rise in relative humidity in the environment. When dry air is directed onto a wetted surface, the direct evaporation process is initiated. A drawback of this system is the increase in moisture content in the air supplied to indoor spaces. Vernacular architecture has utilized this system, particularly in hot and dry climates. The integration of wind towers has also been employed to lower energy consumption in buildings (Bilgiç, 2003). Wind towers or solar chimneys can be used together with an evaporative tower to create a closed loop as a system by which cool air is provided by the evaporative tower, and warm air is then removed by wind towers as a stack, as shown in Figure 17. This system is successful in a hot and arid climate to improve thermal comfort and decrease energy consumption in the building, through reducing the cooling active system. As much as the air is collecting at high elevation, the greater pressure will be created, and more air flow through the building will be produced (Mahdavinejad and Khazforoosh, 2014).

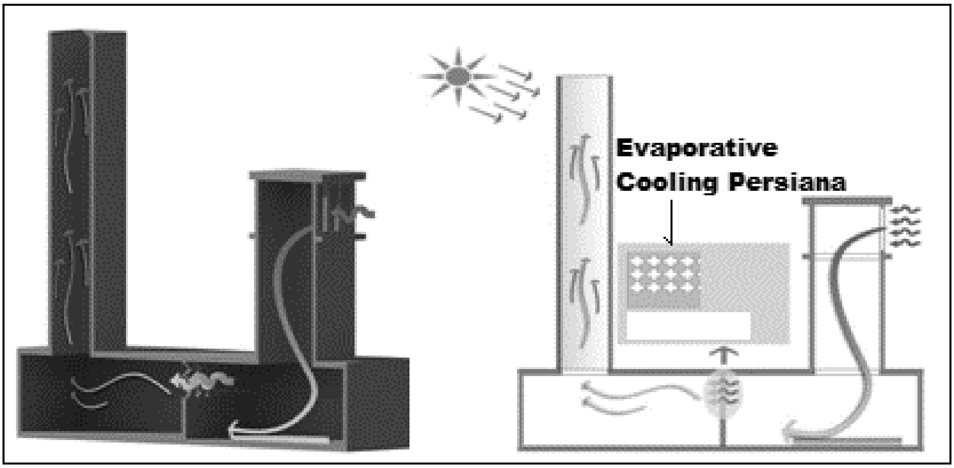


Figure 17. A combination of Evaporative towers and a Windcatcher. (Mahdavinejad and Khazforoosh, 2014)

The second system is Indirect evaporative, where this system tries to evade the problems related to relative humidity levels. The cooled air by evaporation is segregated from the conditioned air of the room, which allows for decreasing the dry-bulb temperature without increasing humidity in the inner air. The heated envelope of the building (exterior walls and roofs), by solar radiation or convection, could be cooled by water spray. While the sprayed water evaporates from the envelope surface, it will cool the surface, thus it is adequate to make the surface moist. (Bilgiç, 2003).

The dwellers were using deep earth insulation in hot-arid areas, for example, they were storing water in 'cisterns' 10-20 m deep in the ground for the summer time. During the cold winter nights were filling them by water, and keeping this water cooled through a natural cooling mechanism, which was supplied through wind towers. The wind tower cistern norm in Iran-Yazd were applied, as seen in Figure 18, it is deep by 12m, and the wind tower is high by almost 12m (Sayigh, 1979).

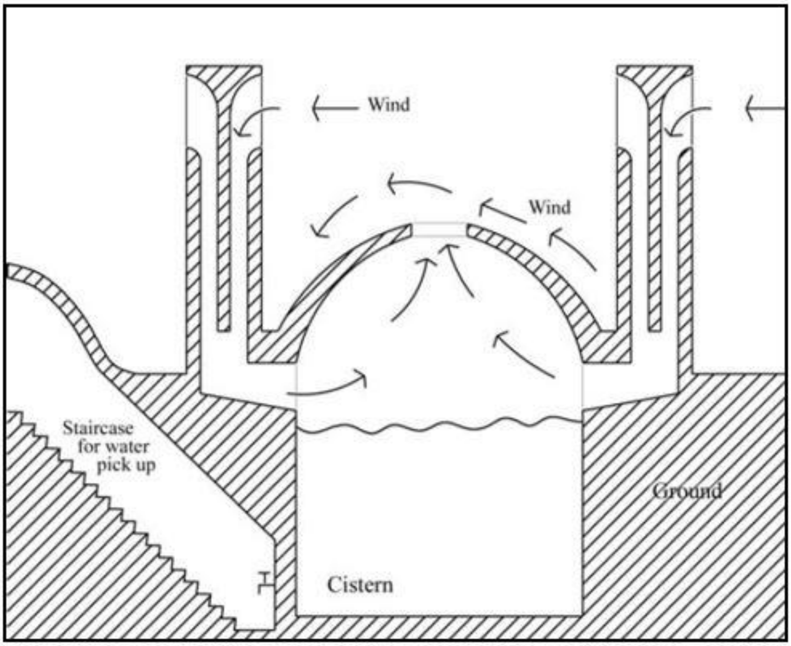


Figure 18. The principle of the Wind towered cistern for cooling the underground water in a hot and arid climate. (Sayigh, 1979).

1.3.2.3.3 Radiative Cooling

Heat transfer occurs from a hotter surface to a cooler surrounding environment. Typically, objects release energy through electromagnetic radiation. When two bodies with different temperatures come into contact, the warmer body will lose heat through net radiation. If the cooler body maintains a constant temperature, the heat from the warmer body will cause it to cool down until it matches the temperature of the cooler body. This effect is the fundamental principle of radiative cooling (Goulding et al., 1992). The term radiative cooling refers to the effective radiation from an exposed horizontal surface to the surrounding air through convective and radiative heat transfer (Gupta, 1984). Courtyards exemplify the benefits of using radiative cooling as a passive strategy.

A courtyard is defined as an area within a building that is enclosed by walls or structures and is open to the sky without a roof (Markus and Morris, 1980). A roof can be designed to enhance the courtyard's cooling cycle. The roof surrounding the courtyard is sloped so that it directs downwards toward the courtyard. When the roof cools at night by radiating absorbed heat into the sky, the air layer above the roof also cools, causing it to flow into the courtyard and displace the warmer air. See Figure 19.

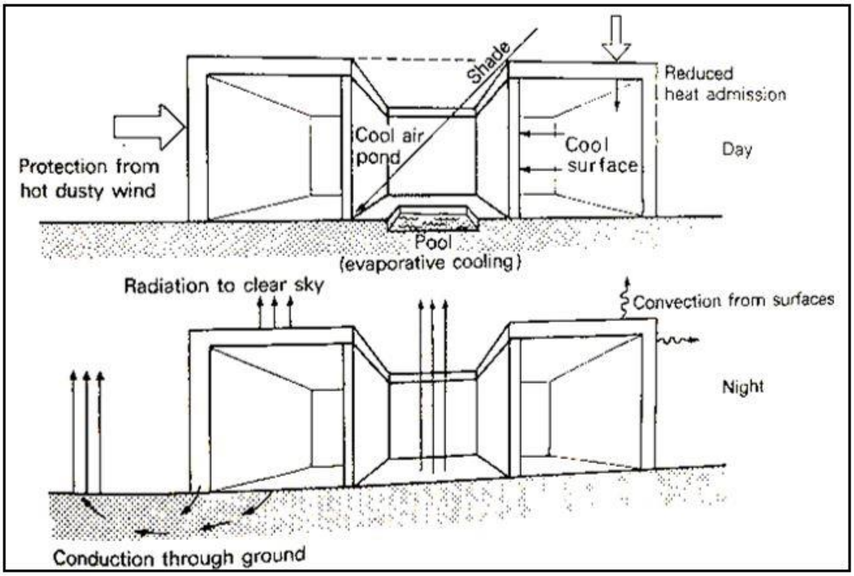


Figure 19. The House Courtyard's concept and thermal process. (Koenigsberger, et al., 2010, 205).

As a result, the courtyard passive strategy plays a big part in hot and dry environment architecture. Numerous successful examples of the researched courtyard design categories may be found in homes in the Middle East, Mesopotamia, and, of course, Baghdad, as well as in northern Africa in Egypt, Tunisia, and Libya (Markus and Morris, 1980). A further illustration of radiative cooling techniques is the "Pond Roof," which lowers the building's energy usage by absorbing morning solar radiation, sinking it in water, and then reradiating it to the sky at night when the outside temperature drops (Brawm and Dekay, 2001).

1.4 Essential Elements of Passive Design Techniques in Hot and Dry Climates

Reducing or even eliminating the requirement for active mechanical systems while preserving or even enhancing occupant comfort is the core goal of passive design solutions (Marler and Cobalt Engineering, 2008). Additionally, to prevent undesired heat gain in the summer and to enhance heat gain and prevent heat loss in the winter (Evan, 2007). Building orientation, building shape, thermal mass, aperture design, shading, and natural ventilation are the essential components of passive methods in dry or semi-arid regions, as will be covered in the sections that follow. See Figure 20.

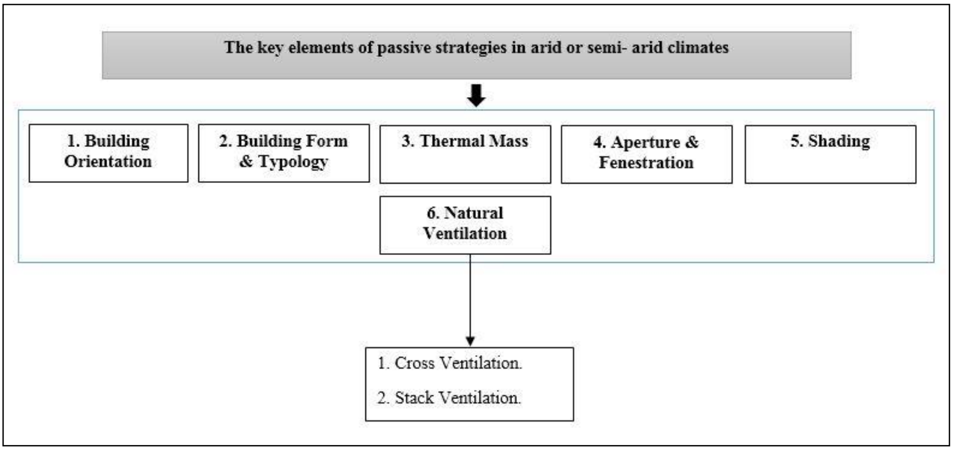


Figure 20. The essential elements of passive tactics in arid and semi-arid environments. (By Author).

Although each of these components operates independently, they work together to improve thermal comfort and save energy usage.

1.4.1 Building Orientation

The building's orientation controls which parts receive direct solar radiation and which may be impacted by wind, and it also impacts the building's capacity to gather solar irradiance (Chiras, 2002). Socrates created the "solar house," which has a roof that lets in winter sunlight while blocking out summer sun on the south facade. According to the exposure to the sun's rays, Vitruvius suggested several orientations (Rowland and Howe, 1999). Generally speaking, buildings with a western orientation receive more sunlight, provide less shade during the hot season, and have warmer temperatures throughout the day. This also applies to structures with a southern front. On the other hand, northern faces would receive less sunlight (Givoni, 1969). The building's orientation has a significant impact on its thermal performance since different building orientations receive different amounts of heat from the sun (Karasu, 2011). Refer to Figure 21.

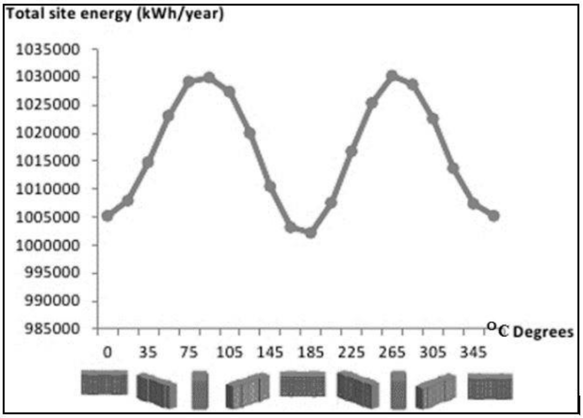
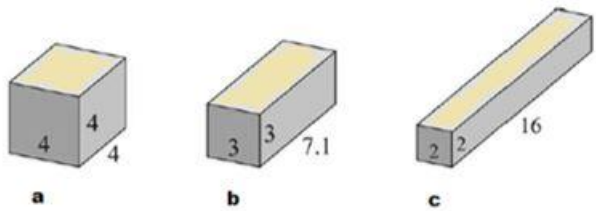


Figure 21. The impact that orientation has on buildings' energy usage. (Tokbolat, et al., 2013).

The building's orientation concerning the incidence of sunlight is crucial in areas where the temperature of the surrounding air has a greater impact on comfort than ventilation. However, orientation has a significant influence on positioning the building according to the main winds in areas where air ventilation is the primary source of comfort. Because the sun only slightly enters via façades and openings in those directions during the warm season, it is preferable to have the principal façades oriented north-south. In contrast, during the winter, when the sun's altitude is low, access to the sun is possible (Rosenlund, 2000).

1.4.2 Building Typology and Form

This issue has played a crucial role in advancing passive design in architecture. An architect who understands environmental considerations in their designs should craft the building's shape by taking into account the interplay between heat losses and gains and the building’s form. The building’s shape and structure impact wind dynamics and airflow patterns, while optimizing natural daylight is a key consideration when choosing a building's design in the context of passive strategies. For instance, in colder regions, the objective is to enhance solar heat gain while minimizing heat loss through the building envelope since heating is necessary. Hence, it is essential to design a compact building shape with strategically placed openings. Conversely, a compact form also helps to reduce unwanted heat gain when cooling is needed (Goulding et al., 1992). Behsh (2002) noted that different geometrical forms with the same space and volume can have varying envelope areas. Typically, this is expressed through the envelope-to-volume ratio. Thus, to achieve a compact form, it is essential to lower the envelope area relative to the building’s volume, which improves thermal comfort and thus reduces energy use. A smaller envelope area per heated volume means less energy is necessary to maintain the building (Markus and Morris, 1980), as illustrated in Figure 22.



Type	Area of Envelope	Volume	Envelope/ Vol. Ratio
a	96	64	1,5
b	103,2	64	1,61
c	136	64	2,13

Figure 22. The relation between envelope area and shape compaction in a building. (Markus and Morris, 1980).

Additionally, according to Ling et al. (2007), the width-to-length (W/L) ratio or the width and length of a geometric form determine the exposed envelope-to-volume ratio. The envelope-to-volume (envelope to volume) ratio is lower in forms of geometry with a high (width-to-length) ratio. He underlined that one of the most important factors in comprehending the relationship between building form and solar insolation levels is the (W/L) ratio.

Arranging rooms in clusters represents one of the passive strategies to minimize the envelope area, leading to a decrease in heat loss and gain within the structure (Muhy Al-Din et al., 2017). Self-shading building designs contribute to lowering energy usage in buildings (Capeluto, 2003). Research has shown that a building's capacity for self-shading largely depends on its structural form. For instance, buildings with (H)-shaped or (L)-shaped configurations can provide self-shading for their surfaces, thereby reducing the amount of direct solar radiation hitting the building's exterior (Lavafpour and Sharples, 2015).

Furthermore, the heat gains through the building's surface correlate with the total area for the outer walls (Lam et al., 2005).

The proportion of the roof to exterior walls greatly affects the thermal efficiency of buildings in specific climates, suggesting that a larger roof-to-external-wall ratio results in enhanced thermal effectiveness and reduced energy use, and vice versa. Hence, low-rise buildings demonstrate better thermal properties than taller buildings with the same (envelope/volume) ratio (Muhaisen and Abed, 2015). Refer to Figure 23.

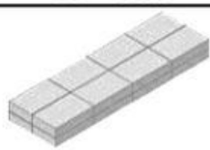
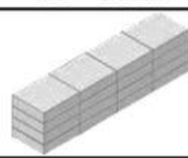
Height	H= 6m	H= 12m	H= 24m
Perspective			
Percentage of increas-ing in the total loads (%)	0	33%	55.5%

Figure 23. The impact of the height of a building on its energy usage. (Muhaisen, and Abed, 2015)

Compact and low-height buildings may be the best option for cold, Mediterranean, and hot-arid regions. The reason for this is that there is less conductive heat exchange between the building and the ambient air. However, in some climates, such as hot-humid climates, where natural ventilation is necessary to provide thermal comfort, longer external envelopes will provide more opportunities for natural light and additional cooling capacity (Hyde, 2000). When compact forms are needed, there are additional helpful ways to improve thermal comfort and energy efficiency, according to PSD ideas. As a thermal buffering technique, thermal zoning is advised. This is accomplished by positioning as many unheated areas as feasible on the north side. Locations with lower temperature requirements, such as stairwells and hallways, as well as garages, service areas, and retail establishments, are most suited for indirect solar areas (Chand and Krishak, 1971).

1.4.3 Thermal Mass

Thermal mass refers to the capacity of a building's envelope to retain thermal energy for heating and cooling (Der Aa, et al., 2011). Essentially, it defines a material's ability to store heat. This concept in architectural design illustrates how the mass of a building provides "inertia" in response to temperature shifts, often called the "heat flywheel" effect. Thermal mass plays a crucial role in climates where temperature varies significantly between day and night or across seasons, like desert environments. When outside temperatures fluctuate throughout the day, a sizable thermal mass within a home's thermal mass component might help reduce daily temperature swings. This happens because the thermal mass releases heat when the outside temperature drops and absorbs heat when the outside temperature rises (Szokolay, 2004). Using thermal mass enables the structure, especially the roofs and external walls, to absorb a large portion of the heat gain in buildings during hot weather (Meir, 2000). As shown in Figure 24, using thermal mass can delay heat transfer through the building envelope by almost 10 to 12 hours, making the house warmer at night in the winter and cooler during the day in the summer. This helps to prevent excessive temperature increases and overheating within the indoor space. Although thermal mass doesn't prevent heat flow from entering or exiting occupied spaces in the same way insulation does, it can slow down the heat transfer, thereby contributing to occupant comfort rather than causing discomfort (Moore, 2013).

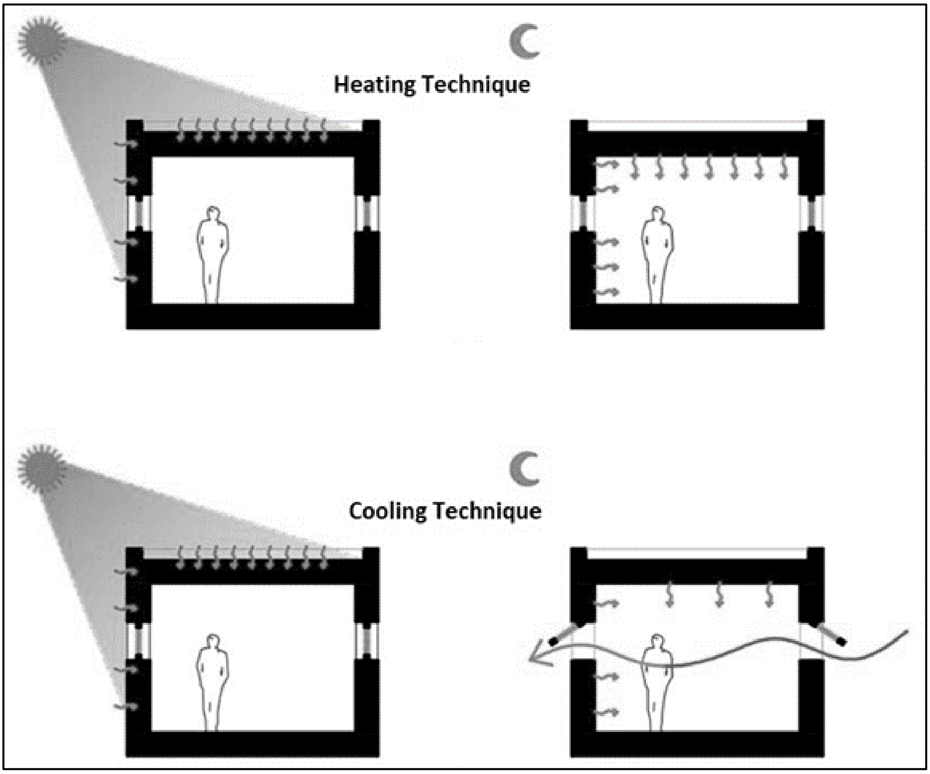


Figure 24. Thermal mass- Heat control techniques during summer and in winter (Toroxel and Silva, 2024).

The quantity and positioning of thermal mass around a building play a crucial role influenced by the climate and environment, as well as the building's orientation and the desired time lag. Typically, the southern and western facades require a significant time lag, often necessitating at least an 8-hour delay to slow down heat transfer from the warmer periods of morning and afternoon to the cooler evening hours, which in turn demands a larger mass. In contrast, the northern and eastern facades generally have little need for a time lag (Rinaldi, 2009).

Implementing a thermal mass strategy presents a significant opportunity for energy conservation, which is essential for enhancing the thermal performance of buildings and boosting energy efficiency by lowering energy consumption. This not only elevates living standards but also benefits the environment by decreasing the reliance on fossil fuels. In buildings with high thermal mass that are shaded, indoor energy usage can be reduced by 35-45% when the buildings are not ventilated (Givoni and Reinhold, 1994). The implementation of large thermal mass as a method of a passive technique has been extensively studied and validated. It is recognized as a traditional and suitable approach for hot and arid climates. The thermal mass strategy has proven effective in lowering energy consumption for both naturally ventilated and conditioned buildings across various climates and building types (Szockolay, 1996).

1.4.3.1 Connections between insulation and thermal mass

Insulation can effectively manage the process of heat transfer between a building's interior and the exterior environment. It plays a crucial role in minimizing heat gain during the summer and heat loss in the winter. This contributes to maintaining indoor thermal comfort and subsequently reduces the energy needed for heating/ cooling. Insulation is efficient in lowering heat exchange within buildings. When there is a temperature difference between the outside and inside, installing insulation on a building's exterior greatly reduces the amount of heat entering or leaving the structure. Insulation helps to regulate the internal mean radiant temperature (MRT) by separating the internal surfaces from the effects of external conditions and also mitigates drafts caused by temperature differences between the building envelope and the air. Insulation is essential when a building requires active heating or cooling, as it lowers the internal conditioning loads, consequently reducing energy use (Kamal, 2012).

Two key elements in insulation are its location and thickness. In warm climates, insulation is placed on the exterior of the wall or roof so that the building's thermal mass does not significantly interact with the outdoor environment and closely aligns with the indoor environment. Utilizing vermiculite concrete insulation for the roof and 4 cm of expanded polystyrene insulation for the outside walls can lead to approximately a 15% reduction in a building's energy consumption (Majumdar, 2001). Another effective insulation method is incorporating air cavities within walls or an attic space within the roof, which also leads to decreased energy consumption. Heat is transferred by convection and radiation through the air cavity; hence, ventilating this space enhances thermal performance. The primary principle for effective thermal mass is to determine the location of the insulated exterior of the building. A masonry wall with external insulation is thermally efficient and beneficial during both heating and cooling periods. In warmer months, it can absorb solar heat during the day and release it at night. Conversely, in the colder months, it can absorb heat from indoor sources when occupied and re-emit that heat within the space at night (Szokolay, 2004, pp. 61-73). When a brick wall's inside is insulated, it becomes thermally isolated from both indirect and direct heat gain entering through windows. Thus, its mass is relatively ineffective in regulating indoor temperatures. Uninsulated masonry walls lack thermal activity, allowing summer heat to penetrate the building, especially in walls facing east and west, while enabling internal heat to escape outdoors in winter, and affecting thermal lag based on masonry thickness. When heating is required, integral insulation (insulation embedded within the wall) yields greater savings in heating load compared to the other wall types, whereas for cooling needs, it outperforms interior insulation in terms of thermal control (Byrne and Ritschard, 1985), as illustrated in Figure 25. In traditional architecture in hot-arid climates, this inactivity is mitigated by the use of thick walls, often ranging from 60 to 90 cm, to counteract the diurnal heat transfer (Kamal, 2014).

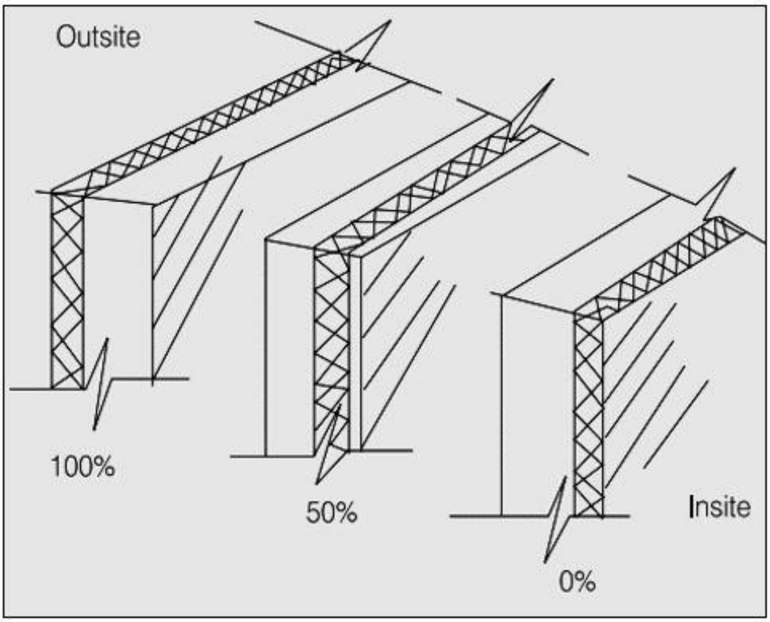
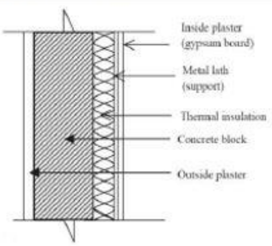
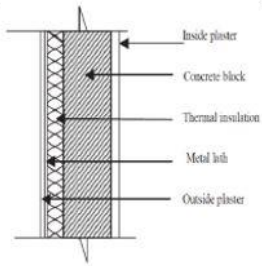
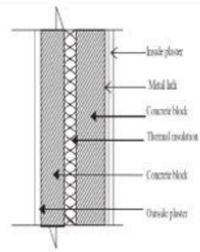


Figure 25. Effectiveness of Thermal Mass by Percentage as Insulation Moves from Exterior to Interior. (Kamal, 2014)

In hot regions, placing insulation on the exterior is more efficient compared to other methods, while in colder regions, having insulation integrated within the walls proves to be more effective. In this regard, Al-Homoud (2005) has examined the impact of insulation material placement within walls, as illustrated in Table 1.

Table 1. Properties of insulation material positions in walls. (Al-Homoud, 2005).

Insulation placement toward inside	Insulation placement toward outside	Insulation placement in the middle
- Protected by mass against outside environment and damage. The structure will be closer to the outdoor temperature. - Expansion and contraction becomes more important. - More thermal-bridges due to the unavoidable crossings and penetrations. Therefore, all joints and penetrations should be tightly sealed. - Minimized potential heating benefits from the mass of the building structure.	-Support for summer convective cooling and winter passive-solar heating. - Allows mass to store internal gains and excess solar. However, less durability due to the exposure to damage effects and outside environmental.	- Provides even distribution of the insulation in the component.
		

1.4.4 Aperture and window system

The style of aperture or fenestration is a crucial technique in passive design, as it plays a key role in the heat gain of large buildings. The shape, properties, and location of apertures are vital in managing heat gain and loss within a structure. The proportion of the opening area relative to the floor area varies based on the building's site location and the surrounding topography. For instance, walls oriented to the south in mountainous regions may require an opening percentage of nearly 40%, while coastal areas necessitate 24%, and inland areas need only 18% (Lapithis, 2002). Additionally, vertical surfaces for southern-facing windows can impede sun irradiance from entering the building during warmer months, unlike sloped surfaces, particularly when combined with overhangs. In winter, the sun's low altitude enables irradiance to directly enter the interior space of buildings through south-facing windows (Muhy Al-din, et al., 2017), as illustrated in Figure 26.

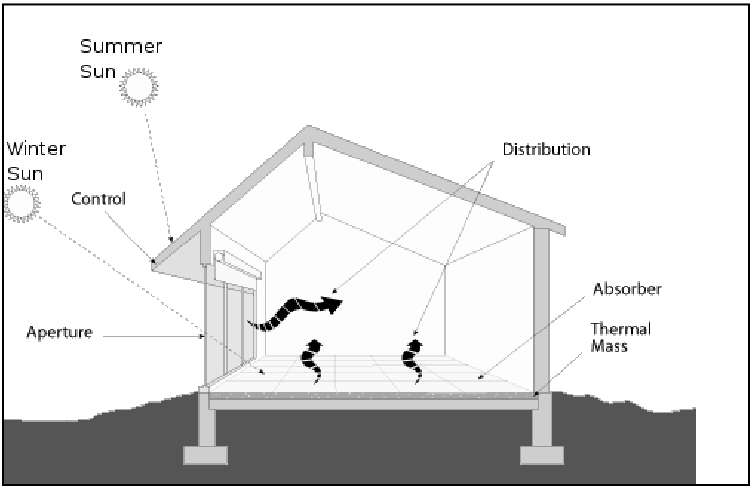


Figure 26. Windows regulate the amount of sunlight entering the building during the summer and winter. (U.S. Department of Energy, 2001).

The window-to-wall ratio (WWR) refers to the proportion of the window area compared to the total area of the external walls. Research has shown that solar gains are higher with an increased WWR. It has also been noted that the ideal WWR for maximizing daylighting is 25%, and any additional increase in window size will lead to heightened gains of heat (Zain-Ahmed et al., 2002). Guidelines for WWR in buildings located in Saudi Arabia, which experiences a hot and arid climate, have been established by Al-Shaalan et al. (2014) for various types of glazing, factoring in U-value and SHGC (solar heat gain coefficient), as outlined in Table 2.

Table 2. The regulations of WWR concerning the positioning of structures in a hot and dry climate. (Al-Shaalan et al., 2014).

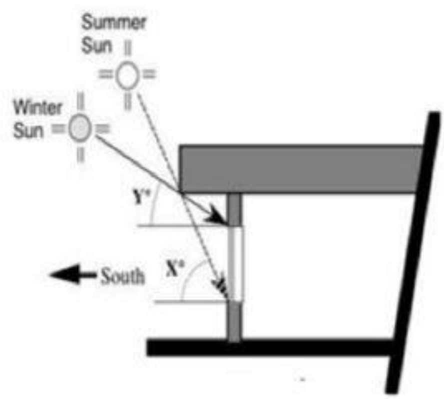
Glazing Type	U-value [W/m K]	SHGC	Window to Wall Ratio [%]			
			East	West	South	North
6 mm, single, clear	6.08	0.710	< 5	< 3	< 4	< 5
6 mm, single, reflective	6.42	0.342	7	6	8	9
6 mm, double, tinted	3.43	0.370	12	10	9	13
6 mm double, reflective	3.35	0.241	20	17	22	18

The wall window ratio (WWR) is a metric that is frequently used to represent the glazing area in a construction, according to ANSI/ASHRAE (2013). A high WWR indicates that a substantial proportion of the building's outer walls are made of glass as opposed to solid materials like concrete, brick, or wood. The areas of the external wall's opaque and transparent sections are almost equal when the WWR is 50%. ASHRAE/IES (2013) states that a building's ideal WWR is 24 percent. When assessing the design requirements for buildings in the study region, this value will be taken into consideration.

1.4.5 Shading

Sun control and shading mechanisms should be developed in accordance with the climatic and geographic context of the structure. The effectiveness of shading devices is influenced by the orientation and positioning of the building's facade. These devices can be integrated into the building as part of its architecture, such as elements and surface textures, or they can be installed as separate features on the building's surfaces. Implementing shading can substantially reduce a building's energy consumption by lessening the heat gain and cooling requirements during the summer, while also enhancing the quality of natural light within the interior space. A straightforward overhang, for instance, is particularly efficient in shading south-facing windows during the summer months when the sun is at a higher altitude (Brawm and Dekay, 2001).

Ossen and Madros (2005) have assessed how horizontal shading devices can minimize excessive solar heat gain and energy consumption in buildings, effectively reducing around 80% of incoming direct solar radiation through windows. The dimensions of the shading device are influenced by various factors, including the orientation, height, and width of the opening, as well as the vertical and shadow angles in relation to the geographical latitude of the location. Refer to Figure 27.



Angles to correctly size overhangs for shading

Latitude	X°	Y°	Latitude	X°	Y°
24	74.0	46.0	35	62.5	34.5
25	73.0	45.0	36	60.5	32.5
26	72.0	44.0	37	59.5	31.5
27	71.0	43.0	38	59.0	31.0
28	70.0	42.0	39	58.5	30.5
29	69.0	41.0	40	58.0	30.0
30	68.0	40.0	41	57.0	29.0
31	67.0	39.0	42	56.0	28.0
32	65.5	37.5	43	55.0	27.0
33	64.5	36.5	44	54.0	26.0
34	63.5	35.5	45	53.0	25.0

Figure 27. Fundamental horizontal shading approach for the south-facing side of buildings. (Morad, 2014)

According to Jorge et al. (1993), the design of overhangs is primarily determined by three key parameters: the width, depth, and angle of the overhang. Following this idea, Ossen et al. (2005) conducted a study that explored the relationship between the depth of a horizontal overhang and the height of fenestration, expressed through the Overhang Ratio (OHR), which is defined as the ratio of the horizontal shading depth (D) to the height of the fenestration (H). The findings of the study resulted in several proportional outcomes, as illustrated in Table 3.

Table 3. The relationship between horizontal shading (overhang) depth and fenestration height. (Ossen et al., 2005).

OHR = D/ H	Overhang Depth	
	In Meters	In Feet
0 (Base Case)	0	0
0.4	0.73	2.4
0.6	1.09	3.6
0.8	1.46	4.8
1	1.82	6
1.4	2.55	8.4
1.6	2.92	9.6

Shading plays a significant role in cooling buildings, among other techniques for solar passive cooling. When solar shading methods are implemented, a reduction of approximately 6°C in indoor temperature has been observed (Bansal et al., 1994). The application of solar shading strategies leads to a nearly 2.5°C to 4.5°C decrease in indoor temperature when utilizing solar passive cooling techniques. Therefore, solar shading is recommended as a highly effective cooling approach for creating a passive cooling system to lower air temperatures in enclosed spaces compared to conventional buildings without shading (Kumar et al., 2005). Shading from trees can reduce the external temperature near the building's walls by 2°C to 3.5°C (Potcher et al., 2006). Various types of plants, including trees, shrubs, and pergolas, can be utilized based on their shading capabilities to achieve the necessary shading for different window orientations and positions. Deciduous trees provide shade during the summer while permitting sunlight in during the winter. The southern and western sides are ideal for these trees, as they lose their leaves in winter, allowing sunlight to warm the interior spaces. In contrast, evergreen trees, when placed on the southern and western sides, offer optimal protection from the afternoon summer sun and chilly winter winds. Canopy trees with branching limbs can effectively shade the roof, walls, and windows (Kamal, 2003). See Figure 28.

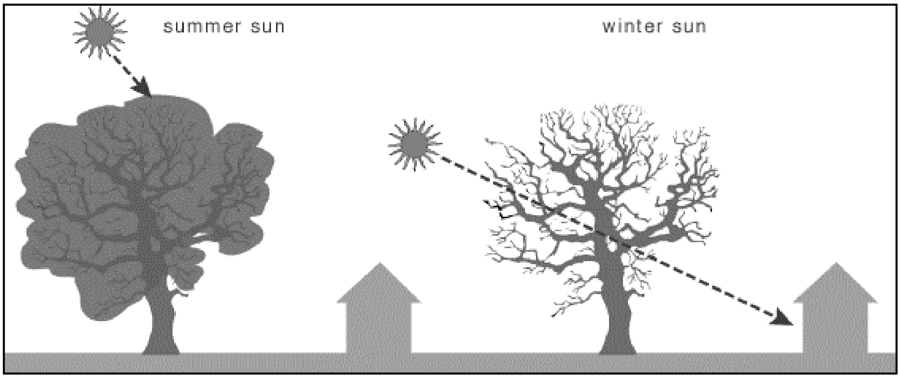


Figure 28. Deciduous trees provide shade during the summer while permitting sunlight to reach buildings in the winter, serving as a PSD technique for structures (Savvides, 2015).

Providing shade for the roof is an essential method to reduce the building's heat accumulation. This can be achieved by installing a covering made of concrete, canvas, clay pots, or various plants. Shading should come from external sources and must not interfere with nighttime cooling. Utilizing deciduous trees and climbing plants as coverage proves to be an effective strategy. The evaporation occurring from the leaf surfaces helps lower the temperature around the ceiling area while also shielding the roof from sunlight during the day. At night, the temperature of these plants is generally cooler than the ambient sky temperature. A protective layer of galvanized iron sheets, aluminum, or concrete can shield the roof from direct solar radiation. However, this approach has the drawback of hindering heat release to the sky at night (Kamal, 2012). See Figure 29.

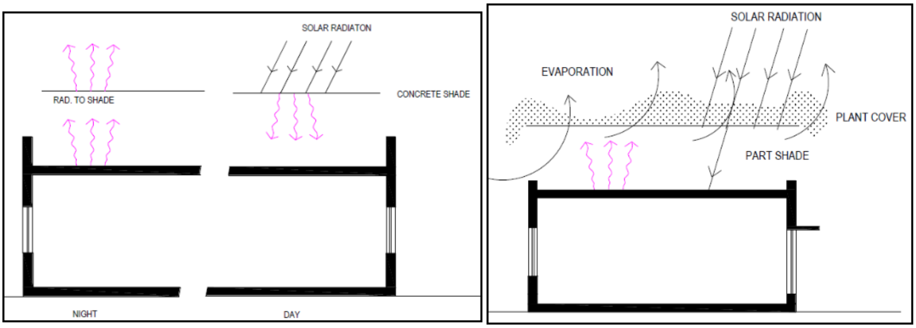


Figure 29. Roof shading using concrete or metal and the issue of heat retention at night (Left), alongside plant coverings for roof shading (Right). (Kamal, 2012)

An affordable and efficient solution is a removable canvas cover that fits over the roof. It prevents the sun's rays and heat from entering during the day, while at night, it can be taken off to allow for radiative cooling (Gupta, 1984).

1.4.6 Natural Ventilation

Natural ventilation refers to the process of bringing in and expelling air within a building using natural methods. As a PSD approach, natural ventilation is one of the most affordable cooling strategies that helps reduce the building's cooling demand and enhances the thermal comfort of its occupants. Airflow occurs due to pressure differences between the building's interior and exterior, which arise from variations in air temperature and wind movement (De Gids and Phaff, 1982).

The effectiveness of natural ventilation is influenced by the characteristics of the local climate (Ramponi et al., 2014). In passive solar cooling through ventilation, strategically positioning openings (fenestration) in the building's surfaces facilitates improved air circulation within the spaces. Proper placement of air inlets and outlets within rooms is crucial to achieving adequate airflow. Natural ventilation exploits the available resources of wind, solar radiation, and thermal energy. Although these natural resources are cost-free, they can be challenging to control; therefore, developing an effective control system is key to improving indoor air quality (Linden, 1999, p. 12). The primary objectives of ventilation encompass the occupants' thermal comfort, energy efficiency, and indoor air quality. Providing suitable thermal conditions by ensuring effective airflow and removing excess heat produced inside the spaces makes ventilation a critical component in enhancing air quality by eliminating contaminants generated by inhabitants. For many years, architects and designers have utilized natural ventilation to fulfil two essential functions in buildings: to expel polluted air and moisture and to enhance thermal comfort for occupants (Goulding et al., 1992; Aynsley, 2007).

Generally, natural ventilation can be classified into two main categories, differentiated by three distinct concepts: single-sided ventilation, cross-ventilation, and stack ventilation. The ventilation concept indicates the significance of the external and internal wind streams, and therefore how the natural driving forces contribute to the building's ventilation. Moreover, this concept provides insight into how air enters and exits the building. Air infiltration through the building's envelope also plays a vital role. However, during hot months when outdoor temperatures exceed 35°C, ventilation can become less effective. Likewise, in cold months when outdoor temperatures fall below 15°C, this method can result in heat loss (Raja et al., 2001).

1.4.6.1 Cross-Ventilation

Cross-ventilation is a natural ventilation technique that involves air flowing through two sides of a building's outer walls, aided by the pressure differences created by the wind on each side. Air enters the building from the side facing the wind and exits from the opposite side (Raja, et al., 2001). Refer to Figure 30.

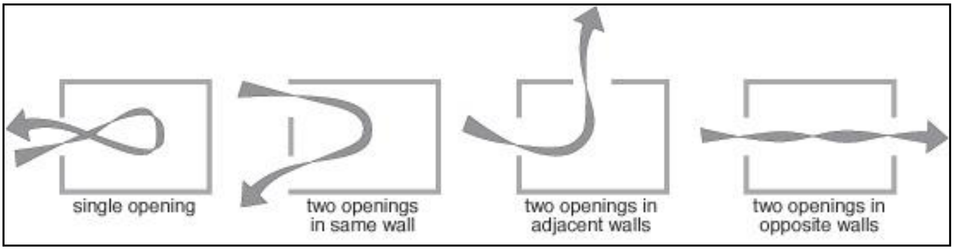


Figure 30. Types of openings in the external walls of a building for facilitating cross-ventilation. (Brown and Dekay, 2001).

Brawm and Dekay (2001) indicate that the quantity, dimensions, and positioning of openings greatly influence air flow. Table '4' below illustrates the connection between the number and placement of openings and the air velocity as a proportion of the external wind speed.

Table 4. Illustrate the location, dimensions, and quantity of openings influence air circulation in enclosed areas. (Brown and Dekay, 2001).

opening height as a fraction of wall height	1/3		
opening width as a fraction of wall width	**1/3**	**2/3**	**3/3**
single opening	12-14%	13-17%	16-23%
two openings in same wall	—	22%	23%
two openings in adjacent walls	37-45%	37-45%	40-51%
two openings in opposite walls	35-42%	37-51%	47-65%

range = wind 45° perpendicular to opening

For ventilation on one side of the room, the primary driving force during summer is the wind disturbance. When the ventilation openings are positioned at different heights on the façade, the ventilation rate can be enhanced by the buoyancy effect. The level of thermal comfort within the building is influenced by the temperature difference between the interior and exterior environments, the size of the openings, and the vertical spacing between them. The vertical spacing of the openings and the greater temperature contrast between inside and outside are key factors influencing comfort performance. In single-sided ventilation, the airflow rate is lower than in other forms of cross ventilation, and the circulated air does not fully reach every area of the room (Brawn & Dekay, 2001).

In a double-opening scenario, the openings can be situated on the same side, adjacent side, or opposite side. The airflow through openings on the same side is typically less effective than if the openings were positioned on adjacent sides, with the most efficient ventilation occurring when openings are located on opposite sides. Air enters from the side facing the wind and exits from the side shielded from the wind, as previously described. Airflow can traverse multiple rooms through open doors or gaps. As air enters the living space, it removes heat and pollutants; thus, certain criteria should be considered to monitor and control the limitations regarding the depth of the inner space to facilitate efficient cross ventilation (Bilgiç, 2003).

1.4.6.2 Stack Ventilation

Another type of natural ventilation is stack ventilation, which takes place when the lighter air exits the building, allowing fresh air to enter through lower-level ventilation openings. One of the key advantages of this method is that it does not rely on the building's orientation. Typically, fresh air is drawn into the building through openings positioned lower down, while stale and contaminated air exits through openings that are higher up. By aligning the outlet with the wind pressure direction, the effectiveness of stack ventilation can be enhanced (Calcerano and Cecchini, 2014). The height difference between the upper outlet openings and the lower fresh air intakes is vital for the efficiency of stack ventilation. When wind pressure is low or nonexistent, stack-effect ventilation encourages air circulation within the building, contributing to improved thermal comfort and energy efficiency. The primary force driving stack ventilation is generally thermal buoyancy (Edwards, 2000). See Figure 31.

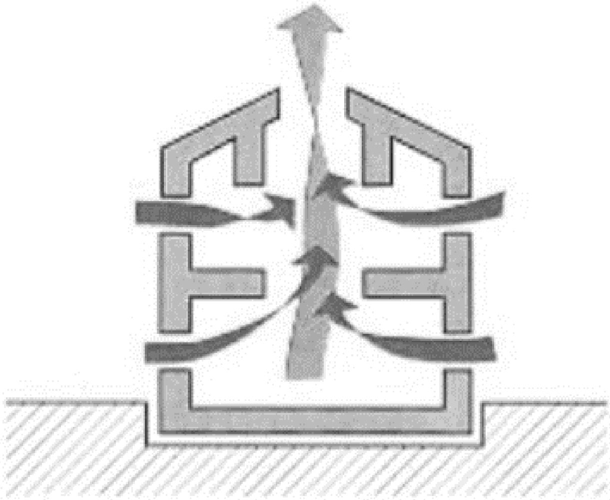


Figure 31. The stack ventilation principle involves the expulsion of warm, lighter air and the influx of fresh air. (Aflaki et al., 2014)

1.5 Summary

This chapter has provided a full overview of PSD, including its historical evolution, key ideas, and practical applications in building, with a focus on extreme climates, especially hot and dry geographical regions. It investigates how the heat flow mechanisms of radiation, convection, and conduction are integrated into building design using tactics such as orientation, form, thermal mass, aperture design, shading, and natural ventilation to improve thermal comfort while reducing energy consumption. A coherent framework for meeting various climatic needs is provided by the division of passive solar systems into two categories: cooling (solar protection, heat gain management, and heat dissipation) and heating (direct, indirect, and isolated gain). Compact shapes, light-coloured surfaces, and efficient shading reduce solar heat intake in hot, dry climates, whereas high thermal mass and south-facing apertures increase warmth in cold climes. Site-specific, energy-efficient solutions are further informed by microclimatic elements like vegetation and topography.

This chapter is distinctive because it skilfully combines modern and conventional passive solar techniques to produce a flexible, climate-responsive design methodology. By combining traditional knowledge with contemporary developments, it emphasizes how these methods may be applied in a variety of climates, utilizing regional resources and cutting-edge materials to lessen dependency on fossil fuels. This all-encompassing viewpoint enhances architectural practice and motivates researchers, architects, and students to create creative, sustainable designs. The chapter promotes solutions that strike a balance between thermal comfort, energy efficiency, and ecological stewardship across a range of climatic conditions, positioning PSD as a turning point in environmentally conscious building.

To enhance thermal performance in hot, dry, and cold environments, future studies on PSD should explore novel materials, including phase-change materials and adaptive envelopes. Efficiency can be increased by researching hybrid passive-active systems, including ventilation powered by solar energy. To evaluate the longevity of systems like Trombe barriers, longitudinal studies are necessary. Applications at the urban scale that combine green infrastructure and passive design are worth investigating. It is crucial to look into resilience to changes in solar patterns and temperature brought on by climate change. Lastly, incorporating smart technologies, such as Internet of Things (IoT) sensors, can improve energy efficiency and user control, which is consistent with the chapter's innovative fusion of conventional and contemporary methods for sustainable construction.

REFERENCES

Aflaki, A., Mahyuddin, N., Mahmoud Awad, Z. A. C., and Baharum, M. R. (2014). Relevant indoorventilation by windows and apertures in tropicalclimate: A review study. E3S Web of Confe-rences, 3. https://doi.org/10.1051/e3sconf/20140301025

Ahmed, M. A. D. (2012). Natural Ventilation Techniques as a Base for Environmental Passive Architecture: With Special Reference to Residential Buildings in Greater Cairo. Master Thesis, Ain Shams University, Cairo. Egypt. Ain Shams University.

Al-Homoud, M. (2005). Performance characteristics and practical applications of common building thermal insulation materials. Building and Environment, 40(3), 353–366.https://doi.org/10.1016/j.buildenv.2004.05.013

Al-Shaalan, A., Ahmed, W., & Alohaly, A. (2014). Design guidelines for buildings in Saudi Arabia considering energy conservation requirements. *InApplied Mechanics and Materials*, *548*, 1601-1606. https://doi.org/10.4028/www.scientific.net/AMM.548-549.1601

ANSI/ASHRAE Standard 55. (2013). Thermal Environmental Conditions for Human Occupancy. Retrieved from. https://www.ashrae.org/File%20Library/Technical%20Resources/Standards%20and%20Guidelines/Standards%20Addenda/ad55_2004_-h.pdf

ASHRAE/ IES (2013). *Energy Standard for Buildings Except Low-Rise Residential Buildings*. Las Vegas, NV, USA: American Society of Heating, Refrigerating and Air-conditioning Engineers.

Aynsley, R. (2007). Natural Ventilation in Passive Design. The BEDP Environment Design Guide. Royal Australian Institute of Architects, 2, 1-11.

Bahadori, M.N. (1978). Passive cooling systems in Iranian architecture. Scientific American 238:2(2), 144-145. https://doi.org/10.1038/scientificamerican0278-144

Baker, N. V. (1987). Passive and Low Energy Building Design for Tropical Island Climates. London, UK: The Commonwealth Secretariat

Bansal, N. K., Hauser G. and Minke G. (1994). *Passive Building Design – A Handbook of Natural Climatic Control*. Amsterdam, Netherlands: Elsevier Science B.V.

Behsh, B. (2002, June 17 - 19). Building Form as an Option for Enhance the Indoor Thermal Conditions. In Building Physics 6th Nordic Symposium. *Indoor Environment, 2*, 759-766.

Ben Othman, A., Belkilani, K., Besbes, M. (2018). Global solar radiation on tilted surfaces in Tunisia: Measurement, estimation and gained energy assessments. *Energy Reports, 4*, 101-109. https://doi.org/10.1016/j.egyr.2017.10.003

Bhamare, D.K., Rathod, M.K., and Banerjee, J. (2019). Passive cooling techniques for building and their applicability in different climatic zones—The state of art. *Energy & Buildings 198*, 467–490. https://doi.org/10.1016/j.enbuild.2019.06.023

Bilgiç, S. (2003). *Passive Solar Design Strategies for Buildings: A Case Study on Improvement of an Existing Residential Building's Thermal Performance by Passive Solar Design Tools*. Master Thesis, İzmir Institute of Technology, İzmir. Turkey: İzmir Institute of Technology.

Birkeland, J. (2008). *Positive development: from vicious circle stovirtuous cycles through built environment design*. University of Auckland, UK: Earthscan.

Bisoniya, T.S., Kumar, A., Baredar, P. (2013). Experimental and analytical studies of earth–air heat exchanger (EAHE) systems in India: a review. *Renew Sustain Energy Rev., 19*, 238–246.https://doi.org/10.1016/j.rser.2012.11.023

Brawm, G.Z. & Dekay, M. (2001). *Sun, Wind & Light- Architectural Design Strategies. (*2nd edition). United States of America: John Wiley & Sons.

Burt, S. (2022). Measurements of natural airflow within a Stevenson screen and influence on air temperature and humidity records. *Geoscientific Instrumentation, Methods and Data Systems, 11* (2), 263-277. https://doi.org/10.5194/gi-11-263-2022

Byrne, S. J. and Ritschard, R. L. (1985 Dec., 2nd -5th). A Parametric Analysis of Thermal Mass in Residential Buildings, presented at ASHRAE/DOE/BTECC Conference: Thermal Performance of the Exterior Envelopes of Buildings III, (1225–1240), Clearwater Beach. Florida, USA.

Calcerano, F., Cecchini, C. (2014). *Mediterranean Buildings Refurbishment: Thermal Mass and Natural Ventilation Simulated Control*. Paper presented at Fifth German-Austrian IBPSA Conference: BauSIM 2014, Aachen. Germany: RWTH Aachen University

Capeluto, G. (2003). Energy performance of the self-shading building envelope, *Energy and Buildings, 35*, 327-336. https://doi.org/10.1016/S0378-7788(02)00105-6

Carpenter, P. (1994). *Sod It: An Introduction to Earth Sheltered Development in England and Wales*. Coventry, UK: Coventry University Press.

Carter, C. and Villiers, J. (1987). *Principles of Passive Solar Building Design: With Microcomputer Programs*. New York, USA: Pergamon Press.

Chand, I., and Krishak, N.V.L. (1971). Studies of Air Motion in a Room Having a Door Opening into a Lounge. *Civil Engineering Construction and Public Work Journal*.

Chiras, D. (2002). *The Solar House: Passive Heating and Cooling*. Vermont, USA: Chelsea Green Publishing Company.

Cofaigh, E. O. Olley, J. A. Lewis, J. O. (1996). *The Climatic Dwelling: An Introduction to Climate Responsive Residential Architecture*. London, UK: James&James (Science Publishers) Ltd.

Cook, J., and Santos, M. (2000). *Passive Cooling*. Cook, J. (ed.). Massachusetts, United States: MIT Press

Cook, J. (1983). ROCK BED DESIGN AND CONSTRUCTION FOR HEATING AND COOLING. In S. Yannas (Ed.), *Passive and Low Energy Architecture* (pp. 361-370). Pergamon, https://doi.org/10.1016/B978-0-08-030581-3.50048-7

Cunliffe, D.W., and Muncey, R.W. (1965). Thermal inertia effects on building air conditioning loads. Australian Refrig. Air- cond. And Heating, 18-28.

Der Aa, A. V., Heiselberg, P., Perino, M. (2011). Designing With Responsive Building Components. Denmark: Aalborg University Publication.

De Gids, W, Phaff, H. (1982). *Ventilation rates and energy consumption due to open windows*. Brief Overv Res Neth. Presented at (The 3rd IEA Air Infiltration Center Conference, vol. 1, (4-5).

DeKorne, C. (2019). Heat Transfer Through Buildings: An introduction to some building-science basics. *The Journal of Light Construction*. Access from, https://www.jlconline.com/training-the-trades/heat-transfer-through-buildings_o

Du, Y., and Zhu, Z. (2023). Research on the Form of Energy-saving Building under the Influence of Natural Ventilation Technology. Journal of Physics: Conference Series, 2468(1), Article 012163. https://doi.org/10.1088/1742-6596/2468/1/012163

Edwards, C, (2000). *Design rules of thumb for naturally ventilated office buildings in Canada*. Master thesis, University of British Colombia, Canada.

Evans, J. M. (2007). *The Comfort Triangles: A new tool for bioclimatic design.* Ph. D. Thesis, University of Buenos Aires. Argentina.

George, C., and Kimba, J. (2010). Earth-tubes for Building Heating and Cooling in Drylands. *Annals of Arid Zone 49*(3&4), 285-301.

Givoni, B. (1998). *Climate Considerations in Building and Urban Design*. New York, USA: Van Nostrand Reinhold.

Givoni, B., and Reinhold, V.N. (1994). *Passive and Low Energy Cooling of Building*. United State of America: John Wiley & Sons, INC.

Givoni, B. (1969). *Man, Climate and Architecture*. London, UK: Elsevier Science Ltd.

Goulding, J. R., Lewis, J. O., Steemers, T. C., and Commission of the European Communities. Directorate-General for Science, Research, and Development. (1992). Energy in architecture: The European passive solar handbook (Rev. Ed). London, UK: B.T. Batsford for the Commission of the European Communities, Directorate General XII for Science, Research and Development.

Graiz, E., and Al-Azhari, W.W. (2019). Energy Efficient Glass: A Way to Reduce Energy Consumption in Office Buildings in Amman. IEEE Access, 7, 61218-61225. https://doi.org/10.1109/ACCESS.2018.2884991

Gu, Z. (2007). *Approaches to Energy Efficient Building Development – Studying under Chinese Contexts*. Thesis, Royal Institute of Technology. Stockholm, Sweden: Universitetsservice US AB

Gupta V. A. (1984). *Study of Natural Cooling Systems of Jaisalmer*. Ph.D. Thesis, Indian Institute of Technology. New Delhi, India.

Han, J., Zhang, G., Zhang, Q., Zhang, J., Liu, J., Tian, L., Zheng, C., Hao, J., Lin, J., Liu, Y. and Moschandreas, D.J. (2007). Field study on occupants' thermal comfort and residential thermal environment in a hot-humid climate of China. *Building and Environment, 42*, 4043-4050. https://doi.org/10.1016/j.buildenv.2006.06.028

Holubec, I. (2008). *Flat Loop Thermosyphon Foundations in Warm Permafrost*. Canada: Prepared for Government of the NT Asset Management Division Public Works and Services and Climate Change Vulnerability Assessment Canadian Council of Professional Engineers

Hoppe, P., (1998). Comfort requirements in indoor climate. *Energy and Buildings, 11*(1-3), 249-257. https://doi.org/10.1016/0378-7788(88)90040-0

Hyde, R. (2000). *Climate responsive design: a study of buildings in moderate and hot humid climates*. New York, USA: E & FN Spon.

Jorge, J., Puigdomenech, J., and Cusido, J.A. (1993). A Practical Tool for Sizing Optimal Shading Devices. *Building and Environment, 28* (1), 69-72. https://doi.org/10.1016/0360-1323(93)90007-P

Kalantar, V (2005, 13-14 March). Natural ventilation the building with wind tower and renewable energy without using fuel oil. Presented at the third conference on fuel conservation in building, (1566-1577). Tehran, Iran.

Kamal, M. A. (2014). *Thermal Mass: A Passive Design Technique for Climate Responsive Architecture*. Retrieved from, https://www.masterbuilder.co.in/thermal-mass-passive-design-technique-climate-responsive-architecture/

Kamal, M. A. (2012). An Overview of Passive Cooling Techniques in Buildings: Design Concepts and Architectural Interventions. *Acta Technica Napocensis: Civil Engineering & Architecture, 55* (1), 84-97.

Kamal, M. A. (2003). Energy Conservation with Passive Solar Landscaping, presented at (National Convention on Planning for Sustainable Built Environment), M.A.N.I.T. Bhopal, India. (92-99)

Karasu, A. (2011). From Tradition to Modernity: Innovative shadings to save energy in residential architecture of Bodrum, Turkey. *Journal of the International Society for the Study of Vernacular Settlements* (*ISVS) e-journal, 2*(1), 52-64

Koenigsberger, O.H., Ingersoll, T.G., Mayhew, A., and Szokolay, S.V. (2010). Manual of Tropical Housing and Design: Climatic Design. Hyderabad, India: Universities Press.

Kumar, R., Garg, S. N., and Kaushik, S. C. (2005). Performance evaluation of multi-passive solar applications of a non-air-conditioned building. *International Journal of Environmental Technology and Management*, *5*(1), 60-75. https://doi.org/10.1504/IJETM.2005.006507

Lam, J. C., Tsang, C. L., Li, D. H. W., and Cheung, S. O. (2005). Residential building envelope heat gain and cooling energy requirements. *Energy*, *30*(7), 933-951. https://doi.org/10.1016/j.energy.2004.07.001

Landsberg, H.E. (1947). Microclimatic research, in relation to building construction. *The Arch. Forum, 86*(3), 114-119.

Lapithis, P.A. (2002). *Passive Solar Architecture in Cyprus*. PhD Thesis, University of Wales, UK.

Lavafpour, Y., and Sharples, S. (2015). Summer Thermal Comfort and Self-Shading Geometries in Passivhaus Dwellings: A Pilot Study Using Future UK Climates. *Buildings, 5*, 964-984. https://doi.org/10.3390/buildings5030964

Linden, P. F. (1999). The Fluid Mechanics of Natural Ventilation. *Annu. Rev. Fluid. Mech. University of California* (31:201-38), 201-239. https://doi.org/10.1146/annurev.fluid.31.1.201

Mahdavinejad, M., and Khazforoosh, S., (2014). Combination of Wind Catcher and Chimney for More Energy Efficient Architectural Buildings. *Sustainable Energy*, 2 (1), 35-38.

Majumdar M. (2001). *Energy efficient buildings of India*. New Delhi, India: Tata Energy Research Institute.

Markus, T. A. and Morris, E. N. (1980). *Buildings, Climate, and Energy*. USA & UK: Pitman Pub.

Marler, H. C., and Cobalt Engineering. (2008). *Passive Design Toolkit - Best Practices*. Canada: City of Vancouver.

Mazria, E. (1979). *The Passive Solar Energy Book: A Complete Guide to* Passive Solar *Home, Greenhouse and Building* Design. Pennsylvania, USA: Rodale Inc.

MEEF Roman Architectural Glossary. Retrieved from: http://www.eng forum.com/articles/Glossaries/Architecture_Roman.htm

Meir, I. A. (2000). Integrative approach to the design of sustainable desert architecture – a case study. *Open House International, special issue on Environmentally Responsive Architecture, 25*(3), 47-57.

Merriam-Webster. Retrieved from: https://www.merriam-webster.com/dictionary/portico

Moore, F. (1993). *Environmental Control Systems: Heating, Cooling, Lighting*. New York, USA: McGraw-Hill.

Morad, D.L. (2014). *Learning from Comparative Examples of Passive Houses in Different European Countries*. Master Thesis, EMU. Gazimağusa, Northern Cyprus.

Muhaisen, A.S., and Abed, H. M. (2015). Effect of Building Proportions on the Thermal Performance in the Mediterranean Climate of the Gaza Strip. *Journal of Engineering Research and Technology, 2*(2), 112-121.

Muhy Al-Din, S., Iranfare, M., Surchi, Z. (2017). Building Thermal Comfort Basedon Envelope Development: Criteria for selecting right case study in Kyrenia- North Cyprus. *Energy Procedia (Open Access), 115,* 80-91. https://doi.org/10.1016/j.egypro.2017.05.009

National Building Code of India. (2005). New Delhi, India: Bureau of Indian Standards (BIS).

Ossen, D.R., Ahmed, M., and Madros, N. H. (2005). Optimum Overhang Geometry for Building Energy Saving in Tropical Climates. *Building Engineering, 4*(2), 563-570. https://doi.org/10.3130/jaabe.4.563

Ozsen, E. (2010). *Passive Solar Design Guidelines*. Denmark: Ministry of Energy and Public Utilities

Passerini, F. (2012). *Sunspaces for passive building heating Calculation models and utilization of empirical data*. Ph. D. thesis, University of Trento, Trento. Italy: University of Trento.

Paul, J. K. (1979). *Passive Solar Energy Design and Materials*. USA: Noyes Data Corporation (NDC).

Potcher, O., Cohen, P., and Bitan, A. (2006). Climate Behavior of Various Urban Parks During Hot and Humid Summer in the Mediterranean City of Tel Aviv, Israel. *International Journal of Climatology*, 26: 1695–1711. https://doi.org/10.1002/joc.1330

Raja, I. A., Nicol, J. F., McCartney, K. J., Humphreys, M. A. (2001). Thermal comfort: use of controls in naturally ventilated buildings. *Energy and Buildings, 33*, P: 235-244. https://doi.org/10.1016/S0378-7788(00)00087-6

Ramponi, R., Gaetani, I., Angelotti, A. (2014). Influence of the urban environment on the effectiveness of natural night-ventilation of an office building", *Energy and Buildings, 78,* 25–34. https://doi.org/10.1016/j.enbuild.2014.04.001

Rathnayake, U., Lau, D., & Chow, C. L. (2020). Review on energy and fire performance of water wall systems as a green building façade. Sustainability, 12(20), 8713. https://doi.org/10.3390/su12208713

Rinaldi, N. (2009). Thermal Mass, Night Cooling and Hollow Core Ventilation System as Energy Saving Strategies in Buildings. Master thesis, KTH, Stockholm, Sweden.

Roaf, S., Fuentes, M., and Thomas, S. (2002) *Ecohouse: a design guide.* (*2ed* Ed.) Oxford, UK: Architectural Press.

Rosenlund, H., (2000). *Climatic Design of Buildings using Passive Techniques*. Sweden: Lund University Publication (LUP).

Rowland, I. and Howe T. N. (1999). *Vitruvius: Ten Books of Architecture*. Cambridge, UK: Cambridge University Press.

Santamouris, M. (2009). *Advances in Building Energy Research* (Vol. Volume 3). London, UK: Sterling, VA : Earthscan.

Santamouris, M. (2005). *Passive Cooling of Buildings*. In 'Advances of Solar Energy', ISES, London, UK: James and James Science Publishers.

Sarihi, S. (2015). *Adaptable Architecture, Via Studying Iranian Vernacular Architecture*. In 1st International Conference on Human, Architecture, Civil Engineering and City, ICOHACC 2015, Tabriz, Iran. https://doi.org/10.2478/alfa-2023-0002

Sayigh, A. A. M. (1979). *Solar Energy Application in Buildings: Passive Cooling of Buildings*. New York, San Francisco, USA: Academic Press. https://doi.org/10.1016/B978-0-12-620860-3.50013-8

Savvides, A. (2015). Pedestrianization of a Vehicular Urban Corridor: Designing for User Comfort. *Journal of Engineering and Architecture, 3*(2), 1-8. https://doi.org/10.15640/jea.v3n2a1

Subramanian, C.V., Ramachandran, N., Senthamil Kumar, S. (2017). Design and Analysis of Solar Passive Architecture for Thermal Comfort of Residential Buildings in Warm-Humid. https://doi.org/10.17485/ijst/2017/v10i9/103647

Szokolay, S. V. (2008). *Introduction to Architectural science: the basic of Sustainable design*. (2ed edition). United States: Architectural press, Elsevier. https://doi.org/10.4324/9780080878942

Szokolay, S. V. (2004). *Introduction to Architectural Science*. Oxford, UK: Architectural Press.

Szokolay, S. V. (2001). The building envelope. In: Krishnan, A., Baker, N., Yannas, S.,

Szokolay, S., (Ed.). *Climate responsive architecture, a design handbook for energy efficient buildings*. Tata McGraw-Hill Publishing Company, New Delhi, pp. 97-109.

Szockolay S. (1996, 16-18, July). *Thermal design of houses for warm-humid climates*. Presented in Building and Urban Renewal - 13th PLEA International Conference Proceedings, "de Herde A, ed., Louvain-la-Neuve: Architecture et Climat", (337-342), Belgium.

Taleb, H.M. (2014). Using passive cooling strategies to improve thermal performance and reduce energy consumption of residential buildings in U.A.E. buildings. *Frontier of Architectural Research, 3*, 154-165. https://doi.org/10.1016/j.foar.2014.01.002

Tavakolinia, F. (2011). *WIND-CHIMNEY: Integrating the Principles of a Wind-Catcher and a Solar-Chimney to Provide Natural Ventilation*. Master Thesis, Faculty of California Polytechnic State University, San Luis Obispo. California, USA: California Polytechnic State University

Toroxel, J. L., & Silva, S. M. (2024). A Review of Passive Solar Heating and Cooling Technologies Based on Bioclimatic and Vernacular Architecture. Energies, 17(5), 1006. https://doi.org/10.3390/en17051006

Thumann, A., Mehta, D.P. (2008). *Handbook of energy engineering*. Georgia, USA: Fairmont Press.

Tokbolat, S., Tokpatayeva, R., Al-Zubaidy, S. N. (2013). The Effects of Orientation on Energy Consumption in Buildings in Kazakhstan. *Jornal of Solar Energy Engineering, 135*(4). https://doi.org/10.1115/1.4025427

U. S. Department of Energy, and National Renewable Energy Laboratory. (1994). Sunspace Basics. Office of Energy Efficiency and Renewable Energy. https://docs.nrel.gov/docs/legosti/old/15971.pdf

U.S. Department of Energy (DOE). (2001). *Passive Solar Design for Home*. DOE/GO-102001-1105 FS121. USA: by the National Renewable Energy Laboratory (NREL). Retrieved from, https://www.nrel.gov/docs/fy01osti/27954.pdf

Wilson, J. (2014). *How Heat flows and How to Stop It: The three mechanisms of heat flow work together at all times. Under different circumstances, each takes turns being the dominant force*. eBooklet by Construction Instruction. Retrieved from: https://constructioninstruction.com/wp-content/uploads/2015/06/How_Heat_Flows_Ci_eBook1.pdf

Xu, R. (2023). Simulation of photo thermal building and thermal comfort analysis of PMV. *Journal of Physics: Conference Series, 2580*, Article, 012010. https://doi.org/10.1088/1742-6596/2580/1/012010

Zain-Ahmed, A., Sopian, K., Othman, M. Y. H., Sayigh, A. A. M., & Surendran, P. N. (2002). Daylighting as a passive solar design strategy in tropical buildings: A case study of Malaysia. *Energy Conversion and Management*, *43*(13), 1725-1736. https://doi.org/10.1016/S0196-8904(01)00007-3