INNOVATIVE APPLICATIONS AND RESEARCH METHODS IN ARCHITECTURE, PLANNING AND DESIGN

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İÇİNDEKİLER

CHAPTER 1

Depiction of a Historical Building with Senses and Emotions: Samsun Tashan

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1. INTRODUCTION

Space is the experience area that gains meaning through the interaction of the individual with environment. Various emotional expressions emerge in the individual's interpretation of the space that experiences with senses. The space perceived by the individual's senses; beyond being a physical place, it integrates with emotion and turns into experiences in the memory of the individual. The spatial experience of the individual includes the mental processing of emotions and senses to gain meaning and representation. In this context, historical buildings integrated into today's life stand out by offering unique and rich experiences to individuals. In addition to their historical and architectural identities, historical buildings are multi-layered experience areas with their environmental, cultural, economic and social values related to the period in which they were built. At this point, the building allows the individual to experience multiple senses and allows the expression of different emotional expressions. The combination of multiple senses transforms the experience of space into a multisensory experience and this sensory experience produces emotional bonds with the associations in the individual and turns into various representations in the individual's memory. The sensory and emotional relationship that the individual establishes with the space concretises the connection with the past and offers a multifaceted representation. Thus, historical buildings leave a trace in individual and collective memory through senses and emotions. Accordingly, the representation of sensory experience and emotional associations play a critical role in the survival of historical buildings. From this point of view, the spatial experience of a re-functionalised historic building is discussed in this study. This study, which is analysed through senses and emotions, focuses on the representation of a historical building with a sensory approach and emotional layers. In this direction, the study offers a perspective on how to contribute to the representation of the multi-layered structure of historical buildings with an approach that appeals to the senses and emotions. In this study, which aims to reveal the spatial experience and interaction in a historical building through user evaluations, strategies for design and conservation processes were developed by aiming to determine the sensory and sentimental tendencies towards the space.

2.CONCEPTUAL FRAMEWORK

In the most general terms, experience is the name given to all the experiences that an individual has gained over a certain period of time (Oxford Dictionary, 2025). Experience, which has a complex structure that is relative, non-absolute and non-generalised, emerges as a result of the interactions of individuals with their environment. Even if sensory perceptions are the same, information is processed differently in the minds of individuals. Individuals interact differently with both the physical environment and the social context through their subjective processes such as mental structure, emotions, beliefs and lifestyle (Bergson,

2007). In this context, experience is not limited to the sensory perceptions of the individual, but has a holistic structure that covers all mental and physical interactions (Lang, 1987). Spatial experience is defined as the interaction between the individual and the space. In other words, spatial experience is the accumulation of the physical actions performed by the individual in the space as a result of processing on the cognitive plane (Asar, 2023a). As a result of this interaction with the environment, individuals embody the impressions they produce in their mental planes and create their own spatial representations in line with the dialogues they establish with spaces. Spaces have a dynamic structure that finds meaning through the mutual relations that individuals establish with their environment (Pallasma, 2012). The interaction network established by the individual with the space and the objects around him/her creates the spatial experience. Perception has an important place in spatial experience, which is a multi-layered process built by the individual through interaction with the space. Perception, defined as the state of being aware through the senses, has a decisive role in the formation of spatial experience. Perception enables the initiation and maintenance of the interaction between the individual and the environment (Merleau-Ponty, 2005). The perception experience, which is unique to the individual, is shaped by the individual's own accumulation. The individual begins to perceive his/her environment through the senses when he/she encounters the space and perception turns into experience during the time he/she spends in the space. The experiencing of a space is possible not only through its physical existence, but also by making sense of the sensory data of that space through perception; therefore, the senses are the primary element of spatial experience.

Senses are physical formations that are specialised according to the stimulus mode, which enable the individual to obtain information about the environment, store this information in a meaningful way and reinterpret it when encountered again. The senses, which mediate a subjective connection with the space, provide the formation of spatial experience with the recognition and perception of space. In this context, the spatial experience that starts in the body with the senses expresses a process that is completed in the mind (Tuan, 1977). The senses, which are diversified as sight, hearing, touch, taste and smell, make it possible to perceive the space with different layers (Zaredar, 2015). The sense of sight is formed as a result of the stimulation of light in the eye and stands out in the perception of the individual's surroundings. The human brain processes approximately 80-90% of the information it receives from the outside world through the sense of sight. It is one of the most important senses in terms of space and architectural perception (Soltani, & Kirci, 2019). This sense has a wide range from form, shape, colour and lighting. The sense of sight, which is related to how individuals perceive space, facilitates exploration, navigation and interaction (Howes, 2005). In the sense of hearing, the sound, which is a stimulus, is related to the acoustics of the space and directly affects the spatial experience of the

individual with events such as absorption, dispersion and echo (Spence, 2020). Touch, another sense, is a sense based on feeling through the skin. The sense of touch, which establishes the bodily interaction between the individual and the space, is experienced through contact, especially temperature and roughness levels of surfaces in spatial experience. Another sense, smell, is the sense that stands out in the smell and atmosphere of the space and has a strong relationship with space and memory (Krishina et al., 2010). The sense of taste, on the other hand, has a relatively more indirect relationship with space design and allows to create a holistic space experience together with other senses.

In spatial experience, the individual not only perceives the physical environment through the senses, but also deepens it with the emotions he/she has established in his/her mental world (Ryhl, 2009). In other words, while the senses enable the perception of space, emotions enrich the spatial experience by attributing meaning to the perceived space. While the individual contacts the environment with the senses, the mind internalises the stimuli coming from the senses by making sense of them. This process has both a cognitive and emotional dimension. In this context, spatial experience is sensed in the individual's body, shaped in the mind and gains meaning through emotions. Thus, in the spatial experience of the individual, senses carry clues about the spatial atmosphere and emotions carry clues about the traces left by this atmosphere on the individual.

Spatial experience, which is a multi-layered and dynamic process, is formed as a result of the interaction of the individual with his/her environment through senses and emotions (Asar, 2023b). In addition to the physical perception of the environment, establishing a strong relationship with memory and context is important in the formation of spatial experience. In this context, historical buildings offer a layered spatial experience potential not only with their physical presence, but also with their historical continuity, the way of life, social relations, sociocultural dynamics and cultural production forms of the period in which they were built. In this context, historical buildings are multi-layered spaces of experience. On the other hand, these buildings contribute to the formation of collective memory by gaining an important place in urban memory with their architectural and functional identities (Latham, 2000; Sipahi et al., 2025). Due to changing social needs over time, the functions of historical buildings become obsolete and new forms of use are needed (Ahunbay, 2016; Yıldız, & Asatekin, 2016; Bekar et al., 2024). Bringing historical buildings back into use with functions that meet today's needs allows for the experiential continuity of the building along with its physical protection. Re-functionalised historical buildings continue to exist by integrating into the present with new layers of experience perceived through the senses and internalised through emotions. At this point, the subject of the study is the spatial experience of a re-functionalised historical building. The study reveals how a building with a historical identity is experienced by individuals as a result of its re-functionalisation.

3. METHOD

In the study, it is aimed to reveal the spatial experience and interaction in a historical building in line with user evaluations. In this direction, it was aimed to determine the sensory and emotional tendencies towards the space (Figure 1). Thus, by determining the senses that stand out in the spatial performance of the historical building after restoration/re-functionalisation and the emotional tendencies reflected in the user evaluations, the strengths and weaknesses of the space in terms of user experience were analysed and suggestions for design and conservation processes were developed in line with the findings obtained.

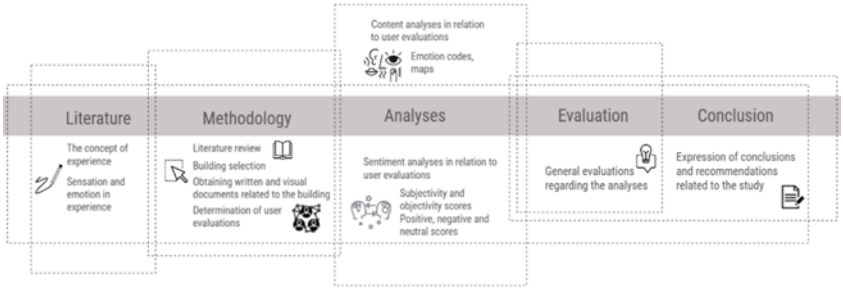


Figure 1. Research design

The study started with a literature review on spatial experience and user interaction. After the theoretical infrastructure of the study was established, Tashan in İlkadım district of Samsun province was determined as the study area (Figure 2). The fact that Tashan is an important cultural heritage of the city with its architectural identity and historical value has been an effective criterion in the selection of the study area (Faiz Büyükçam, 2021). In addition, the fact that Tashan, as a re-functionalised building, exhibits a multi-layered existence in the intersection of past and present is also effective in determining Tashan as a study area. In addition to these, another important criterion was that Tashan has various functions that allow it to be experienced by various user groups.

Figure 2. Field of work (Photographed by the authors).

Tashan is an Ottoman city inn built in 1508. The building has a square plan of approximately 28x28 m², a central courtyard, two storeys and rubble stone with brick beams. There are stables and storerooms on the ground floor and the upper floor is divided into 3x3 m² rooms. Although it is known that the interior spaces of Tashan were completely burnt down as a result of a fire in the 19th century, a part of the west wing was demolished in the middle of the 20th century due to

reconstruction works. The building, whose original plan scheme and qualities were lost, was used as a workshop for many years. Registered in 1985, restoration works were initiated in 2016. Tashan, which is located in the busy commercial centre of the city, has been re-functionalised with restoration works and integrated into contemporary use. Tashan, whose original courtyard and portico plan scheme is preserved, is used as a multifunctional space including handicraft workshops, sales units and food and drink areas (Faiz Büyükçam and Eyüboğlu, 2022). In this context; wet areas, technical units, cafeteria, kitchen, administration units and shop/room units are located on the ground floor of the inn. The upper floor is reserved for the workshops of artisans and sales units (Figure 3).

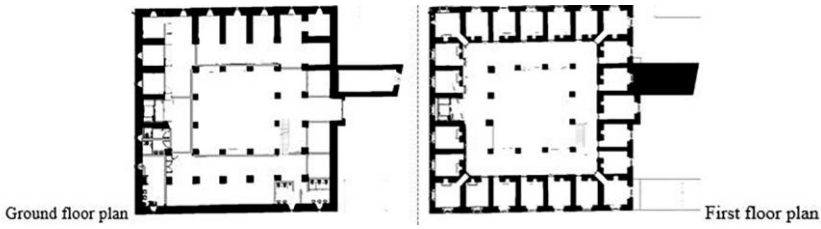


Figure 3. Samsun Tashan's plan (Samsun Foundations Regional Directorate, 2022).

After determining the study area, data collection was carried out. Qualitative data collection technique was used in the study and data were obtained in two separate categories. The first category consists of documents belonging to the building. In this direction, the survey, restitution and restoration projects and project reports of Tashan were obtained from the Regional Directorate of Foundations of Samsun, and then the current situation of the building visited on site was determined by photographing. The second category of qualitative data consists of user evaluations of the building. These evaluations/comments were obtained through Google comments, a digital platform open to the public. All 340 comments left on the digital platform about Tashan were read by the researchers and 56 comments related to the themes of architecture, space and planning were included in the study. Others were excluded from the scope of the study. Textual data were obtained from the user comments included in the study. Textual data were used by coding and anonymising user identities with “r” for confidentiality and ethical reasons.

Quantitative and qualitative methods were used together in the analysis of the study data In this context, emotional experiences expressed by user comments were deciphered and coded by content analysis. In this analysis, how the users evaluated the building in terms of senses was examined and sensory categories were created and the number of emphasis of each sense was calculated. This analysis was done manually. A matrix was created with the data obtained. In addition, maps of the connection levels between the senses were created. Following the content analyses, sentiment analyses of user comments were performed. Emotion analyses were performed through Python, one of the natural

language processing (NLP) based software. With this analysis, the emotional tendencies of the users regarding the space were determined and the effects of spatial elements on emotions were examined. In addition, the emotion values of each of the user comments were calculated and comparative analyses were performed with histograms. Following the analyses of sensory and sentimental tendencies, general evaluations were made. At this stage, the effect and relationship of senses and emotions on the spatial experience were analysed. In the conclusions and recommendations of the study, the effect of senses and emotions on the multi-layeredness of the spatial experience was revealed, and spatial solution suggestions were developed to improve the spatial experience.

3. FINDINGS

In this section, the findings of 56 user comments expressing the Samsun Tashan experience textually on the Google platform regarding the emotional and sensory perception parameters are presented. Analyses based on user comments detail the effect of space perception and emotions on user experience. In this context, polarity and subjectivity values were calculated over textual expressions in emotion analysis. Polarity (p) ($-1.00 \leq p \leq +1.00$) value analyses positive ($p > 0$), negative ($p < 0$) and neutral ($p = 0$) emotions. Subjectivity (s) ($0.00 \leq s \leq +1.00$) value determines whether the statements are subjective ($s \geq 0.5$) or objective ($s < 0.5$). In addition to sentiment analyses, content analyses were conducted for the senses of sight, hearing, smell, touch and taste through the comments of the users about the building. In this context, polarity and subjectivity values of 56 visitor comments were calculated, and the tendencies towards the five senses were determined for each comment (Table 1 and Table 2).

Table 1 shows the emotion codes, polarity and subjectivity values of each user's comments on the structure. According to the listed comment contents, it was observed that neutral emotions ($p=0$) also contained completely objective ($s = 0$) expressions. At this point, it was determined that neutral comments mainly contain descriptive expressions and do not have an emotional determinant characteristic. In addition, it was determined that negative emotions ($p < 0$) were used together with subjective expressions ($s \geq 0.5$). It was observed that users included subjective evaluations while expressing their negative experiences. Moreover, it was observed that the texts containing positive emotions ($p > 0$) ranged between 0.08 and 0.77, while those containing negative emotions ($p < 0$) ranged between -0.09 and -0.40. According to this distribution, it was determined that the emotional intensity of positive expressions varied in a wider range, while negative expressions remained in a more limited range. In addition, comments containing subjective ($s \geq 0.5$) statements had values between 0.50 and 0.94, while objective ($s < 0.5$) statements had values between 0.8 and 0.00. According to these value ranges, it was observed that subjective and objective expression weights were in similar tones.

Table 1. Polarity and subjectivity values all comments.

R	Emotional values		R	Emotional values	
	P	S		P	S
1.	0.10	0.61	29.	0.27	0.39
2.	0.36	0.64	30.	0.24	0.60
3.	0.51	0.66	31.	0.77	0.94
4.	0.45	0.60	32.	0	0
5.	0.32	0.53	33.	0.29	0.39
6.	0.56	0.56	34.	0.55	0.60
7.	0.42	0.50	35.	0.39	0.45
8.	0.36	0.50	36.	0	0
9.	0.33	0.60	37.	0.43	0.54
10.	0.36	0.44	38.	0.34	0.48
11.	0.18	0.31	39.	0.42	0.50
12.	0.26	0.67	40.	-0.09	0.56
13.	0.09	0.43	41.	0	0
14.	0.08	0.44	42.	0.36	0.46
15.	0.17	0.50	43.	0.50	0.50
16.	-0.40	0.60	44.	0.13	0.16
17.	0.42	0.86	45.	0.70	0.76
18.	0.60	0.80	46.	-0.37	0.62
19.	-0.32	0.85	47.	0	0
20.	0.28	0.71	48.	-0.21	0.59
21.	0.19	0.72	49.	0.20	0.20
22.	0.10	0.41	50.	0	0
23.	0.35	0.50	51.	0.12	0.87
24.	0.10	0.15	52.	0.41	0.65
25.	0.37	0.66	53.	0.48	0.68
26.	0.50	0.75	54.	0.30	0.59
27.	0.45	0.71	55.	0.45	0.70
28.	0.25	0.46	56.	0.40	0.60
R: Review P:Polarity S:Subjectivity					

Analysis of the senses of the comments in the data set revealed that all 56 comments included expressions related to the sense of sight. The sense of touch was the second most dominant sense with 45 comments. Regarding the users' sense of sight and touch, "...it is very unique to experience a historical building of 512 years, when you touch the stone walls, I feel like travelling to the past...(r40)", "...the lighting of the space is successful, we are constantly watching the architectural details of the building... (r1)" emphasise the use of artificial lighting, architectural details and natural materials in the space. The expressions of the users regarding the senses of sight and touch took place within the scope of artificial lighting, architectural details and the use of natural materials in the space. Besides, the fact that the sense of taste was mentioned in 18 comments was related to the presence of the act of eating in the place. Hearing and smell were the least expressed senses with 9 and 8 comments, respectively. The fact that

auditory and olfactory experiences were relatively less emphasised showed that these aspects of the space were less noticed by the users (Table 1 and Table 2). According to Table 2, in the interaction of the emotional content of user comments, it was observed that four senses were mostly involved together. While the senses of touch and sight were common in these four comments, the other senses were hearing and smell. In this context, it was determined that 4 of 56 comments included four different senses, 18 included three different senses, 32 included two different senses and 2 included a single sensory expression.

Table 2. Sense contents of all comments

R	H	S	TO	V	TA	R	H	S	TO	V	TA
1.	●	●	●	●	●	29.			●	●	
2.	●			●	●	30.			●	●	
3.			●	●		31.			●	●	●
4.				●	●	32.	●			●	
5.			●	●	●	33.			●	●	
6.		●	●	●	●	34.			●	●	
7.			●	●		35.	●		●	●	
8.		●	●	●	●	36.			●	●	●
9.				●	●	37.			●	●	
10.			●	●	●	38.		●	●	●	
11.			●	●		39.			●	●	
12.			●	●	●	40.			●	●	
13.			●	●		41.			●	●	
14.	●		●	●		42.			●	●	
15.			●	●	●	43.			●	●	
16.		●	●	●		44.	●		●	●	
17.			●	●		45.			●	●	
18.				●	●	46.			●	●	
19.		●		●		47.			●	●	
20.			●	●		48.				●	
21.	●	●	●	●	●	49.				●	
22.			●	●		50.	●			●	
23.		●	●	●		51.		●	●	●	
24.			●	●		52.			●	●	●
25.			●	●		53.	●			●	●
26.			●	●		54.				●	●
27.			●	●		55.			●	●	●
28.			●	●		56.			●	●	●
Review: R	Hearing:H		Smell:S		Taste:TA		Touch:TO			Visual:V	

The relationship levels of the senses with each other in each comment were determined. If it is necessary to evaluate the matrix related to the relationship

levels; although the expressions for the sense of sight were included in all comments, they were most frequently used together with the sense of touch. Accordingly, it was observed that expressions related to the sense of sight and sense of touch were used together in 45 different comments. The sense of vision and the sense of taste were the second most frequently used pair of senses in 18 different comments. Sight and hearing were used together in 9 different comments, while sight and sense of smell were used together in 8 different comments. Moreover, the sense of touch was the most frequently used sense after the sense of sight. The strong relationship between the sense of touch and sight was followed by 12 comments in which touch and taste were mentioned together. Touch and smell were mentioned in 7 separate statements and touch and hearing in 5 separate statements. Taste was the third most frequently used sense. The relatively strong relationship between taste and sight and taste and touch was followed by a weak relationship between taste and hearing and taste and smell pairs. Hearing and smell were the least frequently mentioned senses in the dataset (Table 3).

Table 3. Matrix showing sense relations

	Hearing (H)	Smell (S)	Taste (TA)	Touch (TO)	Visual (V)
Hearing (H)	0	1	3	5	9
Smell (S)	1	0	2	7	8
Taste (TA)	3	2	0	12	18
Touch (TO)	5	7	12	0	45
Visual (V)	9	8	18	45	0

The average of polarity and subjectivity values belonging to the emotion analysis of 56 user comments were determined. It was observed that the mean polarity value of 56 comments about Samsun Tashan was 0.26. This value shows that although the texts are largely neutral, positive expressions are partially dominant. The users made positive evaluations about the building with statements such as "...a beautifully restored place...(r3)", "... it was very calm and relaxing in terms of atmosphere...(r1)". The mean value of subjectivity, which represents the subjectivity or objectivity of the comments, was determined as 0.52. According to the average subjectivity value, it was observed that user comments contained both emotional expressions and factual information. In relation to this, users said "...they have beautifully restored a historical place, there are antique items in the rooms on the upper floor inside (r7)", "...this place, which is central in location, easy to reach, located in a historical square, we liked it very much...(r9)", "It is really a very nice place, its historical texture and atmosphere fascinated us...(r10)". Although there are elements containing personal comments and emotions in the content of the texts, it was determined that they do not carry a strong subjectivity. In this direction, according to the average polarity (0.26)

and average subjectivity (0.52) values, the emotional impact of Samsun Tashan on users is positive, but it carries subjective expressions to a certain extent as well as objective expressions. It was observed that positive emotions were concentrated around the statements that Tashan is a restored historical place. In addition, depending on the restaurant function, food flavours were also expressed positively. Subjective expressions were related to the atmosphere of Tashan as a historical place. In addition, food flavours were also among the subjective expressions. On the other hand, although limited in number, negative, neutral and objective statements were included in the comments. Accordingly, negative emotions were related to the heating, ventilation and lighting system, while neutral expressions without any emotional tone were related to the car parking problem and urban density. Objective comments included informative statements about the historical and current functions of the building. Accordingly, it was observed that the negative emotions were related to the heating, ventilation and lighting system with the expressions "...the air quality inside the building was bad...(r16)", "...food odours were dominant instead of traditional stone and wood odours...(r19)". On the other hand, the user evaluations "...traffic, construction and environmental noises disturbed the silence of the place...(r32)", which did not contain any emotional tone, were found to be related to the car parking problem and urban density by containing neutral expressions. The distribution of Samsun Tashan user comments around the mean values was analysed by calculating the standard deviation value. The standard deviation value for the polarity value expressing positive, negative and neutral moods was calculated as 0.24. Considering the average polarity value (0.26), it was observed that there were no large fluctuations in user comments, generally slightly positive and close to each other. The standard deviation of the subjectivity value, which expresses the objectivity and subjectivity of the comments, was calculated as 0.23. Considering the average subjectivity value (0.52), it was observed that there was a moderate deviation. Accordingly, it was determined that although most of the texts had subjective expressions, they also had partially informative objective sections (Table 4).

Table 4. Average value and distribution of polarity and subjectivity values.

	Polarity (p)	Subjectivity (s)
Average value	0.26	0.52
Standard deviation value	0.24	0.23
Positive($p > 0$)	%82.14	-
Negative ($p < 0$)	%8.92	-
Neutral ($p = 0$)	%8.92	-
Subjective sentence ($s \geq 0.5$)	-	%66.07
Objective sentence ($s < 0.5$)	-	%33.92

In Table 3, in addition to the data on mean values, the percentage distributions of positive ($p > 0$), negative ($p < 0$) and neutral ($p = 0$) comments were also

calculated. Accordingly, the rate of comments with positive emotional tones in the whole data was determined as 82.14%. The proportion of neutral comments without any emotional tone and comments containing negative emotions was 8.92%. According to these data, it has been observed that the users have a positive attitude towards the place to a great extent and their spatial experiences include satisfaction. On the other hand, 66.07% of the comments containing subjective ($s \geq 0.5$) statements and 33.92% of the comments containing objective ($s < 0.5$) statements were included in the data set. Accordingly, it was observed that individual perceptions and emotions were predominantly effective in the spatial experiences of the users, but concrete observations were also included to a certain extent.

A stacked histogram was created to summarise the distribution of each comment in the polarity and subjectivity categories and to make sense of the relationship between these categories. It was observed that the polarity value of the 56 comments constituting the data set mostly varied between 0.25 and 0.50. These values indicate that textual expressions are dominated by moderate positivity. Although the number of objective ($s = 0$) comments was low, subjectivity values were mostly between 0.5 and 1.00. The high subjectivity value ($s = 1.00$) in some content indicates that strong emotional expressions are used depending on personal experience, but most of the comments are based on emotions and impressions (Figure 4).

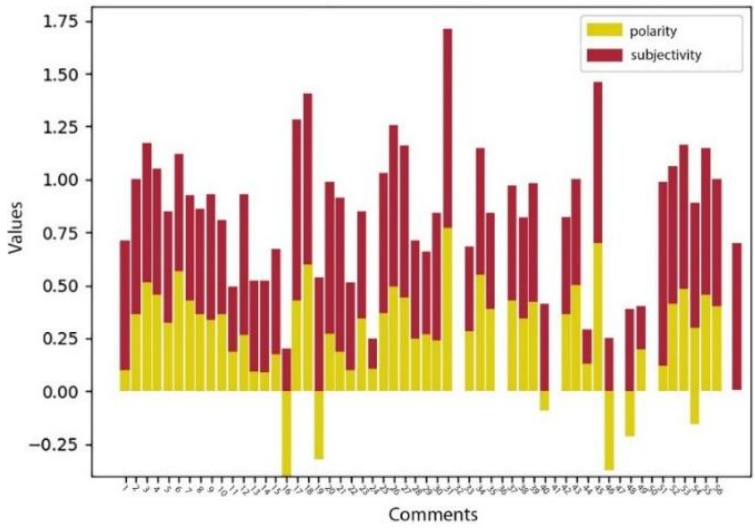


Figure 4. Stacked histogram according to polarity and subjectivity values.

The stacked histogram, which was created to see the range and frequency of polarity values, shows that positive expressions are dominant in the texts that make up the data set. In the histogram, which shows an asymmetric distribution, a positive accumulation was observed. Positive statements were concentrated in

the range of 0.25 - 0.5, while negative comments were not spread over a wide range but remained at a low frequency. On the other hand, it was observed that these comments were moderately negative, although they were far from being overly critical. Neutral comments were also included in the histogram in small numbers. It was observed that the polarity values of the textual expressions that make up the data set did not show great diversity, the emotional tone was positive and the users were satisfied with the building experience process (Figure 5).

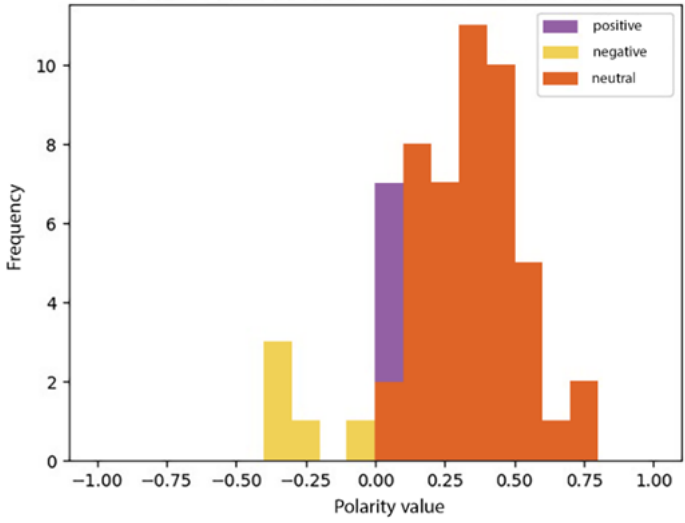


Figure 5. Stacked histogram according to polarity values.

The subjectivity value ranges and density levels of the data set are visualised (Figure 6). It was observed that subjective expressions ($s \geq 0.5$) were concentrated in the range of 0.5 - 0.7. In addition, according to the highest aggregation in the range of 0.5 - 0.6, the texts contain objective and subjective expressions. Objective statements ($s < 0.5$) were concentrated between 0.3 - 0.4, although their intensity levels were low. On the other hand, overly subjective expressions are relatively less intense. Accordingly, although subjective statements based on purely emotional and personal judgement are in the minority in the data set, the subjective tendency is evident.

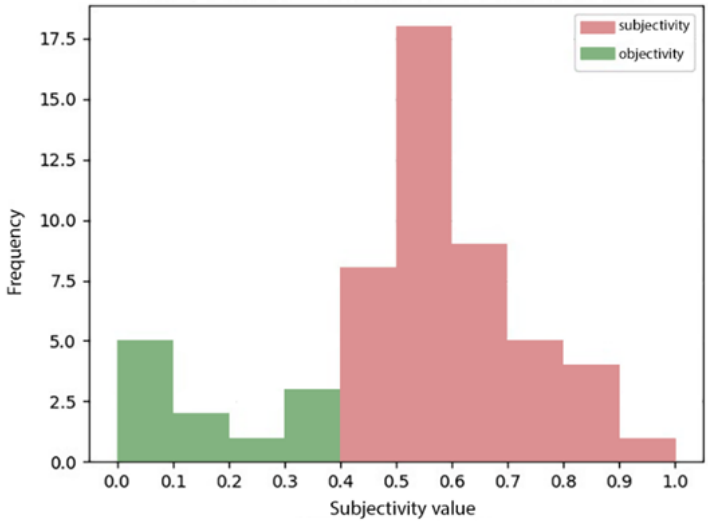


Figure 6. Stacked histogram according to subjectivity values.

4. DISCUSSION

In the analysing part, it is discussed how emotional expression corresponds to sense experiences. For this purpose, firstly the intensity of emotional experience, inter-sensory relations and general emotional expression are emphasised and then the emotional tones of sensory perceptions are evaluated. Content analyses of user evaluations of Tashan show that the sense of sight is used predominantly. At the same time, the sense of sight was the sense with which the most relationship was established with other senses (Figure 7). This situation is related to the fact that the sense of sight is the sense that provides the most information in the perception of space, but it can also be associated with the successful restoration process of Tashan. Here, the dense stone texture and the combination of closed, semi-open and open spaces are the elements that directly affect the sense of sight. On the other hand, the products produced in the art and craft workshops on the upper floor of Tashan also affected the user visually. The fact that the insufficient natural lighting in the building causes a negative experience can be directly related to the inward-oriented original plan fictions of the han buildings. However, the level of natural lighting provided on the ground floor from the courtyard to the porticoes and from there to the rooms has relatively increased with small window openings in the upper floor rooms.

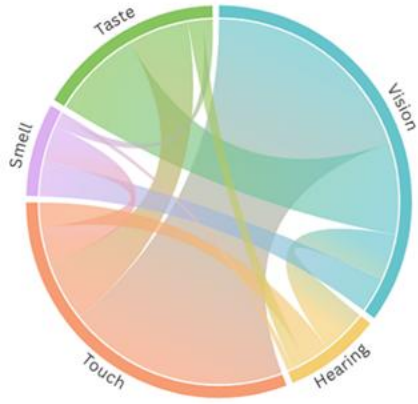
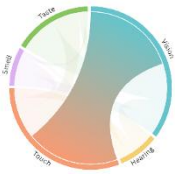
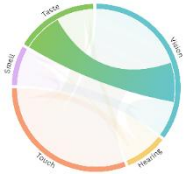
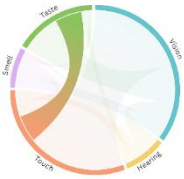
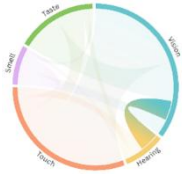
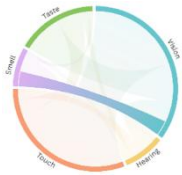
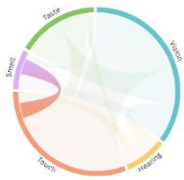
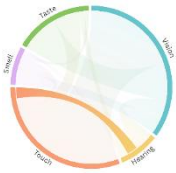


Figure 7. Network of sense relationships.

Although the sense of vision is related to all other senses, it is intensely associated with the sense of touch. The use of natural and textured materials such as stone and wood has been an effective factor in this relationship. However, it is clear that issues such as space dimensions, material feel and the quality of seating units that provide physical comfort are related to the interaction of the senses of touch and sight. The sense of sight and the sense of taste intersect in the dining experience. The use of the ground floor of the space as a restaurant has been effective in the connection established here. The presentation of the food and the features reflecting the spirit of the place (historical texture, use of materials, etc.) were handled together. Accordingly, it can be said that the dining experience and the physical characteristics of the dining area are important. The level of relationship between the sense of touch and taste may have resulted from the interaction of physical comfort conditions with the dining experience. Accordingly, tactile elements such as comfortable seating arrangement and ambient temperature may have increased the continuity of the act of eating by positively affecting the atmosphere of the space. The relatively medium intensity connection between the senses of vision and hearing reflects the effects of appropriate music selection or environmental noise pollution on user experiences depending on the visual atmosphere of the space. However, the connections between the senses of vision-smell, touch-smell and touch-hearing were not strong. The connection levels in these relationships may be related to the way, time and duration of the users' experience of the building. It can be said that the sensory associations here stand out as the historical structure of the place and traditional food and presentations. In the connection between the senses of touch and hearing, acoustic comfort and physical comfort of the space were evaluated together and factors such as echo, noise and seating discomfort were addressed. The weakest relationships between the sensory pairs were in the senses of taste-hearing, smell-taste and smell-hearing. However, the sense least associated with other senses was odour. This is thought to be related to the fact that the sense of

smell appears in the users' experience of the space only in limited situations such as eating, and on the other hand, it can be said that users generally show low sensitivity to the sense of smell and are in the background compared to other senses. The fact that smell is not emphasised when describing the dining experience may mean that the environment is odourally neutral or not as noticeable as other senses (Table 5).

Table 5. Relationship map of the senses

Strong Connections	Medium-strong Connections	Medium-weak Connections	Weak Connections
	 	   	  

When the emotional tones (polarity and subjectivity) of the senses were evaluated, the most positive sense was the sense of taste with a value of 0.376. This sense is also highly subjective with a value of 0.596. Accordingly, it is understood that the dining experience is generally positive, but the quality of the food does not create a homogeneous perception among users and varies with individual differences. Positive and subjective evaluations are also dominant in the senses of touch and sight. Accordingly, the physical comfort and aesthetic values of the place are mostly good, but individual preferences and comfort played an important role. On the other hand, the lowest polarity values were observed in the senses of smell and hearing. The sense of smell has the lowest polarity value (0.138) but the highest subjectivity value (0.621) among the

senses analysed. These values indicate that odours can disturb people and that olfactory design is important in the space and does not produce positive associations. In addition, disturbing food or coffee smells may not disrupt the integrity of the historical atmosphere and may have created a negative experience for some users. Auditory senses have both low polarity (0.192) and low subjectivity (0.411) values. Although factors such as noise, traffic sound, and music selection were evaluated negatively by some users, the fact that the space did not meet the expectation of silence may have led to some complaints. However, it can be said that elements such as music and noise were evaluated more similarly by different individuals (Table 6).

Table 6. Emotional tones of the senses.

Sense	Polarity (p)	Subjectivity (s)
Hearing (H)	0.192	0.411
Smell (S)	0.138	0.621
Taste (TA)	0.376	0.596
Touch (TO)	0.274	0.521
Vision (V)	0.271	0.516

The average polarity and subjectivity values of the senses are visualized in a stacked histogram. Thus, the total emotional tones of the senses are compared. As seen in Figure 5, the sense of taste has the highest total value. It is clear that this situation is directly related to the new function of the historical structure. The positive tone and subjectivity of the user comments directly affect this value. The sense of hearing has the lowest total value, as it contains less subjectivity and generally neutral expressions. While the total values of the tactile and visual senses are quite close, emotional expressions are also in similar ranges. However, the total value of the sense of smell is close to the senses of touch and vision, but it varies in terms of emotional tone. While the sense of smell is the most subjective sense, emotional polarity is close to neutral values (Figure 8).

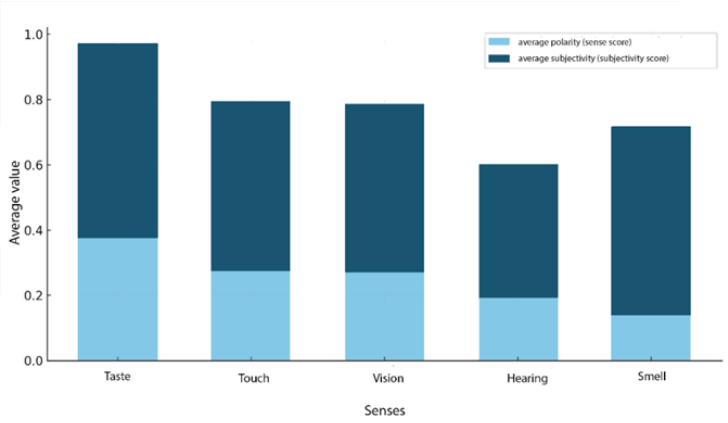


Figure 8. Polarity and subjectivity distributions of senses.

5. CONCLUSION

Space is an area of experience that gains meaning through the individual's sensory perceptions and is shaped by emotional bonds. Historical structures, on the other hand, leave permanent marks in the memory of individuals by offering effective areas of experience with the cultural, social and architectural values they possess. In this direction, the prominent effects of historical structures that are re-functionalized, re-produced and layered on spatial experiences have been determined and suggestions have been presented.

The study revealed that user comments about Samsun Tashan generally showed a positive tendency. While the vast majority of comments carried positive emotional tones, subjective expressions also took place predominantly. While users evaluated the space with personal perceptions and emotional experiences, they made informative objective comments about the historical and functional features of the space. Accordingly, it can be said that Samsun Tashan was generally perceived positively by users and that the historical and functional features of the space had a strong impact on users. On the other hand, it can be argued that criticisms towards Tashan were limited and moderate. In user evaluations, it was observed that positive experiences were conveyed with various and rich expressions, whereas negative experiences were expressed with limited emotional intensity but in a subjective language. This situation reveals that users tended to make personal evaluations in negative spatial experiences and used general expressions in positive experiences. Therefore, it can be said that spatial satisfaction was represented by a variety of expressions, while dissatisfaction was represented by a personal emphasis intensity.

In Samsun Tashan user evaluations, the senses that shape spatial perception most strongly are vision and touch. While the sense of vision was associated with the stone texture and art workshops, especially during the restoration process, insufficient natural lighting created a negative experience. The sense of touch was

associated with the historical texture and material use of the space, and the sense of taste was associated with the restaurant function, creating positive experiences. The sense of smell was less pronounced, generally noticed based on dining experiences, and remained in the background due to the influence of other senses. Accordingly, it is clear that spatial experiences are mostly shaped by visual and tactile elements, while auditory and olfactory elements play a less decisive role.

In order to support positive experiences with a wider range of expression in spatial designs, it can be suggested to diversify visual and tactile elements. In particular, more careful planning of lighting, architectural details and material selections that appeal to the senses of sight and touch can ensure that the space has a positive effect on users. In addition, making auditory and olfactory elements more prominent in spatial design can strengthen the multi-sensory effect of the space by increasing the user's perception of different sensory experiences. In this way, a richer and more diversified interaction can be provided in the user's emotional expressions representing the spatial experience.

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CHAPTER 2

Ideology in Architecture and Planning

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INTRODUCTION

The term “ideology” originated during the contentious philosophical and political discourse of the French Revolution and has since evolved in meaning from the early days of the First French Empire to the present. It was first employed by Destutt de Tracy in 1796 to refer to a facet of his ‘science of ideas.” He categorized his ‘science of ideas” into three aspects: Ideology, General Grammar, and Logic, each pertaining to Subject, methods, and rationale of this science, respectively. He referred to “ideology” as the most general and encompassing term because it encompasses the study of the interpretation and manifestation of ideas. He characterized “ideas” as a scientific discipline that offers a rational foundation for both enthusiasts of idea exploration and critics of the same. The phrase, however, has faced scrutiny and has evolved into a concept prone to modification. The term “ideology” denotes interdependent ideas, concepts, beliefs, behaviors, groups, and even myths that function as a consistent perspective. Conventional notions are susceptible to being overlooked and are employed in interpretation, comprehension, and the alignment of values in opposition to different ideologies. In social studies and the humanities, the concept of ideology is defined in different, sometimes equivalent and variant, but sometimes also contradictory ways:

1) ideology is the sum of all positive and pragmatic beliefs, values, modes of behaviour and acting shared by a group of theorists or agents, that is, members of culture or a specific distinguished formation within the framework of culture;

2) ideology is the sum of all the misconceptions, false beliefs, and effects of illusions shared by the members of a social stratum, class, nation, political party, a specific culture or world of art, which projects a possible, actual, and current world of existence;

3) ideology is the sum of all the symbolic and imaginary, arbitrary and artificial effects produced by the media system in places of expected reality, ideology posits us as objects among objects of consumption, seduction, and ecstasy, that is, ideology becomes, by means of its media realisation, a techno-multiplied new reality;

4) in its essence, ideology is a phantasm construction serving to prop up our reality, in other words, it is an illusion that structures effective social relations and hides traumatic social divisions or confrontations that cannot besymbolized, therefore its function is to provide us with a bearable social reality (Mako, 2014).

An examination of ideology introduces concepts such as “ideologist” and “ideologue.” An ideologue is a someone who subscribes to an ideology, characterized by a degree of inflexibility and dogmatism inherent in that commitment (Larina, 2010). Theory, on the other hand, is a generalization of notions that has been substantiated as true. It is a result of analysis. A theory must

undergo analysis prior to its proposal, and it should exhibit transparency. A theory functions as an analytical instrument for comprehending, elucidating, and forecasting a specific topic. It primarily addresses the intellectual dimensions of a subject, delineating its essence, yet frequently omits the practical considerations. It elucidates a phenomenon. In contrast to theories, ideologies represent the opinions or views of individuals within a group and may or may not be empirically tested concepts. The consciousness of individuals is a product of ideologies. Individuals" activities are often influenced by the ideals they espouse. Ideologies may exist consciously or unconsciously in an individual's head and can serve as the governing set of ideas within a certain community in which the individual resides. They are typically products of socialization, although may also originate within an individual's thinking and possess the potential to conflict with societal perspectives. The ideology of a specific society is maintained by the dominant party residing inside it and has the capacity to influence the general populace (Goldberger, 1971). As it is not derived from analysis, evidence, or logic, it is challenging to demonstrate the falsity of ideologies. Theories, however, possess a logical, evidence-based, and analytical foundation and can be falsified by evidence. Ideologies shape a community, whereas theories elucidate actual phenomena. Both ideologies and theories dominate nearly all cultures, imparting meaning to human existence by elucidating the authentic context of events.

Ideology also differs from philosophy in specific ways. Philosophy seeks to comprehend life and its guiding principles through a pragmatic lens, whereas ideology primarily focuses on perpetuating its existence and, at times, promoting it. The advocacy may occasionally embody a desire to better the conditions of a political party, governmental institution, ethnic group, or gender group, or to enhance the existing state of affairs. Philosophy reconciles with the existing reality by seeking to comprehend it as it is, although ideology may also aim at a future vision and the transformation of the present circumstances. Philosophy is objective, cognizant, and adaptable, but ideology is dogmatic, obstinate, and inflexible. Once established, ideology remains immutable despite alterations in the environment. Philosophy welcomes scrutiny and views it favorably, whereas ideology disregards it. It may, at times, even be aversive to difficulties. A philosopher is inclined to establish a foundation for life and other concepts, while simultaneously engaging in discourse and contemplation of other philosophies. A philosopher's receptiveness to criticism demonstrates open-mindedness. An ideologue will refute any challenge to his beliefs. Philosophy promotes critical thinking that transcends conventional thought patterns, whereas ideology inhibits any dissent from its foundational assumptions. Philosophy necessitates disciplined reasoning. Thus, this does not apply to ideology. An ideology encompasses a multitude of emotions. Philosophy, however, is neither detrimental nor beneficial, as it lacks any advocacy, avarice, or materialistic

motives. Conversely, an ideology has the potential to yield both beneficial and detrimental effects on society. It is due to its limited or nonexistent focus on addressing universal topics such as philosophy. Ideology necessitates an advocate to promote it and to transform other beliefs and thoughts to align with that specific ideology. Every ideology is underpinned by a foundational philosophy. Comparable distinctions and divergences exist between ideology and ethics. The moral values that direct an individual's behavior are referred to as ethics. While ethics pertains to the examination of moral principles, ideology represents an intrinsic value rather than a field of study. Morality, on the other hand, comprises innate values inherent to each individual. Ideology is founded on morals. An individual's ideology is shaped by the moral frameworks they endorse. A contrast exists between politics and ideology. Politics can be broadly described as the aggregate of pragmatic social behaviors and institutions through which a social relationship or order is established. Certain theorists differentiate between politics and the political. The political is described as the multitude of antagonisms that form human society (Mullin, 1982). Politics refers to social conflict and the efforts to address those social antagonisms, so striving to resolve the political framework that creates society. An ideology, in political and cultural contexts, is a coherent and defined assemblage of ideas, symbolic notions, values, beliefs, cognitive frameworks, behaviors, expressions, representations, and actions, collectively embraced by members of a specific social group or societal class. Consequently, ideology possesses the qualities of identificatory representation and perception. An individual's ideology encompasses their self-perception as a distinct entity within the framework of society, their role within a community, the community's identity as a collective, and consequently, their understanding of life, nature, and the world as phenomena relevant to the individual" (Mako, 2014). Karl Mannheim, in his historical analysis of the evolution of ideological meanings, asserts that the term "ideology" in contemporary usage originated when the politician Napoleon Bonaparte employed it to disparage "the ideologues" who opposed him. Building on Marx, Louis Althusser reconceptualized "ideology" as a depiction of the illusory connection between persons and their actual circumstances of life. An ideology have tangible life due to its active social manifestation. From this materialistic foundation, Althusser reached the following conclusions:

a) every practice is facilitated by ideology and manifests through ideology, and

b) ideology exists solely from the subject and for the subject. In this context, ideology constitutes a system of representations that performs the interpellation of individuals as subjects in relation to their actual social conditions.

Ideology is a representation of the fictitious relationship between individuals and their actual conditions of existence. Lacanian theoretical psychoanalysis,

building upon Althusser's work, asserts that ideology does not provide the subject with an escape from reality, but rather presents social reality itself as a means of evading a fundamental traumatic core inherent in human existence. According to Lacan, a phantasm is not an antithesis to reality, but rather the final foundation of what is termed reality. For example, Slavoj Žižek posits that ideology is not merely a dreamlike illusion created to evade unbearable reality; rather, at its core, it is a fantastical construct that underpins our very "reality": a "illusion" that organizes our actual social relations and conceals an intolerable, real, and impossible essence (Mako, 2014).

ARCHITECTURAL AND PLANNING IDEOLOGY

Le Corbusier, in his conceptualization of "The Radiant City," sought to address the issues of urban pollution and overpopulation; but, in contrast to Howard, he envisioned upward expansion rather than horizontal sprawl. His proposal, termed "Towers in the Park," advocated for multiple high-rise structures, each encircled by green spaces. Each structure was situated on what contemporary planners may scornfully label as 'superblocks," with distinct separations established between various functions, including residential areas, commercial centers, industries, and warehouses. Le Corbusier's concepts subsequently resurfaced in the construction of extensive public housing initiatives in the United States during the period of "urban renewal." The Land Ordinance of 1785 established a systematic grid of townships, each measuring 6 square miles, in the turbulent heartland west of the Ohio River, subdividing them into 36 square-mile pieces to promote an agrarian, land-owning culture. Its repercussions linger in all those perfectly perpendicular roads and square fields. Frank Lloyd Wright, in his concept for Broadacre City, further employed the geometry of agricultural grids in his vision for a utopia where each family resides on an acre of land. Such a density would have effectively disseminated suburbia throughout the entire nation. The Street Grid Concept denotes the straightforward, logical street grid that has historically been the preferred option for urban planners, which was largely abandoned in the United States during the 1950s as individuals migrated to suburbs. The 1852 map of San Francisco, years later, also disregarded the city's uneven coastline and geography (Mishra&Bhandari, 2018). Planners increasingly idealize subjects related to transportation, the environment, and the economy, not at the scale of communities or cities, but within regions where numerous metropolitan areas can interconnect. The concept of a "Megaregion" is not novel. The 1961 map in Jean Gottman's book Megalopolis depicts a continuous Northeastern Megaregion extending from Washington, D.C., to Boston. Planners have been conceptualizing transects as a graphical instrument for categorizing landscapes into various purposes. Conceived by architect Andres Duany, this model elucidates the continuum between rural and urban environments and has emerged as a favored paradigm among New Urbanists (Spacey, 2016).

Artists and architects who embraced situationism in the mid-20th century subscribed to the belief that cities should be perceived as they are experienced by individuals, rather than how they are conceived through a top-down methodology by architects and planners. That was a period during which they opposed contemporary urban renewal initiatives. Their method fostered a novel viewpoint in planning, emphasizing bottom-up citizen experience and effort. The Hockey Stick approach represents a distinct worldview in urban planning that is mostly unrelated to the field. Michael Mann, a climate scientist, illustrates the temperature increase in the Northern Hemisphere from the onset of the Industrial Revolution. SPUR establishes connections between smart growth and climate change. Grant asserts, "This has emerged as the central narrative of 21st-century planning; the notion that the configuration of cities, settlement patterns, and their climatic repercussions are intrinsically linked is profoundly compelling." Numerous more concepts can be encompassed under the tale. Ideology aims to assert a state that is self-evident. Ideology so thoroughly delineates reality that we occasionally struggle to conceive that our perception of reality could differ. This reinforces our perspective on structures, rendering the significance we attribute to them seemingly accurate and indisputable. Upon acquiring a conventional suburban residence, the location of the living room is unmistakable, despite the absence of signage indicating its position or the placement of the sofa. Our visit to the ranch house, however, revealed that the residents were bewildered and on the verge of an abnormal act when furnishing the living room. Ideology, a curtain obscuring our perception, seeks transparency to clarify the connection between certain meanings and objects, while concealing its role in perpetuating the arbitrary assignment of meaning.

Robert Venturi, a prominent architectural character of the twentieth century, is an American architect who influenced the perceptions of architects, students, and planners regarding architecture and the constructed American environment. His planning and constructions, coupled with theoretical papers and pedagogy, have contributed to the expansion of discourse on architecture and planning. He refers to Las Vegas as his preferred destination. His actions are not motivated by a penchant for gambling, alcohol consumption, or nightlife activities. He states that what he appreciates about Las Vegas is its architecture. What renders that unusual is that, as Venturi acknowledges, architects are generally not expected to appreciate Las Vegas. Venturi not only dismisses the apprehensions of his architectural peers regarding the crude and unrefined nature of Las Vegas's POP architecture, but he also audaciously contends that a meticulous examination of the commercial corridor of the American highway, exemplified by Las Vegas, may hold as much significance for contemporary architects and urbanists as the analyses of Medieval Europe and ancient Rome and Greece did for earlier generations.

The Venturis" perspectives on design could be deemed counterrevolutionary. They favor incremental planning over comprehensive utopian schemes. They prefer the conventional economic structures alongside the roadways, symbolizing architectural vernacular, above the intricate designs of esteemed modern architects (Paul, 1971). One who is wholly willing to embrace the current circumstances, as Robert Venturi articulated in his work, Complexity and Contradiction in Architecture, may be regarded as revolutionary. The urban expansion exemplified by Main Street and Las Vegas is expected to persist. Architects and planners ought to embrace the ideology of the Venturis, or at the very least, learn to engage with it effectively. Denise Venturi states, "There is no acceptable method to contaminate land, air, or water; however, what is referred to as visual pollution, typically concerning another's residence or establishment, is distinct." Venturi asserts in his book, "We can master the strip and urban sprawl; the apparently chaotic juxtapositions of honky-tonk elements convey a fascinating form of vitality and legitimacy." In his book, Learning from Las Vegas, Venturi acknowledged that his interest in connecting such concepts to his work is partially polemical. According to him, contemporary planning is superficially remarkable yet fundamentally a display of exhibitionism. His worldview posits that modern architecture has yet to adequately represent the ordinary, which is insufficient for something as complex as a city. His worldview posits that we require a more modest methodology and a reduction in a prima attitude to the landscape.

CONCLUSION

Architecture and planning have always been shaped as reflections of social, economic, and political power relations. Therefore, it is impossible to consider architectural production processes as an act independent of ideology. Every spatial decision reveals a particular worldview, lifestyle, and value system. Design is not only the organization of the physical environment; it is also a field of ideological discourse where specific social relations, hierarchies, and identities are reproduced. In this context, planning processes often become powerful tools mediating the representation of dominant ideologies on space.

While the modernist approach to planning is presented as a neutral practice with claims of rationality and universality, it has actually legitimized the spatial organization of a particular social order. Similarly, contemporary neoliberal planning approaches extend market-oriented ideological orientations to the spatial scale, redefining public spaces around economic efficiency and capital accumulation rather than principles of social justice and participation. Therefore, planning is not merely a technical activity but also an ideological process of construction.

Consequently, the claim of neutrality within the disciplines of architecture and planning conceals the influence of ideology on spatial formation. The production

of space always bears the traces of a particular power structure, economic system, and cultural ideology. Therefore, a critical evaluation of architectural and urban production processes is crucial for revealing the transformative power of ideology and developing a more equitable and inclusive spatial vision of the future.

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CHAPTER 3

Piezoelectric Materials for Sustainable and Energy-Efficient Buildings

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1. INTRODUCTION

Buildings account for roughly 35–40% of global energy consumption and a notable share of CO_2 emissions (Chen et al., 2019). As a result, interest has grown in material systems that help lower operational demand. One group receiving attention is piezoelectric materials, which generate electrical signals when mechanically deformed and respond mechanically to electric fields. This dual behavior makes them appealing for building components that operate with some self-sufficiency or require minimal external power.

Over the past few years, developments in materials science have widened the range of piezoelectric ceramics, polymers, and composite mixes available for architectural use (Safaei et al., 2019; Aydın & Çelebi, 2023). These materials have been installed in floor assemblies, facade elements, and occasionally within structural layers to capture small amounts of energy from walking, service vibrations, or wind-driven facade movement. At the same time, their ability to function as sensors has aligned well with ongoing interest in real-time monitoring and adaptive building control (Sharma et al., 2022). Together, these trends have encouraged experimentation with piezoelectric systems across different building contexts.

Despite this interest, most practical applications remain at the prototype or pilot scale. Several factors limit broader adoption: durability concerns, modest power output, installation and wiring complexity, and the cost and stability of some material systems. Case studies, such as piezoelectric flooring in educational or public facilities, show that outcomes vary widely depending on footfall intensity, material type, and system configuration (Rumman & Elnaklah, 2024). These differences highlight the need for a clearer understanding of piezoelectric material behavior, their electromechanical limits, and the conditions for effective integration into building systems.

This review examines the current state of piezoelectric materials in energy-efficient and adaptive building design. It outlines the electromechanical principles that enable energy harvesting and sensing, describes the material classes relevant to architectural applications, and reviews recent building-scale experiments, ranging from piezoelectric flooring to facade-integrated harvesters and embedded monitoring layers. It also discusses persistent constraints such as durability, long-term stability, and practical challenges in integrating construction, and considers potential pathways for incorporating piezoelectric technologies into future building systems.

2. FUNDAMENTALS OF PIEZOELECTRICITY

The piezoelectric effect, discovered by the Curie brothers in 1880, is the ability of certain materials to generate an electrical charge under mechanical stress and deform when exposed to an electric field (Curie & Curie, 1880). Once limited to a few natural crystals, it is now known to occur in ceramics, polymers, and some biological materials (Kawai, 1969). Perovskite-based ceramics, in particular, offer high energy conversion efficiency and can be used as thin films or embedded layers, making them promising for building applications such as facades, floors, and structural components that can harvest energy or sense mechanical stress (Sharma et al., 2022). In architectural contexts, this ability to simultaneously detect, respond to, and convert mechanical energy offers new opportunities for creating self-sensing and self-powered building components.

Piezoelectric energy harvesting has been investigated across various sources of mechanical energy, including acoustic vibrations, water and wind flow, and human or vehicular motion. The generated electrical output typically consists of alternating current in the microampere range and voltages of a few volts, which power regulation circuits can condition. Although the absolute power levels are relatively small, the continuous and ubiquitous nature of mechanical excitations in buildings, footsteps, facade vibrations, and equipment operation makes piezoelectricity an appealing supplementary energy source for low-power systems such as sensors, LEDs, and wireless communication modules. Beyond conventional energy generation, recent studies have also demonstrated piezocatalytic and piezoelectrochemical applications, such as water purification and hydrogen production, indicating the expanding multifunctional potential of piezoelectric systems in sustainable technologies (Sharma et al., 2022). The emergence of these additional functionalities highlights the growing relevance of piezoelectric materials within sustainable technologies and opens opportunities for integrated environmental remediation within building systems.

Figure 1 illustrates the fundamental working principles of piezoelectric materials, covering both the direct and inverse effects. In the direct effect, mechanical loading generates electrical charge: compression (Figure 1a) aligns internal dipoles (P), producing a voltage with a positive top and negative bottom surface. Conversely, tension (Figure 1b) reduces dipole alignment, reversing the voltage polarity. In the inverse effect, an externally applied electric field generates mechanical deformation: when aligned with the polarization (Figure 1c), the material elongates; when applied in the opposite direction (Figure 1d), it contracts. These coupled electromechanical behaviors form the physical foundation for using piezoelectric materials as both energy harvesters and electrically driven actuators in advanced building applications.

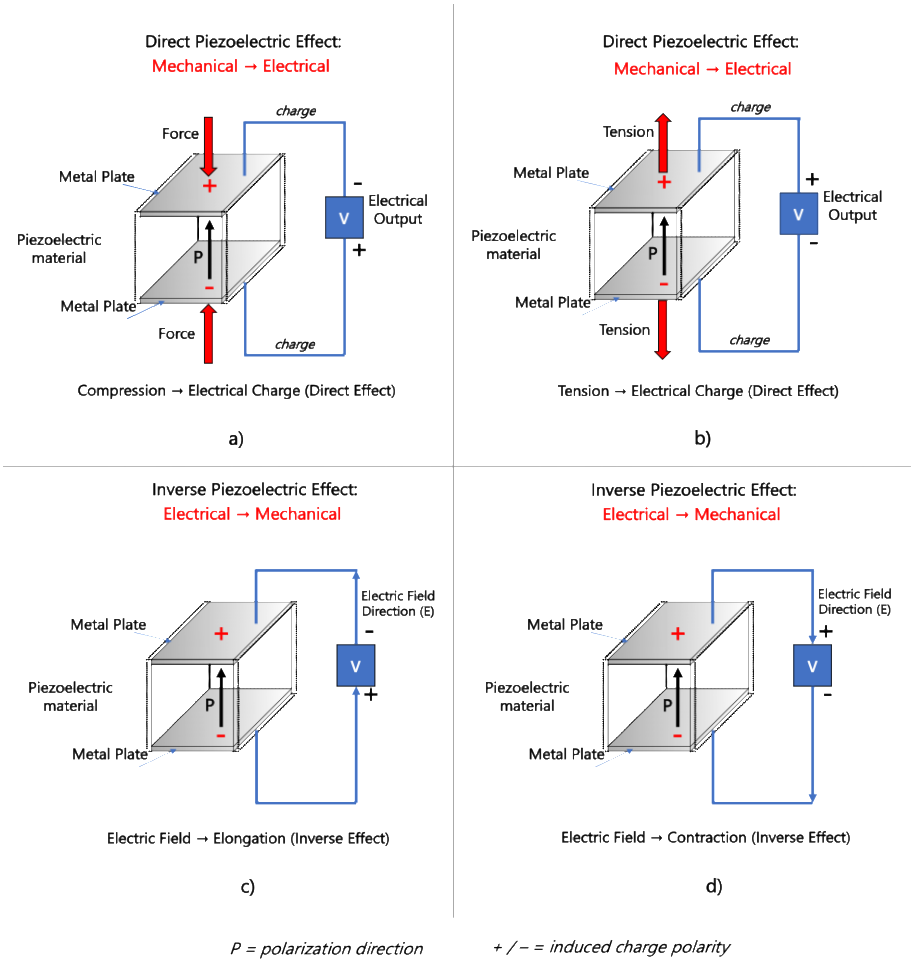

Figure 1. Piezoelectric material behavior: a) direct effect under compression; b) direct effect under tension; c) inverse effect causing elongation; d) inverse effect causing contraction. (developed by the author based on insights from the literature).

3. PIEZOELECTRIC MATERIALS AND THEIR CHARACTERISTICS

Piezoelectric materials, which generate electrical energy under mechanical stress and deform under an electric field, play a vital role in integrating renewable energy generation and self-monitoring capabilities within buildings. Their unique electromechanical behavior enables them to serve as both sensors and actuators, making them key components in sustainable, intelligent building systems.

The energy conversion efficiency of piezoelectric systems depends strongly on material properties (PZT, PVDF, $BaTiO_3$) and resonance frequency tuning to match dynamic mechanical excitations (Shehu et al., 2024). Piezoelectric

materials used in architectural systems exhibit two fundamental behaviors: the direct and inverse piezoelectric effects, in which mechanical stress or applied electric fields generate electrical or mechanical responses, respectively. Understanding this dual behavior is essential for integrating these materials into building elements such as facades, floors, and innovative structural components.

To provide a clear and architecture-oriented framework, piezoelectric materials can be categorized into three groups: (i) inorganic materials, (ii) organic materials, and (iii) composite or cement-based materials. This grouping synthesizes classifications found in previous studies (Shehu et al., 2024; Jue et al., 2022; Aydın & Çelebi, 2023) and aligns them with applications relevant to the built environment.

3.1. Inorganic Piezoelectric Materials (Crystalline & Ceramic)

Inorganic materials include natural crystals (e.g., quartz, tourmaline) and widely used ceramic materials such as lead zirconate titanate (Pb(Zr, Ti)O3,PZT) and barium titanate ($BaTiO_3$). Crystalline materials offer stable and repeatable piezoelectric responses due to their regular lattice structures, resulting in consistent performance in sensing and actuation applications (Habib *et al* 2022). However, their inherent hardness and brittleness create challenges in applications requiring mechanical flexibility or complex shapes, and their processing often requires high temperatures and precise control, which can increase manufacturing costs. Ceramics, especially PZT, provide high electromechanical coupling, excellent sensitivity, and durability, making them suitable for energy harvesting, vibration sensing, and structural health monitoring. They also exhibit exceptional durability and chemical stability, ensuring long service life even in harsh environmental conditions (Liu et al. 2025). These properties make ceramic piezoelectrics highly suitable for energy harvesting, vibration sensing, and structural health monitoring in various industries (Gao et al., 2020). However, ceramics are generally brittle and prone to fracture under tensile stress, limiting their use in flexible or impact-sensitive devices. Environmental concerns over lead-containing ceramics have encouraged the development of lead-free alternatives (Shehu et al., 2024; Aydin & Celebi, 2023).

3.2. Organic Piezoelectric Materials (Polymeric)

Organic piezoelectric materials, most notably polyvinylidene fluoride (PVDF) and its copolymers, offer flexibility, a lightweight structure, and resistance to mechanical fatigue. These characteristics make them ideal for building applications involving repeated deformation, such as flooring systems, curtain walls, ventilated facades, and layered building envelopes. Recently, the significance of polymeric piezoelectric materials has grown because polymers are

more resistant to breaking and less brittle than ceramics, making them better suited for large and complex applications. Polymers are also advantageous for producing large-area piezoelectric films and sensors due to their processability and low cost (Bischur & Schwesinger, 2012).

PVDF is widely used as insulation in electrical cables because it is flexible, resistant to high temperatures and chemicals, has low thermal conductivity, and is lightweight. PVDF's piezoelectric properties enable its use in tactile sensor arrays, affordable strain gauges, and lightweight sound transducers. Besides PVDF, other piezoelectric polymers include Parylene C, cycloolefin polymers (COP), microfibrillated cellulose (MFC), and polypropylene (PP). Additionally, PVDF, polypropylene, and fluorinated ethylene propylene (FEP) are used in accelerometers due to their high sensitivity and ability to operate at high frequencies (Aydın & Çelebi, 2023).

3.3. Composite and Cement-Based Piezoelectric Materials

Composite piezoelectric materials, including piezoelectric nanocomposites, cementitious materials, and polymer-matrix composites, aim to embed sensing and energy harvesting directly into structural components. Recent research focuses on cement-based materials with piezoelectric inclusions or intrinsic electromechanical responses, enabling smart concrete elements capable of both structural monitoring and energy generation (Aydın & Çelebi, 2023). These multifunctional composites support the development of self-powered, low-energy buildings by merging load-bearing performance with embedded intelligence.

Recent reviews highlight that piezoelectric energy harvesting has expanded from laboratory-scale devices to infrastructure systems, including roads, bridges, and building floors, demonstrating the potential for scalable integration (Shehu et al., 2024). In summary, while ceramic materials like PZT remain benchmarks for performance, polymer-based alternatives such as PVDF and emerging cementitious composites are the most promising options for incorporating piezoelectric functionality into sustainable building systems, balancing efficiency, flexibility, and environmental responsibility. Although recent reviews emphasize the versatility of piezoelectric systems, challenges remain in large-scale implementation, particularly regarding durability under cyclic loading and integration within complex infrastructure (Shehu et al., 2024).

Table 1 summarizes the main categories of piezoelectric materials relevant to architectural applications, highlighting representative examples, key properties, advantages, and limitations. The table also establishes the link between material behavior and the specific building components, such as floors, facades, and

structural elements, where piezoelectric technologies are most effectively applied.

Building on the material-level understanding of piezoelectric mechanisms, the next section explores how these properties are used in architecture. Specifically, Section 4 looks at how piezoelectric materials are applied in buildings, focusing on energy harvesting, innovative flooring systems, and integrated monitoring technologies.

Table 1: Piezoelectric Materials and Their Characteristics

Category	Example Materials	Key Properties	Advantages	Limitations	Building Application
Inorganic Piezoelectric Materials (Crystals & Ceramics)	Quartz, Tourmaline, Rochelle Salt; PZT ($Pb(Zr,Ti)O_3$); $BaTiO_3$; Lead-free ceramics (KNN, BNT-BT)	High piezoelectric coefficients (especially ceramics); High thermal stability; Strong electromechanical coupling	High output; Durable; Well-validated in engineering applications	Brittle; Crystals difficult to process; PZT contains lead	High-performance energy harvesting tiles; facade modules; embedded structural sensors; vibration monitoring
Organic Piezoelectric Materials (Polymers)	PVDF, PVDF-TrFE, PAN, Nylon-11	Flexible, lightweight, fatigue-resistant; Lower piezoelectric coefficients but high strain capability	Easy to fabricate; Conformable to curved/complex surfaces; Good environmental stability	Lower electromechanical efficiency than ceramics; Long-term polarization stability concerns	Curved facades; flexible building skins; laminated floor layers; occupant-interaction surfaces; airflow-induced vibration harvesting
Composite & Cement-Based Piezoelectric Materials	PZT-PVDF composites; PVDF-$BaTiO_3$ blends; Piezoelectric nanocomposites (CNT-PVDF, ZnO-PVDF); Cement-based piezoelectric concrete	Tunable properties (ceramic output + polymer flexibility); Ability to embed sensing / energy harvesting in structures	Scalable; Suitable for structural integration; Multifunctional (load-bearing + sensing)	Fabrication uniformity; Performance stability; Early-stage research for large-scale use	Smart concrete; self-sensing pavements; energy-active flooring; structural health monitoring elements

4. APPLICATION OF PIEZOELECTRIC MATERIALS IN BUILDINGS

Buildings are continuously exposed to various forms of vibration originating from human activities, machinery, traffic loads, wind, and seismic events. Piezoelectric materials have promising applications in energy harvesting and structural monitoring within sustainable buildings (Dubey et al., 2025). Integrating piezoelectric materials into structural components enables the conversion of mechanical stresses into electrical energy while also providing a means to monitor and control vibrational behavior. Because they can directly convert mechanical strain into electrical energy, piezoelectric materials are well-suited for use in sensors, actuators, and energy-harvesting systems in civil and architectural applications (Dubey et al., 2025). This dual functionality allows buildings to partially generate their own energy partially, thereby reducing dependence on conventional energy sources and contributing to sustainable operation. Beyond energy production, piezoelectric elements can serve as embedded generators to power auxiliary systems, such as ventilation or water heating, and as sensing units to detect structural responses during dynamic events, such as earthquakes. Hence, the strategic incorporation of piezoelectric materials into building systems offers both environmental and resilience-oriented benefits (Sodano et al., 2004; Aydın & Çelebi, 2023). In bridging material science and architectural applications, research also explores how common structural materials can enhance the role of piezoelectricity in buildings.

Recent research has also emphasized the potential of cement-based materials to exhibit piezoelectric behavior, offering opportunities to develop multifunctional structural components for energy harvesting and self-powered sensing. As one of the most widely used construction materials, cement's piezoelectric properties could enable low-life-cycle-energy buildings by integrating energy generation, monitoring, and structural control within the same material system (Chen et al., 2019). Although piezoelectric materials have been widely applied in civil engineering for functions such as structural control, vibration mitigation, and health monitoring, these principles are increasingly being used at the building scale. In sustainable architecture, piezoelectric systems serve not only as structural sensors but also as integrated energy-harvesting components within facades, floors, and other envelope elements, supporting both energy efficiency and real-time performance monitoring (Aydın & Çelebi, 2023).

To illustrate these multifunctional applications, Figure 2 presents the working principles of piezoelectric materials integrated into buildings. The schematic demonstrates how mechanical energy from footsteps or wind-induced facade vibrations is converted into electrical power through piezoelectric elements. This harvested energy is then rectified and stored, enabling its use in low-power building systems, such as lighting, sensors, and innovative control mechanisms. The figure highlights both floor-based and facade-integrated approaches, emphasizing how piezoelectric technology can contribute to energy self-sufficiency and intelligent performance management in sustainable architectural design.

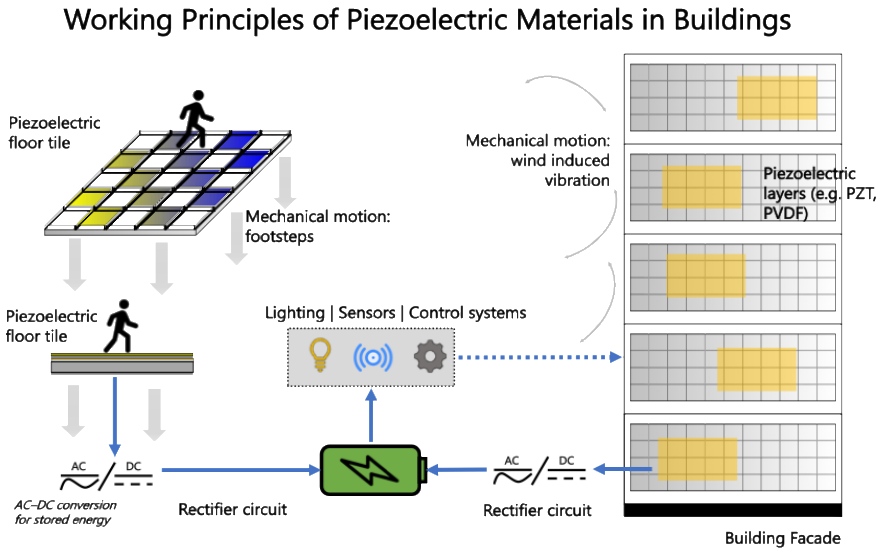

Figure 2. Working principles of piezoelectric materials in buildings. Mechanical motion from footsteps and wind-induced vibrations is transformed into electrical energy by piezoelectric layers (e.g., PZT, PVDF) in floors and facades. The harvested energy is rectified, stored, and used to power lighting, sensors, and intelligent control systems for energy-efficient operation (developed by the author based on insights from the literature).

4.1. Energy harvesting methods

Energy harvesting converts unused mechanical energy into electricity. Due to their high-power density, structural simplicity, and scalability, piezoelectric materials are among the most promising innovative materials for this purpose (Toprak & Tigli, 2014). They generate electrical charge under mechanical stress, typically using non-conductive compounds such as PZT between conductive electrodes (Lu et al., 2021).

Energy harvesting systems have emerged as a practical approach to addressing global energy challenges without depleting natural resources. Such systems typically consist of two main components: a microgenerator that converts mechanical energy from the environment into electrical energy, and a voltage regulation unit that amplifies and stabilizes the output. Piezoelectric materials, particularly PZT and PVDF, play a central role in these systems as electromechanical transducers, converting mechanical stress into electrical energy for structural and architectural applications (Aydın & Çelebi, 2023).

Piezoelectric energy harvesting has been widely explored in smart cities and architectural contexts, where Al Ahmad & Allataifeh converted vibrations from pedestrians, vehicles, or wind into electrical energy (Al Ahmad & Allataifeh,

2018). Within buildings, piezoelectric systems enable the bidirectional conversion of mechanical strain and electrical potential (Xie et al., 2015).

Power generation from piezoelectric modules can occur through two primary mechanisms: hitting and vibrating. In the hitting approach, mechanical energy is transferred directly to the piezoelectric elements, resulting in higher power output compared to the vibrating method. However, this direct impact often causes material fatigue or fracture, particularly in ceramic-based piezoelectric modules, which are brittle under sudden stress. Consequently, the vibrating method, where the modules generate electricity through oscillatory or cyclic deformation, has been more extensively investigated due to its enhanced durability. To overcome the fragility issue while maintaining efficiency, some systems adopt an indirect energy transfer design, incorporating components such as springs and tip masses to moderate the impact forces acting on the piezoelectric tiles (Hwang et al., 2015).

Recent research increasingly focuses on human-motion-based energy harvesting using piezoelectric tiles and pavements that capture mechanical energy from footsteps and convert it into electricity. When applied across large surfaces, these systems function as distributed energy sources within high-traffic zones. However, despite growing research, detailed evaluations of their mechanical design, long-term efficiency, and real-world performance remain limited (Sharma et al., 2022). Among the various approaches to piezoelectric energy harvesting, flooring systems have attracted particular attention for their direct interaction with building occupants. These systems convert the repetitive mechanical motion of footsteps into electrical energy, making them well-suited for integration into high-traffic architectural spaces such as corridors, campuses, and transportation hubs.

4.2. Flooring systems: Human Traffic Energy Harvesting

With growing populations and rising energy demands for indoor comfort, building energy use has increased significantly over the past few decades. This trend presents opportunities to harvest mechanical energy from human movement within buildings. Piezoelectric flooring tiles have emerged as one of the most promising solutions, especially in high-traffic environments such as transit stations, campuses, and shopping centers. Studies have reported energy outputs ranging from a few watt-hours per day in small sensor systems to several megawatt-hours annually in educational and commercial buildings, and even up to 1 GWh per year in large-scale infrastructure. Although this accounts for roughly 0.01%–5% of total building energy demand, it is sufficient to power

lighting, sensors, and low-energy systems, contributing to sustainability and occupant awareness of renewable energy technologies.

Building on this potential, Wu et al. (2010) developed a high-efficiency piezoelectric floor system for intelligent buildings designed to both harvest energy and detect occupant movement. Using a cantilever beam mechanism with a "plucked" excitation method, the system achieved nearly 10 times the energy output of conventional forced-vibration methods, producing up to 20 V at low frequencies. The generated power was sufficient to operate wireless transmitter modules for occupant tracking, marking one of the earliest demonstrations of a dual-function piezoelectric floor capable of both energy generation and smart sensing in buildings. Li and Strezov (2014) evaluated the energy harvesting potential of piezoelectric floor tiles in a university library, focusing on optimizing tile placement in high-traffic areas. Using Pavegen tiles, they showed that covering only 3.1% of the floor area could generate about 1.1 MWh annually, increasing to 9.9 MWh with improved conversion efficiency. Their Density Flow indicator revealed that tile placement significantly affects energy yield. The system also showed potential to offset part of the building's energy use and reduce over 10 tons of CO_2 annually, confirming the feasibility of piezoelectric floors in educational settings. Expanding on optimization and design improvements, Hwang et al. (2015) designed and optimized a piezoelectric floor tile that converts footstep impact into electricity through mechanical and electrical resonance tuning. To prevent ceramic module fracture, the team employed an indirect energy-transfer system using springs and a tip mass to match the tile's resonance frequency (≈22.5 Hz) with that of the piezoelectric module. Under optimal conditions, the system generated 770 mW RMS and 55 mW peak power, enough to illuminate a 60-chip LED lamp. The study demonstrated how mechanical resonance and impedance matching can substantially enhance energy conversion efficiency in floor-based piezoelectric systems for architectural applications.

As the technology evolved toward practical applications, Elhalwagy et al. (2017) conducted a feasibility study on integrating piezoelectric flooring into low-energy building designs, comparing systems such as Waynergy, SEF, and Pavegen in terms of cost, power output, and pedestrian density. Using case studies in Cairo, a metro station and a residential apartment, they developed a life-cycle cost model to evaluate energy and economic performance. Results showed that in dense public spaces, these systems could achieve cost savings of up to 99%, whereas in low-traffic settings, they remained less viable. The study emphasized the role of pedestrian flow analysis and hybrid energy approaches to improve performance and feasibility in architectural applications. In parallel,

Mondal et al. (2017) explored solar-based pedestrian walkways as complementary energy systems for urban areas. Using PVsyst modeling, they simulated photovoltaic walkway modules integrated with micro-inverters, achieving a performance ratio of 78.6% and generating 50.25 MWh annually. While not purely piezoelectric, this study provided valuable insights into the scalability, cost, and potential for hybrid integration of renewable pavement technologies.

Addressing large-scale public infrastructure, Chew et al. (2017) evaluated the feasibility of installing piezoelectric tiles at Kuala Lumpur International Airport (KLIA) to capture energy from passenger movement. Using the TEMIF framework (Technical, Environmental, Managerial, Institutional, Financial), they assessed adoption barriers and sustainability benefits. Each tile, costing about RM 540, produced roughly 3.8 J per footstep, and large-scale installation could yield about 130 kWh per day, enough to power 18,000 LED lights, with an estimated six-month payback when scaled to 1,000 tiles. The study emphasized piezoelectric flooring as a viable complement to solar systems for airports, while noting material durability and long-term financial feasibility as key challenges. Progressing further, Solban and Moussa (2019) examined piezoelectric tiles as sustainable design solutions for interior and public spaces, particularly in regions with energy shortages such as Egypt. Comparing several commercial systems, including Waynergy, Sustainable Energy Floor (SEF), Pavegen, Sound Power, and PVDF-based parquet layers, they analyzed differences in power output, cost, and lifespan. Across multiple case studies, including Club Watt in Rotterdam, Tokyo Station, and the Ponte 25 de Abril Bridge, their findings showed that piezoelectric floors could supply 30–65% of localized energy demand and significantly reduce CO_2 emissions. Despite challenges related to durability, efficiency decay, and installation costs, the study underscored the potential of these systems for self-sustaining architectural applications in high-footfall environments.

Extending applications to outdoor spaces, Moussa (2020) investigated energy harvesting in children's outdoor play areas to promote healthy and sustainable environments. Conducted at El-Shams Sporting Club in Cairo, the study used Sustainable Energy Floor (SEF) tiles and found that installing 260 tiles generated approximately 1,820 kWh/day, meeting 83% of the area's energy demand, and reducing CO_2 emissions and electricity bills by 77%. The study highlighted outdoor recreational spaces as a promising context for visible and educational piezoelectric applications. At the urban infrastructure scale, Lewandowska et al. (2020) investigated the use of piezoelectric energy-harvesting pavements to generate electricity from pedestrian motion. Combining laboratory testing with

finite element analysis (FEA), the study evaluated PZT-based modules embedded in pavement slabs under realistic footstep loads. The results showed that these systems could produce sufficient power for low-energy applications such as lighting and sensors, supporting their integration into smart urban infrastructure. However, long-term performance remains limited by material durability, weather resistance, and maintenance challenges.

Moussa et al. (2022) investigated piezoelectric flooring at Rod El-Farag Metro Station in Egypt, which serves approximately 57,000 passengers daily. Two commercial systems, Sustainable Energy Floor (SEF) and Waynergy, were evaluated through energy-use data and passenger-flow modeling. Twelve SEF tiles produced about 4,788 kWh per day, while eight Waynergy tiles generated 4,560 kWh per day, together covering nearly the station's total energy demand. Waynergy exhibited slightly higher efficiency and lower cost, confirming the feasibility of self-sustaining floor systems for transportation infrastructure, though scalability and durability remain significant concerns. Rumman and Elnaklah (2024) examined the energy-generation potential of piezoelectric flooring in an academic building at Al-Ahliyya Amman University. Using SimWalk simulations, field observations, and a feasibility experiment, they compared Pavegen and Energy tiles under real traffic conditions. Results showed that Energy tiles could meet up to 62% of the building’s daily energy demand, offering substantial long-term savings and a favorable return on investment despite high initial costs. Their comparative analysis with photovoltaic systems highlighted piezoelectric floors as competitive, space-efficient, and weather-independent options for high-footfall educational facilities.

Overall, the reviewed studies reveal steady progress in piezoelectric flooring research, evolving from laboratory prototypes to real-world installations. Reported outputs range from milliwatt levels in experimental setups to several megawatt-hours annually in extensive facilities. Power generation strongly depends on footfall density, tile materials, and placement. Although SEF, Waynergy, and Pavegen tiles have proven effective across contexts such as schools, metro stations, and airports, challenges of cost and durability persist. Still, the transition from concept to practical application underscores the growing potential of piezoelectric flooring as a clean-energy solution for sustainable design. Table 1 below summarizes the most notable studies in this field, outlining their objectives, methods, and key findings.

As summarized in Table 2, the reviewed studies collectively demonstrate the evolution and performance diversity of piezoelectric flooring and pavement systems across experimental and real-world contexts. Energy outputs range from sensor-level power generation in small-scale prototypes to nearly full energy

coverage in extensive public facilities such as metro stations. Key influencing factors include tile technology, footfall intensity, installation context, and maintenance conditions. Despite limitations related to durability, cost, and scalability, these findings confirm the growing feasibility of piezoelectric flooring as a supplementary renewable energy strategy within sustainable architecture. Building on these developments, recent research has expanded to integrate piezoelectric materials into structural and monitoring components, where they serve dual functions: energy harvesting and structural health assessment.

Building on the success of piezoelectric flooring systems, recent research has extended energy-harvesting concepts to vertical and envelope elements of buildings. These efforts seek to transform facades and structural components into active energy-generating layers that respond to wind, vibration, and environmental stress while maintaining architectural functionality and aesthetics.

4.3. Facade Integration for Energy Harvesting

Recent advances have also explored hybrid multifunctional energy-harvesting surfaces that combine piezoelectricity with other renewable conversion technologies. For instance, Mukilan et al. (2025) proposed a sustainable tile integrating solar photovoltaic, thermoelectric, and piezoelectric systems into a single layered structure. Their results demonstrated a significant improvement in power density and conversion efficiency compared to individual systems. Although their study focused on flooring applications, the underlying concept of multi-mechanism energy harvesting provides a transferable framework for vertical applications such as building facades. In facade systems, a similar hybrid integration could enable simultaneous use of solar radiation, temperature gradients, and wind-induced vibrations, thereby enhancing the total renewable energy output of the building envelope. A recent study by Pracucci et al. (2024) demonstrated the integration of piezoelectric energy-harvesting cantilevers into ventilated facade systems to capture wind-induced vibrations for powering fiber-optic sensors. Their InComEss architecture combines piezoelectric generators, supercapacitors, and IoT-based monitoring platforms to enable self-powered facade monitoring. The study confirms the potential of piezoelectric facades to contribute to energy autonomy and smart envelope functions, though limited power density and environmental sensitivity remain challenges for large-scale applications.

Table 2. Summary of piezoelectric flooring and pavement studies

Reference	Objective & Scope	Methodology	Materials Used	Key Findings	Application Types	Gaps & Limitations
Wu et al. (2010)	Develop high-efficiency piezoelectric floor for smart buildings	Experimental testing with plucked excitation method	Piezoelectric cantilever beam structure	Generated up to 20 V, ~10× higher energy than conventional; powered wireless sensors	Intelligent building floors	Energy stability, integration cost
Li & Strezov (2014)	Assess energy harvesting potential of piezoelectric floors in educational buildings	Simulation and spatial optimization study	Pavegen tiles	3.1% floor coverage produced 1.1–9.9 MWh annually; reduced 10 tons CO_2/year	University library floors	Tile placement sensitivity, efficiency improvement
Hwang et al. (2015)	Design and optimization of piezoelectric tile for footstep energy harvesting.	Experimental study with frequency and impedance matching.	PZT–PZNM piezoelectric modules with springs and tip masses.	Optimized 10-g tip mass achieved resonance at 22.5 Hz, harvesting 770 mW RMS and 55 mW peak power, capable of powering a 60-chip LED lamp.	Indoor floors, smart pavements.	Fragility of ceramic modules and lack of large-scale application data.
Elhalwagy et al. (2017)	Feasibility of piezoelectric floors for energy harvesting in interior spaces	Feasibility study and case analysis	Pavegen, Waynergy tiles	Up to 99% cost savings in high-traffic zones; effective for smart applications	Metro stations, residential interiors	Limited viability in low-footfall areas

Table 2. Summary of piezoelectric flooring and pavement studies (continued)

Reference	Objective & Scope	Methodology	Materials Used	Key Findings	Application Types	Gaps & Limitations
Mondal et al. (2017)	Design of solar paved pedestrian walkways for urban energy generation	Simulation and pilot system design (PVsyst modeling)	Photovoltaic walkway modules with micro-inverters	Produced 50.25 MWh/year with 78.6% performance ratio	Pedestrian walkways, urban infrastructure	Cost, shading losses, scalability challenges
Chew et al. (2017)	Feasibility of piezoelectric tile adoption at KLIA, Malaysia	Qualitative feasibility study using TEMIF framework	Lead Zirconate Titanate (PZT) tiles	1,000 tiles could harvest 130 kWh/day (powering ~18,600 LEDs); six-month payback period; promotes renewable mix for airports	Airport terminals, public buildings	High initial cost, uncertainty in adoption rate
Solban & Moussa (2019)	Evaluate piezoelectric tiles for sustainable interior and public spaces	Comparative analysis and multiple case studies	Waynergy, SEF, Pavegen, Sound Power, PVDF tiles	Achieved 30–65% energy savings and CO_2 reduction; feasible for self-sustaining projects	Interior floors, bridges, metro stations	Durability, efficiency decay, high initial costs
Moussa (2020)	Study on energy harvesting in children's outdoor play areas to promote healthy environments	Quantitative analysis of El-Shams Sporting Club, Cairo	Sustainable Energy Floor (SEF) tiles	Installing 260 tiles generated 1,820 kWh/day (≈83% of demand); reduced CO_2 and energy bills by 77%	Outdoor play areas, recreational facilities	High initial cost, maintenance, and scalability limitations

Table 2. Summary of piezoelectric flooring and pavement studies (continued)

Reference	Objective & Scope	Methodology	Materials Used	Key Findings	Application Types	Gaps & Limitations
Lewandowska et al. (2020)	Investigate piezoelectric pavements for urban energy harvesting	Laboratory testing, finite element analysis (FEA)	PZT-based modules	Produced power suitable for low-energy applications like lighting or sensors	Pavements, pedestrian walkways	Durability, weather resistance, maintenance issues
Moussa et al. (2022)	Evaluate piezoelectric floor tiles in a metro station for energy generation	Empirical assessment, energy-use modeling	SEF and Waynergy tiles (piezoelectric systems)	Generated up to 4788 kWh/day, meeting nearly 100% of station demand; Waynergy had higher efficiency	Flooring systems, transportation infrastructure	Scaling, cost, and durability challenges
Rumman & Elnaklah (2024)	Investigate energy generation potential of piezoelectric flooring in educational buildings	Simwalk simulation, field observation, feasibility experiment	Pavegen and Energy tiles	Energy tiles met up to 62% of daily energy demand; competitive with PV systems	Educational buildings, academic spaces	High initial costs, long-term durability

4.4. Structural Health Monitoring and Smart Sensing Systems

Pracucci et al. (2024) further demonstrated that piezoelectric facade modules could not only harvest ambient wind energy but also supply power to low-energy fiber Bragg grating (FBG) sensors for real-time structural health monitoring, forming part of an IoT-enabled network. This integration highlights the dual role of piezoelectric systems as both energy sources and sensing interfaces in adaptive building envelopes.

Complementing facade-focused work, recent SHM literature shows that piezoelectric sensors (PZT, PVDF, and composites) can operate in both active modes (electromechanical impedance; guided/ultrasonic waves) and passive modes (acoustic emission; stress waves) to detect strain, cracks, and vibration in built structures (Ju et al., 2023). These sensors are small, lightweight, and low-cost, and can be surface-mounted or embedded (e.g., smart aggregates in

concrete), enabling building-scale monitoring with minimal intrusion. Emerging trends—flexible PVDF films, integrated active–passive networks, and AI-assisted sensor self-diagnosis—are especially relevant when paired with local piezoelectric energy harvesters, reducing battery dependence and supporting self-powered, always-on SHM in smart buildings (Ju et al., 2023).

Recent reviews (Shehu et al., 2024) also highlight the use of piezoelectric sensors in large-scale civil and building systems, underscoring their scalability and reliability for monitoring infrastructure and architectural structures.

5. CHALLENGES AND BARRIERS FOR PRACTICAL INTEGRATION

The integration of piezoelectric materials into buildings is limited by several building-specific material, mechanical, and implementation challenges. Although ceramics like PZT provide high electromechanical performance, they exhibit brittleness, cracking, and fatigue under the repeated footfall loads and facade vibrations typical of buildings, while polymers such as PVDF face moisture sensitivity and long-term environmental degradation, limiting their durability in floors, facades, and outdoor structural components (Shehu et al., 2024; Safaei et al., 2019; Aydın & Çelebi, 2023).

Installation within building elements also introduces major practical difficulties. Large-scale systems require robust load transfer layers, waterproof encapsulation, and protection from dust, humidity, and mechanical overload, all of which are difficult to ensure in floors, pavements, and facades. As a result, many prototypes suffer from uneven loading, insufficient strain transfer, and low power density, reducing effectiveness in real buildings (Sharma et al., 2022; Rumman et al., 2024).

Economic feasibility remains a critical barrier. Piezoelectric harvesting in buildings typically generates low power per unit area, while requiring costly rectifiers, power-conditioning units, and specialized installation, resulting in long payback periods relative to solar and other conventional building-integrated renewables (Chen et al., 2019; Safaei et al., 2019).

Architectural constraints add another layer of difficulty. Effective energy harvesting requires high-vibration or high-traffic zones, yet these areas often conflict with acoustic requirements, interior comfort, floor leveling, facade appearance, or maintenance access (Elahi et al., 2018; Aydın & Çelebi, 2023). Embedding materials inside structural components can also interfere with design flexibility and occupant experience.

Finally, progress is slowed by the absence of standardized testing methods, unified performance metrics, long-term durability protocols, and real-building validation data, creating uncertainty for architects and engineers considering piezoelectric systems (Ju et al., 2022; Shehu et al., 2024).

Overall, despite strong potential, the widespread adoption of piezoelectric systems in buildings is limited by durability concerns, integration complexity, low energy density, architectural constraints, and the lack of standardization, issues that must be resolved for these materials to become viable components of future intelligent and energy-efficient buildings.

6. CONCLUSIONS AND FUTURE DIRECTIONS

This study highlights the growing potential of piezoelectric materials as multifunctional components for energy harvesting, self-sensing, and smart operation in buildings. By converting mechanical actions, particularly human-induced vibrations and facade-level wind or pressure fluctuations, into electrical energy, piezoelectric systems offer an auxiliary renewable power source that supports the global transition toward low-carbon, adaptive, and intelligent buildings.

Emerging prototypes demonstrate how piezoelectricity can be embedded directly into architectural elements. Hybrid surface technologies, such as the multi-modal energy-harvesting tile developed by Mukilan et al. (2025), show the feasibility of integrating mechanical, thermal, and solar conversion mechanisms within a single building surface. These concepts point toward future facade modules and flooring systems capable of generating on-site power while simultaneously providing structural health monitoring and occupancy-responsive feedback.

Despite this promise, widespread implementation remains limited by several unresolved challenges. Material durability, especially the brittleness and fatigue sensitivity of ceramic piezoelectrics, poses risks under continuous cyclic loading. Installation and integration issues, including alignment, wiring, encapsulation, and compatibility with building codes, further restrict practical deployment. Cost barriers also remain significant for both materials and system-level electronics, and there is a lack of standardized guidelines for designing, testing, and evaluating piezoelectric building components (Shehu et al., 2024).

Overall, while piezoelectric technologies are not yet ready for large-scale adoption in the built environment, rapid advances in flexible polymers, composite materials, and modular fabrication methods are steadily improving their performance and architectural compatibility. As research continues to merge energy harvesting, sensing, and real-time structural monitoring into unified

building components, piezoelectric materials may play an important role in future energy-efficient, resilient, and intelligent architecture.

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CHAPTER 4

Analysis of the Presidential National Library in Accordance with Universal Design Principles

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Introduction

The equal and dignified use of urban and public spaces by all individuals is a fundamental criterion of contemporary societies. The Universal Declaration of Human Rights also emphasizes the principles of equality and participation without discrimination (UDHR, 1948). The World Health Organization's report, which states that individuals living with disabilities account for approximately 15% of the world's population (WHO, 2011), demonstrates that accessibility is not a “special requirement” but a public responsibility on a societal scale. In this context, “Universal Design” aims not only to provide access for individuals with disabilities but also to enable the equal participation of a wide range of users, including those of different ages, genders, physical characteristics, and temporary/chronic health conditions (Mace, 1990; Connell et al., 1997). Universal design is possible not by adapting people to the space, but by adapting the space to people.

This study aims to evaluate the interior design of the Presidential National Library in Ankara in accordance with the seven principles of universal design (equal use, flexibility in use, intuitive/straightforward use, perceptible information, error tolerance, low physical effort, size and space) (Connell et al., 1997). Opened on February 20, 2020, as one of Turkey's largest libraries, the building offers a suitable sample for examining the spatial conditions of inclusive public services with its multi-layered public program.

The study employs the following methods: (i) international universal design literature and principles (Mace, 1990; Connell et al., 1997) and (ii) the interior organization of the National Library. The interior space assessment discusses applications that align with universal design principles within the overall design approach of the building, organized under analytical headings. The study's limitation is that detailed ergonomic measurements, performance tests such as acoustics/lighting, and user experience studies to be carried out in the field are excluded from its scope. Nevertheless, the study's findings lay the groundwork for feasible improvement suggestions in the design axis.

Universal Design

The Universal Declaration of Human Rights states: “All human beings are born free and equal in dignity and rights. They are endowed with reason and conscience and should act towards one another in a spirit of brotherhood.” Article 2 states that “Everyone is entitled to all the rights and freedoms outlined in this Declaration, without distinction of any kind, such as race, color, sex, language, religion, political or other opinion, national or social origin, property, birth or other status.” Within the framework of this principle, equality among individuals is a fundamental human right (UDHR, 1948). Like any healthy individual, individuals with disabilities should be able to participate in the work environment and social life without feeling any discrimination, benefit equally from

transportation services, and have access to public spaces (Bezmez and Yardımcı, 2010). The structural barriers encountered by individuals directly affect equal opportunity in fundamental areas such as education, employment, and access to public services (Gül, 2008; Tutal, 2018).

According to a report published by the World Health Organization in 2011, more than 1 billion people, approximately 15% of the world's population, live with some form of disability (WHO, 2011). This percentage clearly shows that an accessible urban environment is not a "special requirement" but a public service. One of the most important indicators of a modern society is that all individuals participate equally and actively in urban, social, and economic life.

Universal Design is defined as considering every individual in society in every area where design is applied and implementing this consideration according to the scale at which the design is realized. The goal of universal design is to design products, structures, and environments that are accessible and can be used by as large a group of people as possible, to provide similar experiences to all users, ensure that the environment adapts to people rather than people adapting to the environment (Erkovan, 2013; Şenel, Şenel, & Günaydın, 2018; Dikel, 2019). Universal Design is expressed under different names in the literature. These are: inclusive design, lifelong design, design for all, and human-centered design. Although there are nuances between these concepts, what they all fundamentally emphasize is that spaces and services should be designed to support independent living by ensuring that they can meet the potential different needs of all members of society (Tandoğan, 2017).

The concept of universal design was first used in 1985 by American architect Ronald Mace. Mace wrote a book titled "Accessible Environments: Designing for Everyone." In this book, he explains universal design as "simply put, the design of all products, buildings, and open spaces to be usable by as many people as possible." The key point here is that the design should appear and feel normal, and should not lead to marginalization, exclusion, or discrimination. It is essential to remember that the user profile in universal design encompasses not only individuals with disabilities, but also those without. On the contrary, a design conceived specifically and solely for individuals with disabilities is not a design for everyone. Design for all does not discriminate positively or negatively against any group in society. Accordingly, designs should be usable by the elderly, all groups of people with disabilities, children, patients, and individuals who fall outside standard measurements (such as very tall people, dwarfs, those who are overweight or underweight). Universal design targets people of all ages, sizes, and abilities, as well as all structures. Designers who embrace design for all must produce solutions to usage problems with an integrative approach (Mace, 1990).

Due to the unique principles of universal design, it cannot be equated with standards that aim solely to ensure accessibility for people with disabilities.

However, just like other standards in our lives (roads, parking lots, stairs, chimneys, etc.), accessibility standards will serve as a reference source for designers when they move on to the implementation phase.

To promote universal design worldwide and facilitate its implementation, the Center for Universal Design has established seven guiding principles for researchers in various fields during the design process (Altay Öztürk, 2019). These principles are the universal design principles currently in use (Connell et al., 1997).

The principles of universal design are listed as follows:

- Equal use,
- Flexibility in use,
- Simple and intuitive design,
- Perceptible information,
- Error tolerance,
- Low physical effort,
- Size and space.

The principle of equal use means that the design should be used in the same way by all users. The design should prevent individuals from using and labeling it differently due to their disadvantages. The design should be equally accessible and usable for every user (Connell et al., 1997). The same usage should be provided for all users, or if this is not possible, similar or equivalent usage should be offered, no user should be discriminated against, and the concepts of security and privacy should be provided to users on an equal basis (Hacıhasanoğlu, 2003). Privacy, protection, and security must be provided equally to all users, and the design must be made attractive to all users (Olguntürk 2007; Erkovan 2013). Examples of this principle include having ramps and elevators near entrances, as well as signs of different heights and widths, to cater to individuals with varying physical abilities.

The principle of flexibility in use is that the design should be able to respond to the preferences of all users. Designs should accommodate individuals who perceive things differently and at varying speeds (Sayar and Arat, 2017). Furthermore, it should be considered that users' personal abilities may vary, and the design should be flexible enough to accommodate this. The design should be usable according to the user's right- or left-handedness, speed of use, physical characteristics, or preferences (Connell et al., 1997). Usage methods should be varied and correct and precise usage precautions should be taken. Suitability for users with different speeds should also be ensured (Hacıhasanoğlu, 2003).

Examples of this principle include adjustable table heights or armchairs that both right-handed and left-handed individuals can use.

The principle of simple and intuitive use means that the design should be easy to understand and use regardless of the user's experience, knowledge, skills, language ability, or current level of concentration (Kavak, 2010). Knowledge and experience are irrelevant to this principle. General human perceptions should be prioritized (Connell et al., 1997). Unnecessary complexity in design should be avoided. Users' intuitions should be prioritized, considering that users have different levels of knowledge (Hacıhasanoglu, 2003). An example of this is a door handle that triggers intuitive behaviors in people, such as grasping and pressing it.

The principle of perceptible information refers to the ability of the design to convey necessary information directly, effectively, and perceptibly to the user, independent of environmental conditions and user skills (Connell et al., 1997; Şenel, Şenel, & Günaydın, 2018). It is stated that a design should be simple and intuitive and should be enriched with perceptible information. The necessary information should be provided in an understandable way using different forms of expression (pictorial, audio, tactile, etc.), and the elements used should be distinguishable from each other in a way that can be described (Hacıhasanoğlu, 2003; Sayar and Arat, 2017; Mace, 1997; Hacıhasanoğlu, 2003; Dostoğlu, Şahin, and Taneli, 2009). Examples include having Braille next to an elevator button or verbally announcing which floor the elevator is on.

The principle of fault tolerance involves incorporating features that address situations where safety is required or where carelessness is possible, as well as facilitating error recovery (Connell et al., 1997). The most frequently used elements in the design should be easily accessible, while components that pose a hazard should be isolated and clearly labeled. Movements should be restricted in tasks requiring attention. Warnings should be provided regarding hazards (Mace, 1997; Hacıhasanoğlu, 2003; Dostoğlu, Şahin, & Taneli, 2009; Şenel, Şenel, & Günaydın, 2018). Examples include designing stairs with non-slip material or ensuring that faulty furniture can be easily returned.

The principle of low physical effort means that the design should require the least amount of energy to use. It is necessary to ensure that the user is in a natural body position, without straining their body, that repetitive movements are kept to a minimum, and that prolonged use does not require excessive force (Şenel, Şenel, & Günaydın, 2018; Kavak, 2010; Arat & Sayar, 2017; Hacıhasanoğlu, 2003). Body movements that strain the individual or use that require excessive force should be avoided (Connell et al., 1997). Sensor-activated hand washing fixtures can be cited as an example of this principle.

The principle of size and space refers to the consideration of an individual's physical characteristics in the design of access and approach (Connell et al.,

1997). Regardless of the user's body measurements, posture, and mobility, the design should provide appropriate dimensions and space for approaching, reaching, manual use, and general use (Kavak, 2010). In design, anthropometric dimensions, which are the most basic data considered in terms of body measurements for the physical environment to be ergonomic, should be regarded as (Ertaş, 2012). Both seated and standing individuals should be able to see and access all usage elements. An example of this principle is ensuring that reception desks are not all at the same height, but that a specific part or all of them are kept low for individuals with short stature or wheelchair users. Additionally, there should be spaces in kitchens that allow wheelchair users to approach the counter.

Presidential National Library

The Presidential Complex, which includes the National Library, is in the Yenimahalle District of Ankara. In addition to the library, the complex also houses the Presidential Palace, the National Mosque, and the Presidential Exhibition Hall, all of which were built at different times. The library, for which preparatory work began in 2015, opened on February 20, 2020 (URL 1).

Figure 1. National Library

The library, with a capacity of 5,500 people and an area of 125,000 m², is the largest in Turkey. The architectural design of the building belongs to Vizzion Architects, founded by Şefik Birkiye (URL 2). The library structure comprises a ground floor and six upper floors, with four basement floors dedicated to various functions (Figure 2).

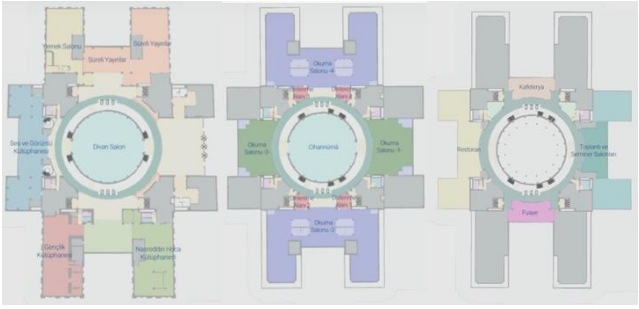


Figure 2. Ground floor, second floor, sixth floor plans

The library's program includes the central reading room, the Ci-hannümâ Hall (with a 33-meter-high dome and 16 symbolic columns) (Figure 2). It consists of halls of various sizes, research and study areas, a children's and youth library (Figures 4, 5, 6), a rare books library, exhibition units, and dining halls (Figure 7) (Presidential National Library, 2020) (URL 3).

Figure 3. Cihannuma hall

Figure 4. Youth library

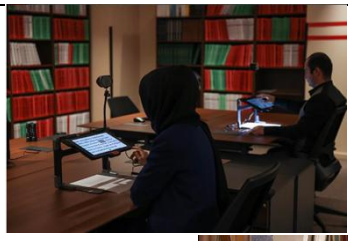
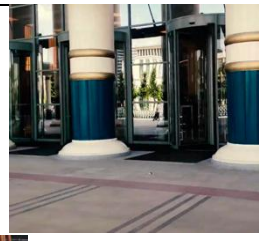
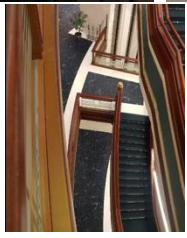
Figure 5. Children library

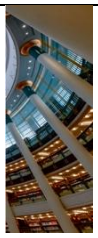
Figure 6. Children library

Figure 7. Dining hall

Within the scope of this study, the interior designs of the National Library will be analyzed in accordance with the seven principles of universal design.

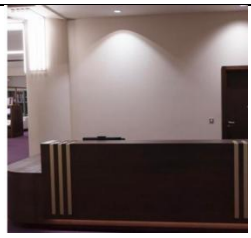
Table 1. Evaluation of the building according to universal design principles

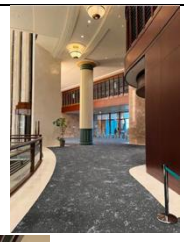
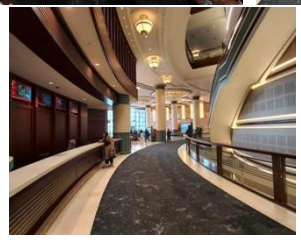
	National Library Interior Spaces
Equal Use	**Technology Class for the Visually Impaired:** A classroom that provides access to information through equivalent means, such as computers with screen readers, Braille printers, electronic magnifiers, etc. **Indoor audio navigation:** Access support that is non-discriminatory for visually impaired readers, guiding users to their destination and the nearest elevator. **Entrance suitable for all users:** Use of photoelectric doors next to revolving doors at the entrance. **Stairs suitable for all users:** Use of high-contrast materials on the stairs and handrails with raised lettering so that all users can use the stairs.
	  
Flexibility in Use	**Multiple work types:** Options suitable for different preferences and abilities, such as group study rooms, open reading tables, and individual viewing/listening booths. **Separate units for different age groups:** Children's/youth libraries with content and environments tailored to the user profile.
	  

Simple and Intuitive Design	**Central atrium (Cihannümâ) and surrounding galleries:** Circular layout providing visual continuity between floors; a spatial "reference point" that facilitates orientation. **Widespread vertical circulation:** Simplified movement between floors, guided by panoramic elevators and tactile surface applications.
	  
Perceptible Information	**Multi-channel information delivery:** The combined use of visual/tactile/auditory cues with haptic surfaces and audio guidance. **Accessible hardware:** The perception of information in multiple formats through the integrated use of Braille printing, electronic magnifiers, and optical character recognition screen readers.
	  
Error Tolerance	**Reducing navigation errors with digital guidance:** Directing users to the shortest route to their destination and the nearest elevator, reducing the risk of wrong turns. Easier navigation with floor plans located on each floor. **Alternative circulation options:** Redundancy in vertical circulation with a high number of elevators (alternative routes in case of malfunctions).
	 

<table>
<tr><td rowspan="2">Low Physical Effort</td><td>Dense elevator network: Ability to move between floors with minimal effort.

Frequently placed information desks: Reduces walking distance and effort by minimizing return trips/trial and error.

Layout of interior fixtures: The location of the information desk, the accessibility of the interior layout for different user profiles, long shelf lines, and distances can increase effort for users with limited mobility; however, the principle of low physical effort is better met with the support of a rail-based book system.</td></tr>
<tr><td>    </td></tr>
<tr><td rowspan="2">Size and Space</td><td>Large-scale reading and circulation areas: spacious openings in the central hall and surrounding galleries; high-capacity seating areas, wide corridors.

Elevators distributed throughout the building: Size/space layout suitable for the approach/access requirements of different users.</td></tr>
<tr><td>    </td></tr>
</table>

Conclusion

This study aims to comprehensively analyze the interior design of the Presidential National Library in the context of the seven principles of universal

design. The study's findings show that the library largely meets universal design criteria, thanks to its scale, program diversity, and accessibility-focused applications. However, due to the monumentality of the space, certain aspects require point-by-point evaluation.

When an assessment is made in accordance with universal design principles;

1. Principle of equal access; Applications such as tactile surfaces for visually impaired users, audio navigation indoors, and the presence of a Technology Classroom for the Visually Impaired, the photoelectric door located next to the revolving door arranged for entry, stair applications with high-contrast materials and embossed handrails, demonstrate that services are provided equivalently and are consistent with the principle of equal access in universal design.

2. Flexibility in use; The Cihannümâ central hall is surrounded by various types of spaces, such as reading areas of different sizes, group study rooms, children's and youth units, and audio-visual work booths, providing flexibility to meet user preferences. The adjustability level of furniture and fixtures (such as table/counter height, seating arrangement, and outlet access) is consistent with the flexibility criterion in use.

3. Simple and intuitive use; Circular circulation and visual continuity, along with tactile surface applications, enhance intuitiveness, while panoramic elevators simplify inter-floor circulation due to their positioning.

4. Perceptible information; Audio guidance and tactile markings, cues provided by detectable surfaces, and material color contrast are examples of interior design applications that provide perceptible details.

5. Error tolerance: To tolerate large-scale complex circulation risks indoors, frequent consultation points, clearly marked return routes, and numerous elevators as a precaution against malfunctions, along with floor plans located on each floor, help tolerate potential errors.

6. Low physical effort: Although access is facilitated by the location and design of information desks, the layout of accessible restrooms, numerous elevators in the building, and technological support, long shelf lines and distances may increase the effort required for users with low mobility. The “fetch-and-carry” service, rail systems, and on-site consultant support ensure that the principle of low physical effort is met.

7. Dimension and space principle: Wide corridors and seating arrangements provide sufficient space for maneuverability and use. Dimensions such as table height, shelf height, and elevator cabin interior accommodate different usage requirements.

In conclusion, it is evident that the interior design of the Presidential National Library largely meets universal design criteria, particularly demonstrating a

strong correlation with the principles of equal use, flexibility, and perceptible information. Conversely, its status as a monumental public building highlights the need for improvement in areas such as wayfinding and accessibility with minimal physical effort. For future studies on this specific structure, it is recommended that evaluations be conducted using methods such as detailed ergonomic measurements, lighting, and acoustic performance tests in the field.

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CHAPTER 5

The Reflection of Power and Ideology in Architecture: The Example of Police Center and Police Directorate Buildings

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1. INTRODUCTION

Public buildings are considered a source of prestige for their surroundings and the city they belong to, as well as a concrete indicator of the power of the state administration. "Public buil-dings" are structures that serve society and are accessible to everyone equally. Public buildings, important for urban identity and aesthetics, are structures designed for various functions and provide public services. Public buildings play a significant role in the spatial organization of cities. These structures often ref-lect the city's identity and culture, reflecting the characteristics of their period and geography. They also facilitate the layout of other buildings. Therefore, public buildings, with their social, cultural, economic, societal, and physical characteristics, are of great importance to the city.

Public buildings, in addition to their functions on building scales, have served as ideological tools for powers that wish to concretize the visual representation of their ideologies and assets through the built environment and to dominate space, with their power to convey meaning and produce discourse. Although the ruling elites and the symbols that represent them have changed, the search for representation has been positioned as a continuous phenomenon throughout the historical process, and architectural practice has been manipulated for this purpose.

Michel Foucault considers the concept of power not as a property but as a set of institutions; instead of a single, visible individual, power now operates through devices that must constantly monitor individuals and society (Bentham, 2008). According to Foucault, power is a concept that has permeated even the smallest aspects of life. Knowledge is produced by power, and this lies at the heart of the debate on the concepts of power and hegemony. The traces of power are distributed throughout social space and can be read like an open book (Yapıcı, 2018). One such trace, public buildings, which occupy an important place in the Turkish architectural environment, have the power to represent the dominant ideology in the public sphere and transform it through their architectural language. In this context, structures representing security and authority, such as police stations, provincial and district police departments, are critically important public structures that embody abstract concepts such as justice, trust, and the power of the state through architectural form.

In 21st century public architecture, a historically selective style, summarized with terms such as "Ottoman" and "Seljuk", is dominant on the facades of such buildings, and an effort to create a historical identity is observed in this way. This historicist architectural approach, presented by its practitioners with reference to past architectural phenomena, progresses with the discourse of keeping the architectural culture alive, while on the other hand, it is criticized in terms of its originality and time representation, and points to a kind of rupture in Turkish

architecture by contradicting the pluralistic and contemporary architectural understanding of the 20th century (Duygun, 2023).

In our country, police station buildings, which operate under the General Directorate of Security, the institution responsible for security services, carry certain direct and indirect meanings in the eyes of citizens. Police stations are critical public structures representing the "security" and "service" functions of the state. However, it has been observed that the "imitative" (neo-historicist, eclectic) architectural language observed in public buildings constructed in Türkiye in recent years has increased considerably compared to modern architectural alternatives.

This study examines police stations, provincial, and district police department buildings located in different geographical regions of Türkiye that exhibit a historicist approach to their facades. The facade designs of selected police stations, provin-cial, and district police department buildings will be formally analyzed to identify the historical periods and architectural elements they draw upon. This will then discuss the impact of existing power and ideology on public buildings.

2. THE CONCEPT OF POWER AND IDEOLOGY

Ideology is defined as one of the most slippery concepts in the social sciences (McLellan, 2009, p. 1). The etymological origin of the concept is based on the Greek words idea (thought) and logy (science). Historically, the term ideology was first coined by Antoine Des-tutt de Tracy as the science of ideas, meaning it was associated with scientific knowledge as a way of inducing thought to be true (Özbek, 2000). However, with Napoleon Bonaparte's negative implication, ideology acquired the connotations of false consciousness and abstract thought detached from reality (McLellan, 2009).

In the Marxist tradition of thought, ideology possesses a class character, causing material reality to be distorted in line with the interests of the ruling class. According to Marx, the class that controls the means of material production also controls the means of mental production (Dant, 1991). However, Althusser rejects the concept of ideology as false consciousness and defines it as a material entity that represents the imaginary relationship individuals establish with their real conditions of existence. In Althusser's view, ideology is a phenomenon structured to reproduce itself and always exists within an apparatus and its practice (Althusser, 2015).

Ideology is a set of beliefs, values and meanings presented as natural, universal and inevitable by the dominant class or group in a society.

Architecture is a reflection of ideology, understood as the process of generating meaning, signs, and values related to social life. In this context, ideology is understood as ideas that reference political or systematic beliefs, clash

in the struggle for power, and have legitimate and action-oriented implications. Architecture both embodies ideology and serves as a tool for its dissemination.

Power, in its most general definition, means oppressive power and is the authority of an individual or society to dominate, oppress and control other individuals or groups (Özmen, 2021).

Louis Althusser distinguishes between the instruments used by power to ensure its continuity: Repressive State Apparatuses (RSA), which operate through force (army, police, prisons), and Ideological State Apparatuses (ISAs), which maintain ideology through consent (schools, family, culture, unions, etc.). No class can permanently hold state power without establishing its hegemony over the ISAs (Althusser, 2015).

Architecture can be considered in the context of space as the Ideological Device of the State (IDA) and is a stage where the transfer of ideology takes place (Gurallar Yeşilkaya, 2003).

Architecture has become one of the most important tools through which ideology and power find concrete, physical expression. The ruling power uses architecture as a tool for its ideological goals; even urban facades and the smallest public buildings are part of this ideological construct.

The ways in which architecture embodies ideology are as follows:

1. *Monumentality and Symbolism:* The imposing public buildings and monumental tombs built for the ruling class demonstrate the power of the state (Sander, 2012). Architectural objects serve as indicators of the power of power and the existence of ideology (Çekmiş, 2009). These structures aim to ensure permanence through size (scale), expensive materials, and meticulous construction techniques; thus, they attain a distinctive structural quality that defies the corrosive effects of ideology and time. Symbolic meanings (sculptures, emblems, and signatures) are inscribed on the facades and prominent locations of the buildings (Özmen, 2021).

2. *Spatial Organization:* Those in power reinforce their existing ideologies through forms of spatial production. The Panopticon, theorized by Foucault, provides the theoretical basis for control-oriented architecture, where power uses an invisible surveillance mechanism. This control is necessary to keep individuals and society under control and to ensure concrete and precise surveillance (Foucault, 2019).

3. *Hierarchy and Separation:* Authority makes its power visible by differentiating and privileging itself from its surroundings (Sennett, 1999). Architecture directs and hierarchically organizes subjects

through its spatial structure. For example, discipline demands "enclosure" (the privatization of a self-enclosed space). In public buildings, hierarchical gradation is advocated through architectural formation; design approaches such as the separate treatment of protocol entrances and their emphasis within the mass are reflections of ideology.

4. *Facade and Style as Ideological Tools:* Facades and architectural styles are the most prominent visual representations of ideology. In creating symbolic representations of their regimes, governments have chosen formal features and architectural styles they believe represent their ideologies (Bilgin, 2023). Architecture is a concept that serves to legitimize power (Göl, 2009).

Architecture can be considered a significant indicator of social order; both architecture and ideology are intellectual products that embody the human need to impose order on the world (Aydınlı, 1996). Ideologies use architecture as a visual communication tool, conveying the thought or belief system they wish to convey to the public memory through concrete architectural products.

2.1. Interaction Of Power And Ideology İn Public Structures

Architectural production is a component that reflects the social structure or the discourse of the powerful segment of society in the physical environment. Because ideology inherently seeks to remind and reinforce itself, it tends to use architecture, like many other media, as a tool. The longevity of architectural products, despite their slow and difficult production, gives the traces of ideology special significance (Göl, 2009).

Power uses architecture as a strategic tool to establish its legitimacy, embody its display of power, and shape social life in its desired direction (Özmen, 2021). This ideological reflection manifests itself in three main areas in public buildings: representation, symbolism, and monumentality (through monumental scale and ideological stylistic choices); spatial configuration and control of everyday life (through spatial divisions that ensure separation, surveillance, and the manipulation of subjects); and ***the direct intervention of power in architecture*** (through political leaders' decision-making authority and the determination of design style).

In Turkey, while a rational-functionalist and modernist ideology materialized in the Early Republican Period, ***public buildings*** in the New Period, aimed at establishing cultural hegemony through a historical revivalist approach (form constructs with Seljuk and Ottoman references), played a significant role in the dissemination of this standardized architectural language. In this context, public buildings are no longer merely construction activities but become visual communication tools and domination mechanisms for the ruling power. This

situation forces the discipline of architecture to deeply examine its relationship with social and political processes, going beyond its technical dimension (Bilgin, 2023).

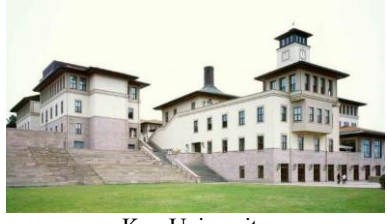
Recently, a distinct ideological preference has emerged in the selection of spatial transformation and architectural style with sentiments such as "attachment to the national, revival and protection of history".

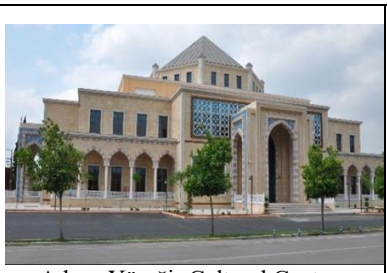
The use of facade design as a tool for a political program or ideological stance is a phenomenon observed throughout history. Architecture conveys meaning to its recipient through the aesthetics and form of a building; this transmission occurs through an ideological narrative encoded within the building, as well as technological solutions and construction quality.

The quest to produce visual representations of power led to the adoption of an architectural language that referenced the formal structure of the Seljuk-Ottoman period. This style (historical revivalist approach) played an active role in the construction of cultural dominance and shaped the formal structure of many public building typologies, including those for justice, education, and healthcare.

Architectural elements with historical references, such as portals, arches, and eaves, chosen in response to political demands and then detached from their context, have resulted in a formal similarity among buildings despite their diverse plan-schematic configurations; this points to the formation of a uniform architectural language. Various public buildings where this style is clearly evident are shown in Table 1. As seen in Table 1, the "historicist facade approach" has been brought together across different cities and functions, reaching a common goal.

Table 1. Examples of public buildings with historical references

 Düzce, 15 Temmuz Şehitleri Secondary School, 2019.	 Aydın, Kuşadası Courthouse
 Konya, Karatay Government Building	 Ankara, Necip Fazıl Cultural Center
 Sivas İmam Hatip High School	 Koç University
 Ankara-Eskişehir Entrance Gate	 Marmara Municipality Building
 Kocaeli Overpass	 Ankara Music and Fine Arts University Gate



Adana Yüreğir Cultural Center

Konya Courthouse

3. PURPOSE AND METHOD

Police stations and police headquarters buildings constitute one of the most concrete and compelling representations of the modern state's authority and institutional identity in urban space. Even if designed solely for shelter or to meet functional needs, these structures serve as political statements in the public sphere. The formal characteristics of a police headquarters or police station its mass, facade details, material selection, and its relationship to the urban context communicate to society the state's official ideological stance on concepts such as power, discipline, accessibility, and transparency through architectural indicators. This study focuses on analyzing these indicators through a formal analysis of the buildings' facade-identity structure.

Within the discipline of architectural criticism, there is a need for an in-depth examination of how institutional structures, beyond mere functionality, embody power relations and historical narratives. Police stations occupy a central position among the disciplinary institutions of modern society (such as prisons, schools, and hospitals). Therefore, the architectural design of these buildings is not merely an aesthetic choice but also a reflection of the relationship between political power and the public.

The main theme of this study is the police station and police department buildings constructed in Turkey in the first quarter of the 21st century. This period saw the acceleration of both political and institutional identity searches, and architectural decisions were shaped by a central ideological orientation. These traces are clearly visible on the facades of the police station and police department. In this context, the facades of the analyzed police station and police department buildings should be considered not merely as an architectural stylistic choice, but as a manifestation of the political power's effort to rebuild its legitimacy through institutional identity.

The context of this study is comprised of ways architecture embodies ideology: monumentality and symbolism, spatial organization, hierarchy and distinction, and the facade and style as ideological tools. However, this study does

not address spatial organization. Facade design, a visual representation in architecture, forms the basis of this study.

In previous studies, Taşkıran (2022) conducted a facade-identity analysis of public buildings in Konya in his study *"The Search for Historicism in Recent Public Buildings in Türkiye: The Konya Example."* Similarly, Yıldız Kuyrukçu and Çınar (2023) conducted a formal analysis of city entrance gates in their study *"Perceptual Evaluation of Historicist City Entrance Gates,"* identifying the historical periods and architectural elements they cited. However, no study has been found that examines the facade-identity analysis of police stations and police department buildings constructed after 2000 and the reflection of power on architecture. This study aims to fill this gap by analyzing the facade-identity chaos of police stations and police department buildings constructed from the beginning of the 21st century to the present and questioning the reflection of power on architecture.

In this study, 20 security buildings (police stations, provincial and district police departments) constructed in the 21st century were selected as the methodology, similar to the studies of Taşkıran (2022), Yıldız Kuyrukçu, and Çınar (2023). All written and visual documents related to the selected buildings were accessed, on-site observations were made, and interviews with expert architects were conducted. The facade identities of the selected buildings were analyzed, and the architectural elements they borrowed from photographs (crown gate, portico, arch, column, vault, tower, domed window, etc.) were marked to determine the period they imitated (Seljuk, Ottoman, 1st National, 2nd National, Regional architecture, etc.).

Development and Structure Types of the Police Organization in Our Country

The development of the Turkish Police Department began with modernization efforts during the Ottoman Empire, and its organizational structure is organized into central and provincial organizations under the umbrella of the General Directorate of Security, currently affiliated with the Ministry of the Interior (Polis Akademi, 2024). During the War of Independence, a new police department was established in Ankara on June 24, 1920, under the name of the General Directorate of Security. On February 24, 1923, the Istanbul-based department was converted into a provincial directorate of the Ankara-based organization, ending the dual structure. Laws adopted in the 1930s largely established the legal infrastructure of the Turkish Police Department, and it was legally clarified that the organization would operate under the Ministry of the Interior (Polis Akademi, 2024).

General Structure and Current Status: Today, the Turkish Police Department operates under the General Directorate of Security (EGM), which is affiliated with the Ministry of Interior. The provincial organization of the EGM consists of

Provincial Police Departments, District Police Departments, and District Police Headquarters. The primary service units of this provincial organization are Police Station Headquarters, formerly known as police stations. As of 2022, the EGM comprises a total of 4,182 buildings, 3,381 of which are service buildings (Police Academy, 2024).

Police Station Building Types and Qualifications: According to the Police Station Directorate Establishment, Duties and Research Regulation (2011), police stations are divided into three main types according to the population and general security situation of the place/region they will serve:

- Type A: It is established in settlements with a population of over 100 thousand. (Minimum usage area is 2000 square meters).
- Type B: It is established in settlements with a population between 20 thousand and 100 thousand. (Minimum usage area is 1500 square meters).
- Type C: It is established in settlements with a population of up to 20 thousand. (Minimum usage area is 1000 square meters).

Architectural and Structural Requirements: According to the Police Station Authority Establishment, Duties and Research Regulation (2011), police stations;

- *It should be a maximum of two floors, with a garden, and detached* (basement, ground, first and second floors). Usage areas should be a minimum of 2000 square meters for type A police station, a minimum of 1500 square meters for type B police station, and a minimum of 1000 square meters for type C police station.
- *It must be in accordance with the plans prepared by the General Directorate of Security, Construction and Real Estate Department,*
- *It is mandatory that the external appearance has distinguishable characteristics.*

However, when examining the current situation, the vast majority of police stations are located beneath residential buildings or existing service buildings due to economic reasons, land allocation constraints, or funding constraints. This situation creates problems such as police station buildings not being included within the city's distinctive architectural structures. Ideally, police stations could be considered separate functions to contribute to the aesthetics of the city. Given their duties and responsibilities, police stations should operate within independent architectural structures that integrate with the city's architecture (Bilir, 2014).

4. FIELD STUDY: FACADE-IDENTITY ANALYSIS OF POLICE CENTERS, PROVINCIAL AND DISTRICT POLICE DIRECTORATE BUILDINGS AFTER 2000

Many civil and official architectural structures today have been constructed with facade designs created by direct copying or stylizing original structural elements from various architectural periods, interpreting them with changes in proportion, material, and function, influenced by political, ideological, sociocultural contexts, popularity, and fashion. Buildings with these characteristics continue to be designed and constructed (Kırcı, 2018). This architectural style, which maintains historical references at the level of form and symbol and adopts a selective style, sometimes incorporating references from a single period and sometimes from multiple periods, ultimately produces structures that are not original and, while contemporary in construction technology, do not reflect their era in form.

The field study aimed to analyze the facade-identity chaos of police stations and provincial and district police department buildings constructed in the first quarter of the 21st century and to discuss the architectural reflection of power and ideology. To this end, a comprehensive literature review was conducted to identify 20 historicist police buildings constructed at the beginning of the 21st century. All written, printed, and visual documentation related to the selected police buildings was accessed. By consulting with architectural historians, photographs were used to identify the unique architectural elements (crown gates, porticoes, arches, columns, vaults, towers, arched windows, etc.) that these buildings mimic using historicism. The historical periods they mimicked (Seljuk, Ottoman, First National, Second National) and citations from regional architecture were identified. The periods and architectural elements imitated by the police buildings constructed within the scope of the study and evaluated using form analysis are shown in Table 2.

Table 2. Police stations, provincial and district police departments in our country and the architectural periods and elements they cite

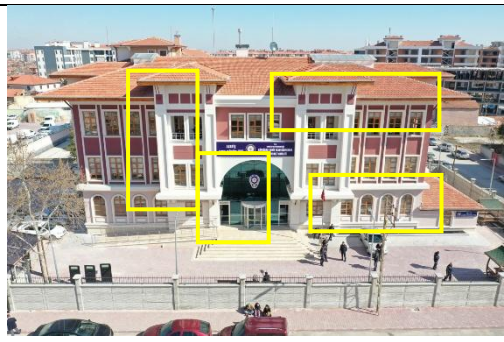


Image: Konya Martyr Azam Güdendede (Old Köprübaşı Police Station), 2020

The Period Imitated	Architectural Elements It Imitates
I. National	Arched windows, arch, tower
2nd National	Wide Eaves, Buttresses, Bay Windows, Columns

Image: Muş Provincial Police Department, 2017

The Period Imitated	Architectural Elements It Imitates
Seljuk	Crown Gate
I. National	Arched windows, arch, tower
2nd National	Wide Eaves, Buttresses

Image: Trabzon Çarşıbaşı District Police Department, 2025

The Period Imitated	Architectural Elements It Imitates
I. National	**Arched windows**
2nd National	Wide Eaves, Bay Window

Image: Ankara Provincial Police Department, 2019

The Period Imitated	Architectural Elements It Imitates
Seljuk	Crown Gate, star motif
I. National	Tower
II. Ulusal	Wide Eaves, Buttresses, Columns

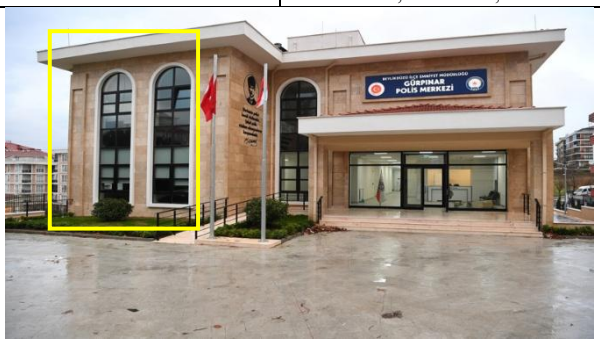


Image: Istanbul Gürpınar Police Station, 2022

The Period Imitated	Architectural Elements It Imitates
Ottoman	Arched Windows

Image: Gaziantep Düztepe Martyr Hüseyin Cengiz Police Station, 2019

The Period Imitated	Architectural Elements It Imitates
I. National	Arched windows, arch, tower
2nd National	Wide Eaves, Bay Window, Buttresses

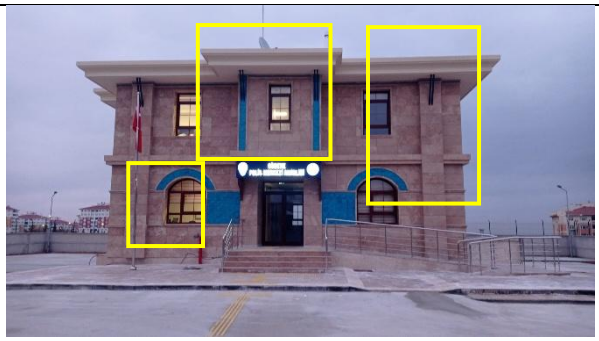


Image: Konya Gödene Police Station, 2023

The Period Imitated	Architectural Elements It Imitates
Seljuk	Tile decoration
Ottoman	Arched Window
2nd National	Wide Eaves, Bay Window, Buttresses, Columns

Image: Gaziantep Yeşilvadi Martyr Ersan Gürpınar Police Station, 2020

The Period Imitated	Architectural Elements It Imitates
Ottoman	Arched Window
2nd National	Wide Eaves, Bay Window

Image: Sivas Zara District Police Department,2023

The Period Imitated	Architectural Elements It Imitates
Seljuk	Motif, decoration
2nd National	Wide Eaves, Bay Window

Image: Rize Provincial Police Department, 2020

The Period Imitated	Architectural Elements It Imitates
Traditional Residential Architecture	Bay window, wooden frame

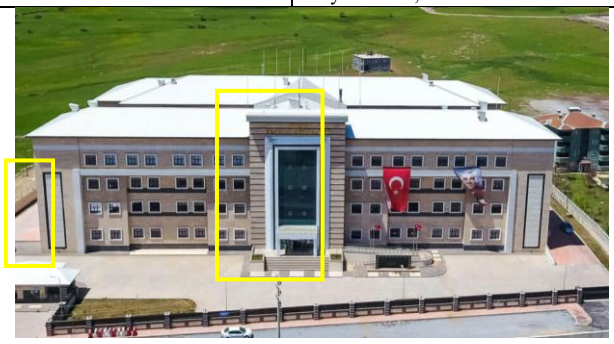


Image: Bitlis Provincial Police Department, 2015

The Period Imitated	Architectural Elements It Imitates
Seljuk	Crown Gate, Motif, Decoration

Image: Hatay Arsuz District Police Department, 2024

The Period Imitated	Architectural Elements It Imitates
Seljuk	Motif, decoration
I. National	Arched windows, arch, tower
2nd National	Wide Eaves, Bay Window

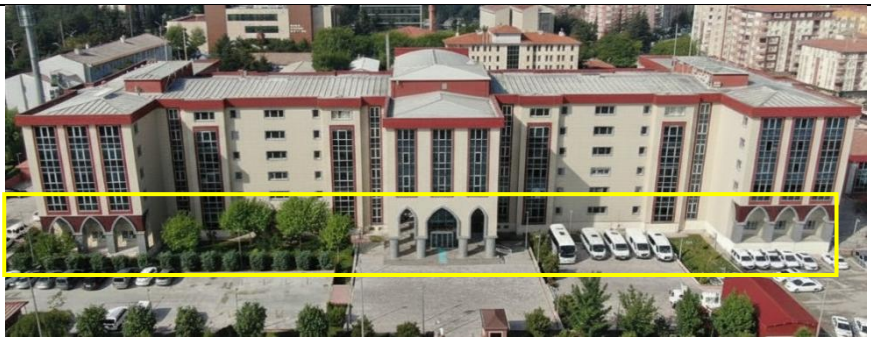


Image: Çorum Provincial Police Department, 2011

The Period Imitated	Architectural Elements It Imitates
Seljuk	Pointed Arch, portico

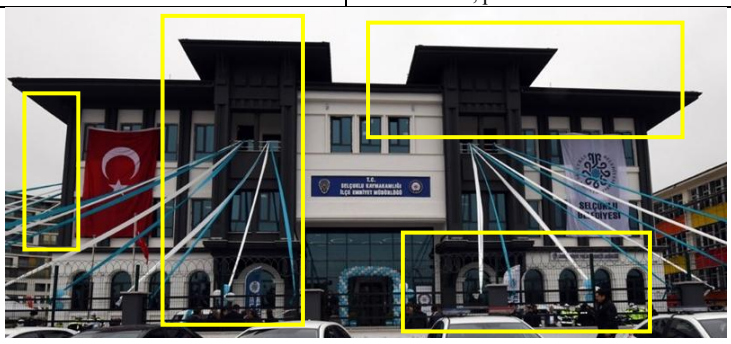


Image: Konya Yazır District Police Department, 2022

The Period Imitated	Architectural Elements It Imitates
Ottoman	Arched Windows
2nd National	Wide Eaves, Buttresses, Bay Windows, Columns

Image: Hatay Reyhanlı District Police Department, 2020

The Period Imitated	Architectural Elements It Imitates
Seljuk	Crown gate, pointed arch
Ottoman	Arched Windows
I. National	Tower

Image: Bitlis Adilcevaz District Police Department, 2015

The Period Imitated	Architectural Elements It Imitates
Ottoman	Arched Windows
2nd National	Wide Eaves, Buttresses, Bay Windows, Columns

Image: Ankara Balgat 10 April Police Headquarters, 2018

The Period Imitated	Architectural Elements It Imitates
I. National	Arched windows, tower

Image: Ankara Ufuktepe Police Station, 2017

The Period Imitated	Architectural Elements It Imitates
I. National	Arched windows, tower
2nd National	Wide Eaves, Buttresses, Bay Window

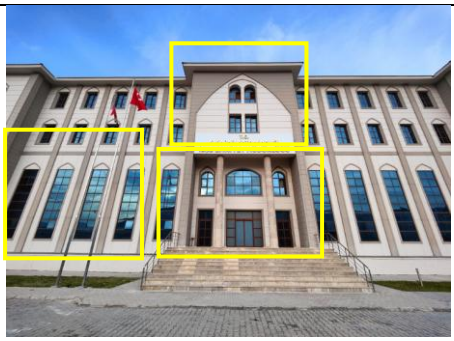


Image: Aydın Kuşadası District Police Department, 2015

The Period Imitated	Architectural Elements It Imitates
Seljuk	Crown Gate, Pointed Arch
2nd National	Column

Image: Yozgat Boğazlıyan District Police Department, 2025

The Period Imitated	Architectural Elements It Imitates
I. National	Arched windows, tower

5. EVALUATION

Police stations and police headquarters, beyond being the physical counterparts of the state's security apparatus, are spatial arrangements where political power is made visible in the public sphere. The relationship between architecture and ideology becomes particularly evident in such structures, as the facade serves as a symbolic face of the building, directed towards both society and the state.

Foucault's understanding of discipline, surveillance, and spatial power reveals that the facade designs of police buildings are not only related to aesthetic preferences but also to the ways in which power legitimizes itself (Foucault, 2019). In this context, the facade, rather than an architectural shell, is a tool that represents authority, generates legitimacy, and encapsulates the individual within an ideological framework.

In the Turkish context, police buildings are closely linked to the state's modernization process and the spatial representation of public authority. The need for state institutions to display visibility and power is also reflected in the architecture of law enforcement units. Police buildings should be considered not only as security units but also as structures that symbolize the continuity of the regime (Özlü, 2019). This desire to dominate the regime within this historical continuity is reflected even today in the design approach to authoritarian representation, such as strong, massive surfaces, symmetrical massing, or the prominent placement of national symbols on the facades of police stations.

The deliberate choice of Seljuk-Ottoman architectural elements on the facades of state-built public buildings should be interpreted not merely as an aesthetic or traditional taste, but as the spatial representation of a political and ideological discourse. The First National Architecture Movement, which began at the beginning of the 20th century, in particular, served this purpose: Kemaleddin Bey and Vedat Tek, its pioneers, combined modern construction techniques with Ottoman-Seljuk aesthetics and decorative traditions, aiming to imbue state buildings with a "national identity" and, therefore, a visual identity representative of the state (Balcı, 2022).

In this approach, facades are adorned with details such as masonry, arches, pointed arches, tile or stone motifs, and traditional stone-brick layouts, transforming them into iconic spaces that emphasize the state's continuity, roots, and public authority. In this context, the use of similar traditional motifs in police stations or police headquarters buildings indicates that these structures are not merely functional but also a tool of ideological and institutional legitimacy. Therefore, the visibility of Seljuk-Ottoman elements on facades is a spatial extension of the modern state's strategy of manipulating public perception by referencing the historical past, nationalist identity, and the discourse of authority. The facades of public buildings constructed with a historicist architectural

approach require consideration beyond purely aesthetic considerations as a visual means of expressing institutional identity and state authority. This approach has been adopted globally since the 19th century, particularly with the motivation to increase the symbolic weight of public buildings in public spaces.

The historicist style attempts to create a layer of meaning by linking the stylistic elements used on the facade to the exalted values of the past. This is an attempt to symbolize the historical legitimacy and permanence of the building's function as an architectural indicator. The heavy stone texture or classical arrangements (columns, pilasters, cornices), combined with the large-scale, monumental mass, strive to imbue the facade with a weight, solemnity, and immovability.

Historicist facades often incorporate an *eclectic* selection of historical references to emphasize national or local identity. This often leads to poor imitations that attempt to maintain spatial memory and institutional continuity.

The use of traditional/heavy materials counters the industrial transparency of modernism, emphasizing both strength and commitment to tradition. However, the mere imitation of materials reinforces this "historicist" approach, effectively voiding the intended purpose.

Police department buildings serve the specific function of representing criminal authority, security, and the state's power to use force within public service buildings. The application of a historicist perspective to such structures is critical to understanding how this specific function is visually negotiated.

The fronts of police departments must simultaneously meet two fundamental, sometimes conflicting, requirements:

Public Access and Conveying Trust: As a public institution, the building is expected to project an image that is welcoming, accessible, and serving the public.

Security and Insularity: As a security institution, the building must project an image of being defensible, with entrances and exits under control and closed to potential threats.

Historicist building facades often adopt the following strategies to resolve this contradiction:

- The main entrance to the facade is symbolically grand and grandiose, with crown gates, to emphasize authority. However, ground-floor windows are generally smaller, positioned high, or protected by heavy bars, conveying a message of introversion and security. This reinforces the facade's image of "fortified authority" rather than "permeable authority" (Tafuri, 1976). As stated in the Police Academy (2024) seminar, "*it is imperative that the facade conforms*

to the plans prepared by the General Directorate of Security's Construction and Real Estate Department and that its exterior appearance possesses recognizable characteristics." This further reinforces the concept of "fortified authority."

- In new historicist buildings, the sense of massiveness achieved through the use of exposed concrete or clad stone aims to visualize the building's resistance to attack and the institution's solidity. This facade language, while also intended to serve as an institutional psychological deterrent, carries with it a vague purpose because it mimics the design language seen in most public buildings.
- Sharp symmetry, a fundamental characteristic of the historicist style, aims to imbue the facade with a sense of order, control, and hierarchy. Symmetry is a visual rhetoric directly aligned with the mission of ensuring security and order. However, it leads to "pretend" facades where form does not reflect function at all.
- The preference for historicist facades in critical public service buildings like the police headquarters can be interpreted as a declaration of authority, contrary to modern architecture's ideals of transparency and democratic openness. These facades, while attempting to instill respect and trust by utilizing the visual codes of the past, also aim to convey the building's inherent functional requirements (security) into the public sphere through architectural rigidity. In this context, the facade, while attempting to become a permanent architectural manifestation of the institution's authority and visible power, is crushed under the weight of historicist, imitative facades.
- Public buildings, through their architectural identity, should be carriers of local memory and social rhythm. However, standardized structures, by rejecting the use of local materials, traditional color palettes, or formal elements, abstract the building from local culture. These structures obscure the source codes that allow us to draw different conclusions about the architectural, morphological, topographic, and socio-cultural structure of the city in which they are located.

While our country attempts to address the theme of trust with a historical perspective, modern police station structures are found throughout the world. Table 3 shows police station structures built in different parts of the world. These structures, in addition to modern design, demonstrate climatic conditions, local materials, adaptation to the terrain, and urban harmony. For example, sunshades are often found in buildings located in hot countries. Wood, brick, glass, and

composite facades were chosen in each region, with the appropriate materials being chosen, and the structural form was shaped by the region.

Table 3. Examples of police stations around the world

 Police Station, Norway, 2009	 Police Station, Medellin, Colombia
 Police Station, Saint-Denis, France	 Police Station, Somerville, Australia
 Police Station, Granada, Spain	 Police Station, Melbourne, Avustralya
 Police Station, Madrid, Spain	 Police Station, Palau-solità i Plegamans, Spain

6. CONCLUSION

In our country, "homogenized" public buildings, detached from their context, standardized, and seemingly identical, are everywhere. This detachment from context is not just a physical failure; it is also a cultural meltdown. Public buildings are responsible for maintaining the urban memory and identity of their locality. These public buildings, which are the same everywhere in Türkiye, incompatible with local cultural rhythms, merely emulating the past, aim to reflect the power of the past, yet they are both disconnected from the era and unable to belong to it, remaining in limbo without an identity.

The facade designs of police and security buildings are concrete indicators of an area where the discipline of architecture has been detached from its purpose and instrumentalized. Even if one sets aside the thesis that capitalist development has deprived architecture of its ideology (Tafuri, 1976), it is clear that under totalitarian regimes, architecture is systematically manipulated and exploited, and that, within the context of the ideology-architecture relationship, powers use architecture as a tool to expand their spheres of influence and maintain their permanence.

The facade, the most visible surface of these structures, is the primary element through which political power transforms architectural language into a propaganda tool and thereby reinforces its social legitimacy. It is a highly effective instrument that enables the ideological encirclement of individuals within the physical environment. As a surface symbolizing authority, personality, and legitimacy, the facade aims to create a powerful psycho-spatial effect that directly appeals to public consciousness and realism. In this context, the discipline of architecture, beyond being an art serving humanity, becomes a tool for the display of ideological approaches through control and propaganda under the control of the masses.

Consequently, the facade design of police stations and police departments is not merely a technical or aesthetic design process; it is a space where the complex relationships between political power, ideological representation, institutional communication, and public perception materialize (Millie, 2012). Designers and policymakers should develop solutions that consider the balance between security requirements and public legitimacy, and adopt participatory approaches that increase transparency and approachability, are sensitive to the human scale, and are responsive to the public. In this way, the facades of police buildings can transform from mere representations of authority into interfaces that strengthen the relationship of trust with the public.

Projects lacking site specificity are typically built on the assumption of a flat, standardized building plot. The uniform historicist approach typically presents a rigid, immutable, and hierarchical spatial scheme. The building uses a facade language that represents institutional authority, often monumental and evocative

of the past. This approach severely limits the ability of police services to adapt to rapidly changing technological and operational needs (e.g., digitalization or community-oriented policing).

Buildings resulting from competitive architectural design processes, on the other hand, prioritize operational efficiency, user-centricity, and spatial flexibility that allows for potential future changes. Structural solutions are generally based on the principles of modularity, transparency, and multifunctionality. This allows the police station to be positioned not only as a security point but also as a hub of access and interaction for the community. The buildings designed around the world, shown in Table 3, provide excellent examples of such structures.

A shift away from a uniform, centralized design approach is necessary, and **architectural competition models** should become a design strategy. This will enable the discovery of **optimal and innovative** solutions specific to each local context, topography, and social needs. The need to prioritize this competitive design across all public buildings in our country should also be considered.

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CHAPTER 6

Balconies as Liminal Urban Spaces: the case of Diyarbakır

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1. Introduction

Urban life is shaped as much by the in-between spaces of the built environment as by its monumental structures. Transitional zones -doorways, courtyards, verandas and balconies-mediate the encounters between private and public realms, allowing people to negotiate visibility, belonging and sociability within the city. In recent decades, urban anthropology, architecture, and human geography have increasingly turned to these liminal spaces to better understand how cultural norms and everyday practices are inscribed into spatial forms (Low, 2017). Among these, the balcony represents a particularly revealing site for examining the dynamic interplay between domesticity and public life. The balcony, as an architectural element, has historically occupied a peculiar and often overlooked position within the built environment. Simultaneously marginal and central, the balcony is never a core structural component of the dwelling, yet it plays a significant role in shaping how people inhabit and negotiate urban life. Across cultures, balconies have served as liminal spaces -thresholds that mediate between interior and exterior, private and public, domestic and civic. In Mediterranean and Middle Eastern contexts, they have been essential features of everyday sociality, symbolic display, and cultural continuity (Zacka, 2018). In Islamic architectural traditions, screened projections such as the mashrabiya modulate air, light, and visibility, demonstrating how built form encodes social norms around privacy and gender (Behrens-Abouseif, 1999). Far from being neutral architectural appendages, balconies enable complex negotiations around visibility, privacy and community belonging.

In recent years, the academic significance of balconies has been reinvigorated by both theoretical and empirical developments. First, within urban studies and cultural geography, the concept of liminality has gained renewed traction. Originally developed by anthropologist Victor Turner (1969), liminality describes transitional states or spaces that are "betwixt and between." In urban contexts, this concept has been extended to cover thresholds such as plazas, streets and doorways -spaces that resist clear classification yet generate distinctive forms of social interaction. Balconies, by their design, embody this liminality: they are part of the house but extend outward; they expose while sheltering; they are simultaneously places of retreat and participation. Second, contemporary global events, particularly the COVID-19 pandemic, have thrust balconies into public consciousness in new ways. From Italy to Turkey, from Lebanon to Spain, balconies became symbolic stages of resilience, where communities sang, clapped and performed collective rituals under conditions of enforced isolation (Gupta, 2023). This reactivation of the balcony as a site of communal expression demonstrated its enduring capacity to adapt to shifting

socio-cultural contexts (Daneshyar, 2025). Yet, despite their significance, scholarly attention to balconies as socially embedded architectural elements remains limited, particularly in historic walled cities where their liminal qualities are pronounced (Erbay, 2021).

This article addresses this gap by examining the balconies of Diyarbakır, located in southeastern Turkey. A historic walled city with roots stretching back to Mesopotamian civilizations, Diyarbakır embodies a layered urban fabric in which traditional courtyard houses coexist with modern apartment blocks. Within its old town, known as the Sur district, balconies and projecting wooden structures (cumba) punctuate narrow streets, establishing visual and social connections between households and public life. These architectural features are not merely ornamental: they have historically shaped gendered patterns of visibility, enabled inter-household sociability and facilitated subtle forms of surveillance. At the same time, balconies in Diyarbakır continue to adapt to contemporary dynamics, including urban redevelopment, demographic change and global cultural flows (Aydın, 2025).

Understanding the role of balconies in Diyarbakır matters for at least three reasons. First, it allows to examine how urban heritage is lived and reinterpreted in everyday practice. While monumental architecture such as city walls and mosques often dominate heritage discourse, smaller-scale domestic features like balconies also embody rich layers of cultural meaning. They tell us how people have historically navigated tensions between privacy and exposure, seclusion and sociability. Second, balconies provide a window into the gendered geographies of the city. Historically, they allowed women to observe street life while remaining within the domestic domain, aligning with cultural expectations of modesty. Examining how such practices evolve in the present sheds light on the shifting terrain of gender, space and visibility in contemporary Turkey (Tuncer, 2020). Third, balconies speak to broader debates in urban design and planning about the importance of thresholds and transitional spaces. As global cities grapple with issues of density, social isolation and cultural preservation, the balcony offers a compelling model of how architecture can simultaneously support community engagement and individual privacy.

This study situates balconies within the framework of liminality, expanding on recent theoretical debates in architecture, anthropology and urban studies. Drawing on Turner's foundational work as well as contemporary elaborations, the analysis positions balconies as spaces of negotiation and ambiguity. Complementary perspectives such as Lefebvre's (1991) theory of the production of space and Soja's (1996) notion of Thirdspace enrich this framework, highlighting how balconies embody the interplay between material form, social

practice and symbolic representation. At the same time, recent contributions from architectural anthropology on affordances (Rietveld et al., 2020) provide a useful vocabulary for understanding how balconies invite certain actions -observation, communication, withdrawal- while constraining others.

Methodologically, the study integrates architectural analysis with ethnographic fieldwork. Documentation of balcony typologies, seasonal and temporal patterns of use and semi-structured interviews with residents' foreground both the material characteristics of balconies and their lived significance. This approach situates Diyarbakır within comparative discussions of Mediterranean and Middle Eastern balcony cultures (Charitonidou, 2021; Emekci, 2021). The central argument advanced here is that balconies in Diyarbakır function as dynamic liminal spaces that mediate between domestic life and public sociability. They operate not only as architectural appendages but as cultural stages where identity, gender, and community are continually negotiated. By examining these spaces, the study has gained insight into how urban dwellers navigate thresholds of visibility and belonging and how architecture sustains cultural resilience amidst historical and contemporary transformations.

In sum, the balcony not as a peripheral feature of domestic architecture but as a vital lens through which to understand the intersections of architecture, culture and everyday urban life. By focusing on Diyarbakır's balconies as liminal spaces, it contributes to ongoing scholarly conversations about thresholds, resilience and the lived experience of urban heritage in the twenty-first century.

2. Literature Review and Theoretical Framework

2.1. Liminality and Threshold Spaces

The concept of liminality was originally developed by anthropologist Victor Turner (1969), building on Arnold van Gennep's (1909) work on rites of passage. In Turner's framework, liminality describes the transitional stage in which individuals or groups exist in a state of being "betwixt and between." While initially applied to ritual contexts, the notion of liminality has since been extended to spatial and urban studies, where it illuminates the ambiguous and transformative qualities of certain environments. Liminal spaces are those that resist binary categorization, existing in the thresholds between categories such as sacred/profane, private/public or domestic/urban (Thomassen, 2014). They embody both ambiguity and potential, often serving as thresholds where identities and practices are negotiated.

In the urban context, liminality has been used to understand alleyways, courtyards, staircases, cafés and street corners as places where formal planning

gives way to informal social life (Low, 2017). Balconies, by their architectural logic, embody this liminality. They are appendages of domestic dwellings yet open to the outside world. They invite visibility but provide seclusion, enabling both participation in and withdrawal from public life. This paradoxical condition makes them a fertile site for exploring the dynamics of urban social life. Recent scholarship has re-emphasized the significance of liminality in urban contexts. He/she argues that liminal urban spaces enable new forms of belonging, particularly for marginalized groups as they negotiate their place within cities. Similarly, He/she highlights the architectural dimensions of liminality, suggesting that thresholds such as balconies are sites where hybrid urban identities are performed. (Rossi & Zetti, 2025)

2.2. The Social Production of Space

Henri Lefebvre's seminal work The Production of Space (1991 [1974]) provides a critical lens for understanding balconies as socio-spatial constructs. Lefebvre argued that space is not merely a neutral container but is socially produced through the interplay of three dimensions: spatial practice (the material and functional), representations of space (the conceptual and symbolic) and representational spaces (the lived and experiential). Applied to balconies, this triadic framework reveals how they operate simultaneously as material extensions of buildings, as symbolic markers of social identity and as lived arenas of everyday practice.

The material dimension of balconies in Diyarbakır is evident in their architectural typologies, ranging from enclosed timber cumba to open terraces constructed in concrete. Symbolically, balconies serve as markers of status, cultural affiliation and family identity, expressed through decoration, plants or modes of use. Experientially, they are lived spaces where residents negotiate rhythms of daily life, interact with neighbors or observe public events. This interplay underscores that balconies are not passive features but active arenas in which urban space is produced and reproduced.

Recent scholarship has extended Lefebvre's ideas into the twenty-first century, emphasizing the relational and performative aspects of space. Low (2020) argues for a renewed focus on the ethnography of space and place, highlighting how everyday practices sustain cultural meanings. In the context of balconies, this suggests that their significance cannot be reduced to architectural form alone but must account for the social practices and symbolic investments that animate them (Schroeter, 2019).

2.3. Third space and Hybridity

Edward Soja's (1996) notion of Third space provides another useful theoretical lens. For Soja, the Third Space is a hybrid realm that transcends the binary of material (First Space) and representational (Second Space) understandings of space, incorporating lived experiences and imaginative geographies. Balconies exemplify this hybridity: they are simultaneously physical structures, cultural symbols and lived sites of sociality. They allow residents to inhabit multiple spatialities at once -being at home yet in public, visible yet private, rooted in tradition yet open to global flows.

In Diyarbakır, balconies manifest Third space through their capacity to mediate between historical architectural traditions and contemporary urban dynamics. For example, while enclosed wooden balconies evoke Ottoman domesticity, modern concrete terraces embody aspirations toward cosmopolitan modernity. Yet both are lived spaces where residents construct identities, perform sociability and negotiate cultural expectations. This hybridity underscores the analytical power of Third space for capturing the multiplicity of balcony life.

2.4. Gender, Space, and Visibility

A critical dimension of balcony culture in Diyarbakır and in Middle Eastern contexts more broadly, concerns gendered patterns of visibility. Feminist urban scholarship has long emphasized how domestic architecture and urban form encode gender relations (Massey, 1994; McDowell, 1999). Balconies exemplify this dynamic by providing controlled visibility for women, aligning with cultural norms of modesty while still allowing them to participate in urban life.

Recent studies have highlighted the evolution of these dynamics. Scholarship on gender and public space in Turkey documents how gendered practices of visibility are being renegotiated in light of shifting cultural values and global influences (Göle, 1996; Mills, 2010). Balconies, once primarily associated with women's constrained participation in urban life, are increasingly used as mixed-gender spaces for leisure, digital connectivity and cultural performance, reflecting broader transformations in Turkish domestic–public boundaries (Kandiyoti, 1991). Post-2020 research further highlights how digital technologies have reshaped everyday spatial practices, with balconies serving as stages for livestreaming, video calls, and social media performances during periods of restricted mobility (Ash et al., 2018). These transformations illustrate how gender, technology and cultural norms intersect in shaping balcony practices.

2.5. Balconies in Global Perspective

While this study focuses on Diyarbakır, it is instructive to situate its balcony culture within a broader comparative context. In Mediterranean cities such as Naples or Barcelona, balconies similarly mediate between domestic and public life, often functioning as extensions of social and cultural performance (Benjamin & Lacis, 1986; Monteys & Fuertes, 2015). In Beirut and Cairo, everyday practices at the thresholds of dwellings—including windows, doorways, and small projections—have long sustained neighborhood sociability under conditions of density and political uncertainty, reflecting broader patterns of street-level interaction in Middle Eastern cities (Bayat, 2012; Khalaf, 2006). In Northern European contexts, by contrast, balconies are more often associated with individualized retreat rather than communal interaction, aligning with cultural norms of privacy and controlled sociability (Gehl, 2010; Hall, 1966).

The COVID-19 pandemic highlighted both the universality and the cultural specificity of balcony practices. Globally, balconies became stages for collective rituals. Yet the meanings of these practices varied with local traditions and socio-political contexts (Aydın & Sayar). They argue that pandemic balconies reveal the potential of liminal spaces to foster resilience and community under conditions of crisis. This underscores the continuing relevance of balconies as adaptive cultural forms (Peters & Masoudinejad, 2023).

Merging scholarship since 2020 has brought renewed attention to the significance of thresholds in urban life. Drawing from earlier work on urban porosity (Benjamin & Lacis, 1986; Stavrides, 2018; Paquot, 2019), recent studies emphasize how spaces of permeability -doorways, windows, balconies- shape flows of people, air, and information (Weizman, 2020). Research on vertical urbanism further highlights how balconies mediate between high-rise living and street-level sociability, extending earlier debates on vertical life in contemporary cities (Graham, 2016). These perspectives underscore that balconies are not peripheral details but integral components of contemporary urbanism. Furthermore, affect theory and sensory urbanism have expanded our understanding of how liminal spaces shape emotional and sensory experience (Anderson, 2014; Pink, 2015). Balconies are atmospherically charged: the sound of street life rising upward, the smell of food drifting outward, the play of light and shade across seasons. All elements that contribute to their affective resonance as lived spaces (Böhme, 2017)

Theoretical perspectives position balconies as multifaceted liminal spaces that embody material, symbolic and experiential dimensions of urban life. Turner's concept of liminality highlights their ambiguous threshold condition. Lefebvre's production of space emphasizes their social and cultural construction. Soja's

Thirdspace underscores their hybridity, while the concept of affordances grounds analysis in embodied practice. Feminist and gendered perspectives reveal their role in shaping visibility and participation, while global comparisons situate their cultural specificity within broader patterns of global development. The post-2020 scholarship reinforces their renewed relevance in an era of global crises, digital-physical hybridity, and shifting urban forms. This theoretical framework provides the foundation for examining Diyarbakır's balconies as liminal spaces that mediate between domestic and public life, tradition and modernity, seclusion and sociability. It highlights the need to analyze not only architectural form but also cultural practices, sensory experiences, and social negotiations.

3. Historical and Urban Context: Diyarbakır

3.1. Diyarbakır as a Layered Urban Landscape

Diyarbakır, located in southeastern Turkey on the banks of the Tigris River, is one of the oldest continuously inhabited urban centers in the Middle East. Its history stretches back over four millennia, encompassing successive layers of Assyrian, Roman, Byzantine, Islamic and Ottoman rule. This layered heritage is physically inscribed in the city's monumental architecture, including its basalt city walls, mosques, churches, caravanserais and vernacular housing. These architectural strata have contributed to a distinctive urban morphology in which continuity and transformation intersect (Karadoğan et al., 2016; Halifeoğlu, 2013).

The old town, known as Sur, enclosed within the city walls, represents the historic core of Diyarbakır (UNESCO, 2015). Suriçi is characterized by narrow, winding streets, inward-looking courtyard houses and a dense urban fabric that reflects both environmental adaptation and cultural values (Aykalp & Ayçam et al., 2020). Unlike modern grid-based urban planning, Sur's organic street patterns were designed to respond to topography, climate and social needs, resulting in a highly articulated spatial environment. Within this setting, balconies and projecting wooden structures (cumba) emerged as key architectural features that mediated the relationship between private dwellings and the public realm (Çetin, 2011; Dalkılıç & Bekleyen, 2009). Courtyard Houses and Domestic Architecture The dominant residential typology in Suriçi has historically been the courtyard house, which reflects a deep-rooted architectural tradition across the Middle East. These houses are typically constructed around an internal courtyard, which serves as the primary locus of family life, providing light, ventilation and privacy (Dalkılıç & Bekleyen, 2009; Ayçam et al., 2020). The courtyard house embodies the cultural emphasis on inward orientation and controlled interaction with the outside world. Within this domestic framework, balconies play a crucial role. Inward-facing balconies overlook the courtyard, facilitating familial sociability

and seasonal adaptation, while outward-facing balconies and cumba extend into the street, connecting the household to the broader community (Yariş, 2020). The dual orientation of balconies underscores their liminal character, negotiating between the inward focus of domestic life and the outward orientation toward public interaction.

3.2. Balcony Typologies in Diyarbakır

The balconies of Diyarbakır exhibit diverse architectural typologies, shaped by historical periods, material availability and cultural practices (Table 1).

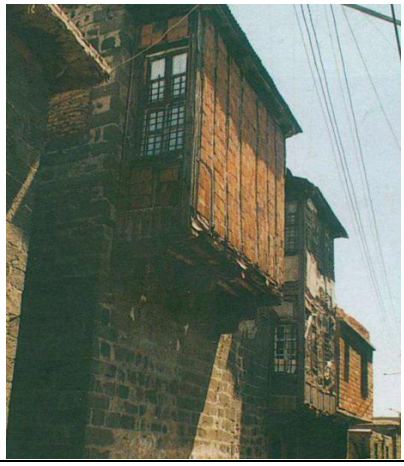
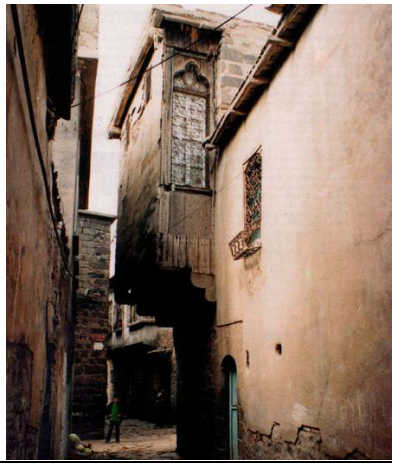
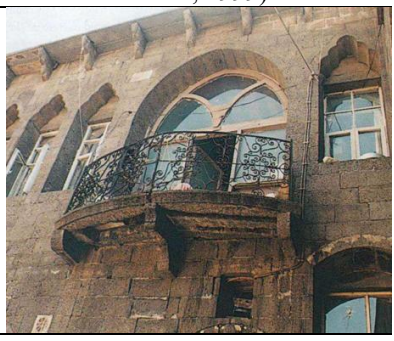
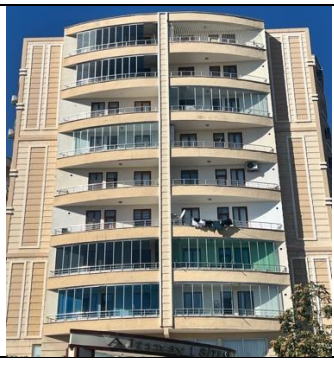
1. Cumba (projecting wooden balconies): Characteristic of Ottoman-influenced architecture, cumba are enclosed or semi-enclosed wooden structures that project over narrow streets. They provided shaded, ventilated spaces for women to observe public life without being seen, reflecting cultural norms of modesty (Çetin, 2011; Budak & Işık, 2024).

2. Stone balconies: Constructed in basalt, the dominant local material, these balconies are more monumental in character, often associated with wealthier households. They symbolize permanence and status within the urban landscape (Dalkılıç & Bekleyen, 2009).

3. Open terraces: Frequently located on upper floors or rooftops, terraces function as flexible spaces for household activities, from drying produce to hosting guests during summer nights (Ayçam et al., 2020).

4. Modern concrete balconies: Emerging in the twentieth century, these reflect shifts toward apartment living and modernist architectural forms. While lacking the ornamentation of earlier types, they continue to serve as liminal platforms for everyday practices (Aykalp & Ayçam et al., 2020).

Table 1. Balcony types in Diyarbakır

Cumba		
	(Tuncer, 1999)	Tuncer, 1999)
Stone Balcony		
Open Terrace		
Modern Concrete Balcony		

This typological diversity illustrates how balconies evolved in response to both cultural continuities and socio-economic transformations.

3.3. Urban Transformation and Heritage Challenges

The twentieth century brought significant transformations to Diyarbakır's urban fabric. Rapid population growth, rural-to-urban migration and modernization policies reshaped the city's built environment. Apartment blocks with concrete balconies proliferated, particularly outside the old city walls, altering the scale and character of balcony culture. In Sur, urban redevelopment and conflict-related destruction in the 2010s further threatened traditional balcony structures. Large sections of the district were demolished or reconstructed, raising concerns about the erasure of vernacular heritage and the homogenization of urban identity (Eren & Şalgamcıoğlu, 2025). These processes underscore the precarious position of balcony culture within contemporary urban development, caught between preservation and modernization.

3.4. Cultural Symbolism of Balconies in Diyarbakır

Beyond their architectural and functional roles, balconies in Diyarbakır hold deep cultural symbolism. They are associated with notions of privacy, particularly in relation to women's visibility. They also symbolize hospitality, with outward-facing balconies serving as extensions of the home where guests could be entertained semi-publicly. Furthermore, they represent cultural resilience, as households use balconies to perform and transmit traditions, whether through decoration, ritual practices, or everyday routines. In contemporary Diyarbakır, balconies also function as sites of cultural adaptation. Younger generations use them for digital connectivity, turning them into stages for online performance or casual leisure. During the COVID-19 pandemic, balconies became critical spaces of resilience, enabling collective rituals such as neighborhood solidarity gestures, aligning Diyarbakır with global balcony practices while inflecting them with local cultural meanings.

In sum, the historical and urban context of Diyarbakır provides essential grounding for the analysis of its balcony culture. The city's layered heritage, courtyard house typologies and socio-cultural dynamics have all shaped the evolution of balconies as liminal spaces. From enclosed cumba projecting into narrow streets to modern concrete balconies on apartment blocks, these architectural elements embody shifting negotiations of privacy, sociability, gender and cultural identity. As the following sections will demonstrate, examining balconies in Diyarbakır through the lens of liminality not only illuminates their local significance but also contributes to broader debates on thresholds, heritage and everyday urban life in the twenty-first century.

4. Methodology

This study utilizes a mixed-methods qualitative approach to investigate the balconies of Diyarbakır as liminal urban spaces. The methodological orientation is informed by an understanding of balconies as socially and culturally meaningful loci of everyday practice, rather than mere architectural appendages. The research design integrates architectural analysis, ethnographic fieldwork and semi-structured interviews, facilitating a multi-scalar perspective that encompasses both the materiality of balcony forms and the lived experiences of their users.

The selection of the Sur district of Diyarbakır is motivated by its historical and cultural significance. As the walled old town, Sur contains the highest concentration of traditional courtyard houses and cumba balconies, thereby providing an exemplary context for examining how these architectural elements embody the intersection of heritage, sociability and liminality. Concurrently, Sur has undergone significant urban transformation and conflict-related destruction, which positions the district as a critical site for analyzing the challenges confronting balcony culture in contemporary settings.

The first dimension of the methodology consists of the architectural documentation of balcony typologies. Field surveys were conducted along selected streets in Sur, recording variations in form, materiality and orientation. The principal typologies identified comprise projecting wooden balconies (cumba), frequently enclosed with latticework; basalt stone balconies, often associated with more affluent households; open terraces situated on upper levels or rooftops; and modern concrete balconies found on apartment buildings. Photographic documentation and spatial measurements were systematically collected to establish a comparative typology. The analysis extended beyond structural details to include decorative elements such as wooden carvings, iron railings, or potted plants, which express cultural values and familial identity. This architectural inquiry provided a material foundation for interpreting the mediating function of balconies between domestic interiors and the public sphere.

The second dimension involved ethnographic observation of balcony use, conducted at various times of day and across different seasons to capture the temporal rhythms of balcony life. Observations focused on social interactions between residents and neighbors, practices of surveillance and observation of street activity, seasonal uses such as drying produce or drinking tea and ritual practices. These observations revealed the adaptability of balconies as liminal platforms, whose functions shift according to temporal and cultural rhythms. Moreover, distinct patterns of gendered usage were observed, with women frequently engaging in domestic activities on balconies during the day and men

utilizing these spaces in the evenings for social interaction with neighbors or guests.

To complement the architectural and observational data, semi-structured interviews were conducted with residents encompassing a range of ages, genders, and socio-economic backgrounds. The interviews explored personal experiences and memories associated with balcony life, perceptions of privacy, visibility and community, gender norms related to balcony use, changes in balcony practices amidst modernization and urban redevelopment and experiences of balcony use during the COVID-19 pandemic. The semi-structured format allowed for flexibility, enabling participants to convey their perspectives in their own terms while ensuring the inclusion of key topics. The interviews yielded valuable insights into the affective and symbolic dimensions of balcony culture, highlighting the ways in which balconies function as sites of nostalgia, identity and resilience.

Several methodological limitations influenced the research process. The fieldwork period captured specific seasonal rhythms but did not encompass the full annual cycle of balcony use. Efforts were made to include participants of diverse ages, genders and socio-economic backgrounds. However, certain groups, such as elderly women and migrants, were more difficult to access consistently. The study conducted a total of 30 interviews, with participants selected based on their residence in different segments, covering an age range from 18 to 75. Despite these constraints, the integration of architectural analysis, ethnographic observation and interviews produced a robust dataset for examining balconies as liminal spaces. This methodological pluralism enhances the validity of the findings through the triangulation of material, observational and experiential dimensions.

In summary, the methodology of this study synthesizes architectural documentation with ethnographic inquiry to elucidate the complexity of balcony culture in Diyarbakır. By combining material analysis with attention to lived experience, the approach recognizes balconies as both architectural forms and cultural practices, thereby offering a model for the study of other threshold spaces in urban contexts.

5. Findings

The findings show that balconies in Diyarbakır perform multiple spatial and social functions shaped by architectural form, historical context, and everyday practices. Field documentation identified several balcony types common to the region, including enclosed cumba associated with Ottoman and Middle Eastern domestic architecture (Arslan & Yıldırım, 2021), inward-oriented courtyard terraces typical of traditional houses (Halifeoğlu, 2013) and modern concrete balconies that emerged with twentieth-century apartment construction. These forms are unevenly distributed across the Sur district, with traditional typologies prevalent in older street patterns and modern balconies dominating newer developments, reflecting Diyarbakır's layered urban morphology.

Ethnographic observations and interviews show that balconies routinely used for domestic activities, such as food preparation, drying laundry and seasonal adaptation, as well as informal sociability across narrow streets. Similar uses have been documented in comparable Middle Eastern and Mediterranean cities, where balconies act as extensions of the house and facilitate everyday interaction (Bekleyen & Dalkılıç, 2011). Interviews reveal that while some residents continue to use balconies as vantage points for observing street life, others treat them as private retreats, highlighting variation rather than a uniform cultural pattern.

Gendered dimensions of balcony practice persist as an important, though shifting, aspect of everyday life. Projecting and enclosed balcony types historically enabled regulated visibility for women in Ottoman and vernacular domestic settings (Eldem, 1955); contemporary accounts suggest these gendered practices continue in some contexts but have become more fluid among younger residents, who increasingly use balconies for leisure, digital activities and mixed-gender socializing. These observations align with broader scholarly accounts that link balcony/oriel forms to gendered geographies and changing social norms in the region. Temporal rhythms structure balcony use: mornings and daytime are often oriented toward domestic labor, evenings toward relaxation and neighborly exchange and warm seasons toward intensified rooftop and terrace use for sleeping and social activities. These temporal and seasonal patterns reflect well-documented domestic adaptations to climate and the courtyard house form in southeastern Anatolia (Bekleyen & Dalkılıç, 2011; Manioğlu & Yılmaz, 2008). Residents routinely adapt the furnishings and decorative elements of their balconies in response to changing weather and social needs, demonstrating the dynamic nature of these spaces (Table 2).

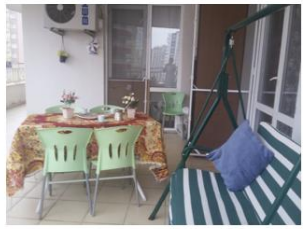
Table 2. Comparison of traditional and contemporary balcony's aspects

ASPECT	TRADITIONAL BALCONIES	CONTEMPORARY BALCONIES
Spatial Typology	Enclosed wooden cumba or stone terraces	Glazed or open aluminum-framed balconies
Function	Observation, sociability, climate mediation	Leisure, decoration, private retreat
Social Orientation	Collective, gendered, outward-looking	Individual, inward-looking
Symbolism	Cultural continuity and social participation	Modernity, aesthetics and personal identity

Residents of new apartment buildings often personalize their balconies with textiles, plants, or seating arrangements, creating microcosms of intimacy within standardized architectural frameworks. The gestures of decoration, conversation across balconies, and evening tea gatherings evoke patterns reminiscent of older practices, even as the physical forms have changed. In this sense, the balcony

continues to mediate between private retreat and public connection, adapting to new material and social conditions while preserving its liminal character (Table 3).

Table 3. Examples of modern balocnies with different decorations

A		B	
			
C		D	
			

These findings support the interpretation of balconies as socially meaningful threshold spaces. Their liminal quality aligns with anthropological and urban studies theories that emphasize the significance of transitional spaces in shaping social interaction (Turner, 1969; Low, 2017). However, the extent to which balconies facilitate sociability, cultural continuity, or neighborhood visibility differs substantially across household type, socio-economic conditions, and architectural form. Modern

balconies, for example, do not inherently reproduce the communal practices historically associated with cumba; instead, their social meaning depends on how residents choose to inhabit and personalize them, reflecting Lefebvre's (1991) argument that space is produced through the interplay of material form and lived practice. Experiences during the COVID-19 pandemic further demonstrate this variability. Although global balcony performances drew attention to their capacity for social resilience (Gür, 2020), residents in Diyarbakır described participation as selective and limited, unlike the widespread practices observed in European cities. This suggests that balcony-based sociability cannot be assumed to reflect a stable, culturally embedded tradition in the local context (Khalil & Eissa; 2022).

Interpretation of these findings is shaped by several limitations. Fieldwork covered only part of the annual cycle and may not reflect long-term seasonal variability. Certain demographic groups, especially elderly women and recent migrants, were difficult to access, shaping the range of perspectives represented. Interview accounts may be influenced by nostalgia or selective recall, a common limitation of qualitative studies. In addition, reconstruction parts of Sur likely affected both the physical availability of balcony types and residents' perceptions of cultural continuity and change. Finally, while frameworks such as liminality (Turner, 1969), the production of space (Lefebvre, 1991) and gendered geographies (Massey, 1994) elucidate important dimensions of balcony life, they do not encompass economic, political, or security-related factors that also shape everyday spatial practices in Diyarbakır. Economic factors, such as fluctuations in property values or income levels, can influence the ability of residents to maintain and customize balcony spaces. Political and security issues, including regional instability or local governance, may affect residents' use and perception of these spaces, potentially altering their communal and cultural functions.

6. Discussion

The findings from Diyarbakır's balconies emphasize their significance as liminal urban spaces that mediate the intersection of domestic and public realms, tradition and modernity, individual privacy and collective belonging. These observations may be interpreted through established theoretical frameworks, situating Diyarbakır within broader scholarly debates on liminality, urban thresholds and everyday urbanism, while comparative perspectives from global contexts further highlight both the particularity and universality of balcony culture.

Balconies in Diyarbakır function as thresholds that are neither entirely private nor wholly public, allowing residents to inhabit an interstitial space that is both socially and symbolically generative. This liminality is manifest in diverse ways:

cumba structures facilitate women's observation of public life without contravening social norms of modesty; balconies themselves serve as environments for private retreat and communal engagement; and during the COVID-19 pandemic, they emerged as platforms for collective rituals, accentuating their role as connectors between isolation and community.

The social production of balcony space in Diyarbakır is illuminated by Lefebvre's triadic model, which recognizes material, symbolic and experiential dimensions. Balconies operate as functional extensions of the home, enable cultural symbolism through their architectural features, and constitute lived spaces imbued with memory and identity. The interplay between form and use is especially evident when modern concrete balconies, though lacking ornamentation, are personalized with plants and textiles, thus acquiring new layers of cultural meaning. In this way, balconies exemplify the notion that space is socially produced rather than passively inhabited (Lefebvre, 1991).

Balconies further embody the hybridity conceptualized in Soja's notion of Thirdspace, simultaneously operating as material structures, cultural symbols and lived thresholds wherein residents negotiate visibility, perform hospitality and cultivate neighborly engagement. The coexistence of traditional cumba and modern balconies testifies to this hybridity, complicating binary distinctions between tradition and modernity and revealing the fluidity of forms and practices across historical periods (Soja, 1996).

The gendered dynamics of balcony use remain a salient theme. Historically, balconies provided women with regulated visibility, facilitating participation in public life while adhering to cultural prescriptions of modesty. Contemporary practices, however, reveal evolving gender norms, with younger women utilizing balconies for leisure, study and digital engagement. Nevertheless, cultural negotiation persists and women's visibility on balconies may remain constrained in certain contexts. Comparative research from other cities affirms the cultural specificity and global significance of balconies as threshold spaces for gendered sociality.

Temporal adaptability characterizes balcony use in Diyarbakır, as their functions shift in accordance with daily cycles, seasonal changes and ritual occasions. Balconies serve as domestic workspaces, leisure venues and sleeping quarters, while also functioning as vantage points for cultural and political events. This flexibility exemplifies the temporality of dwelling, whereby built forms are dynamically inhabited and imbued with meaning across time. Balconies are further imbued with profound cultural symbolism, signifying status, honor and hospitality, and serving as repositories of memory and nostalgia. However, urban redevelopment and conflict-related destruction pose threats to the continuity of

traditional balcony forms and associated cultural practices, rendering the preservation of balcony culture integral to safeguarding intangible heritage.

The COVID-19 pandemic underscored the global resonance of balcony practices, as balconies were transformed into communal stages for rituals of resilience and solidarity. Such practices exemplify the enduring potential of liminal spaces to foster community under duress. Comparative cases from diverse cultural settings reveal both universal and particular aspects of balcony liminality (Emekci, 2021; Ribeiro et al., 2020). A comparative perspective situates Diyarbakır's balconies within a broader spectrum of global practices, demonstrating shared dynamics and contextual specificities. While Mediterranean and Middle Eastern cities utilize balconies for vibrant street life and sociability (Ek Işın et al., 2020), Northern European and Latin American contexts reveal distinct patterns of use and cultural meaning (Smektala & Baborska-Narozny, 2022). Diyarbakır's unique basalt architecture, Ottoman heritage and multi-ethnic composition accentuate the necessity of contextualizing balcony culture within its specific historical and political milieu.

The findings hold significant implications for urban design, heritage policy, and social sustainability. Balconies exemplify the value of threshold spaces for fostering sociability, resilience, and individual privacy in urban environments. Policy efforts should prioritize the conservation of vernacular architectural elements such as cumba, recognizing their role in sustaining both tangible and intangible heritage. Urban planners should establish design guidelines that promote the integration of traditional balcony styles into new construction, ensuring that modern developments respect the cultural aesthetic and historical context of the area. Participatory conservation strategies, involving local communities in the preservation process, can enhance the social relevance and impact of these efforts. Heritage authorities might consider implementing educational programs and workshops to raise awareness about the cultural significance of balcony architecture. The adaptability of balconies offers a model for designing socially responsive urban environments in contemporary cities, demonstrating how new developments can benefit from incorporating flexible, multi-use spaces that encourage community interaction (Smektała & Baborska-Narożny, 2022; Pelsmakers & Warwick, 2022).

In conclusion, balconies in Diyarbakır should be regarded as central rather than peripheral elements of urban life. They encapsulate liminality, hybridity and cultural negotiation, embodying the interrelations of material form, social practice and symbolic meaning. As platforms for community, sites of gender and cultural negotiation, and spaces responsive to temporal and environmental

rhythms, balconies affirm the enduring relevance of threshold spaces in shaping urban experience and envisioning future urbanity.

7. Conclusion

This study set out to understand how balconies in Diyarbakır reflect broader socio-spatial transformations, how they mediate relationships between privacy, sociability, and identity, and how they maintain their function as liminal spaces amid urban change. The findings demonstrate that balconies, whether traditional cumba or modern concrete forms, continue to operate as threshold spaces that balance domestic enclosure with outward engagement. Their everyday use, shaped by gender norms, spatial practices and cultural symbolism, illustrates how residents negotiate visibility, belonging and social interaction within an evolving urban context.

Architectural analysis and ethnographic data reveal that balcony practices have shifted from historically collective and outward-oriented forms of liminality toward more individualized and private uses, yet without losing their capacity to connect residents to the rhythms of the street and neighborhood. This continuity within change underscores the enduring social relevance of liminal spaces in Diyarbakır. The study also highlights how modernization, redevelopment, and changing gender dynamics reshape balcony use, while residents actively reconfigure these spaces through decoration, adaptation and personal expression.

The study's methodological limitations, including a restricted seasonal timeframe, challenges in accessing certain demographic groups and the evolving post-conflict landscape of Sur, mean that the results should be interpreted as contextually rich but not comprehensive. Future research is needed to evaluate balcony practices across different districts and socio-economic groups and to investigate how digital technologies, migration and redevelopment continue to reshape balcony culture.

These insights contribute to broader debates on the production of space, threshold urbanism, and cultural resilience. They demonstrate that balconies are not peripheral architectural features but meaningful cultural interfaces where everyday spatial negotiations unfold. For urban design and heritage policy, the findings emphasize the importance of preserving vernacular balcony forms and supporting design approaches that integrate flexible, multi-use threshold spaces into contemporary housing.

By situating the analysis within the city's layered heritage and lived practices, this research shows that the liminality of balconies remains a key dimension of Diyarbakır's urban identity. Balconies continue to mediate the tensions between tradition and modernity, privacy and sociability and individual experience and communal life which offering valuable insights for understanding the cultural and spatial dynamics of cities undergoing rapid transformation.

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CHAPTER 7

Problems Emerging in the Residential Renovation Process: A Case-Based Technical Assessment

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1. INTRODUCTION

Residential overhaul is a frequently used intervention within contemporary architectural production practices. Overhaul activities are commonly undertaken today to modernize the technical infrastructure of residential buildings, address aesthetic concerns, or repair physical wear and tear caused by long-term use. Residential overhaul is a complex construction process that requires time and effort due to the interdependencies between the projects, requiring a high level of expertise and skilled craftsmanship. Therefore, it is quite common to encounter various construction errors and application-related problems at different stages of the overhaul process. It is a common occurrence in architectural production practices, particularly in successive production steps, when a new application step reveals defects from the previous one. Such situations can lead to structural and functional complications that are difficult to correct and, in some cases, technically impossible to compensate for later in the process. This study presents a comprehensive evaluation of a sample residential overhaul process and systematically documents the problems that arise at each stage of the production chain through on-site observations, photographic documentation, and process-based evaluation. The study details the types of defects identified in flooring renovations, foundation stabilization, mechanical-electrical installation issues, wall construction, paint-plaster applications, and door installation. The findings highlight the critical importance of architectural experience, skilled craftsmanship, and supervision in minimizing cascading problems throughout the overhaul phases. This study provides evidence-based guidance for architects, contractors, and homeowners undertaking residential overhaul to improve renovation quality and prevent recurring problems.

2. MATERIALS AND METHODS

2.1. Case Area

The example residence used in this study is located in the Havzan neighborhood of Meram district, Konya, on the ground floor of a three-story apartment building constructed in 1994 (Figure 1).

Figure 1: Apartment Facede

An examination of the floor plan of the ground-floor dwelling shows that the unit contains three rooms, a saloon, and one each of a bathroom, kitchen, washroom, and toilet. Additionally, the residence includes two balconies—one adjoining the living room and the other connected to the children's bedroom (Picture 2). The balcony attached to the children's bedroom has had its outward-facing façade enclosed with glazed material and is currently used as a pantry.

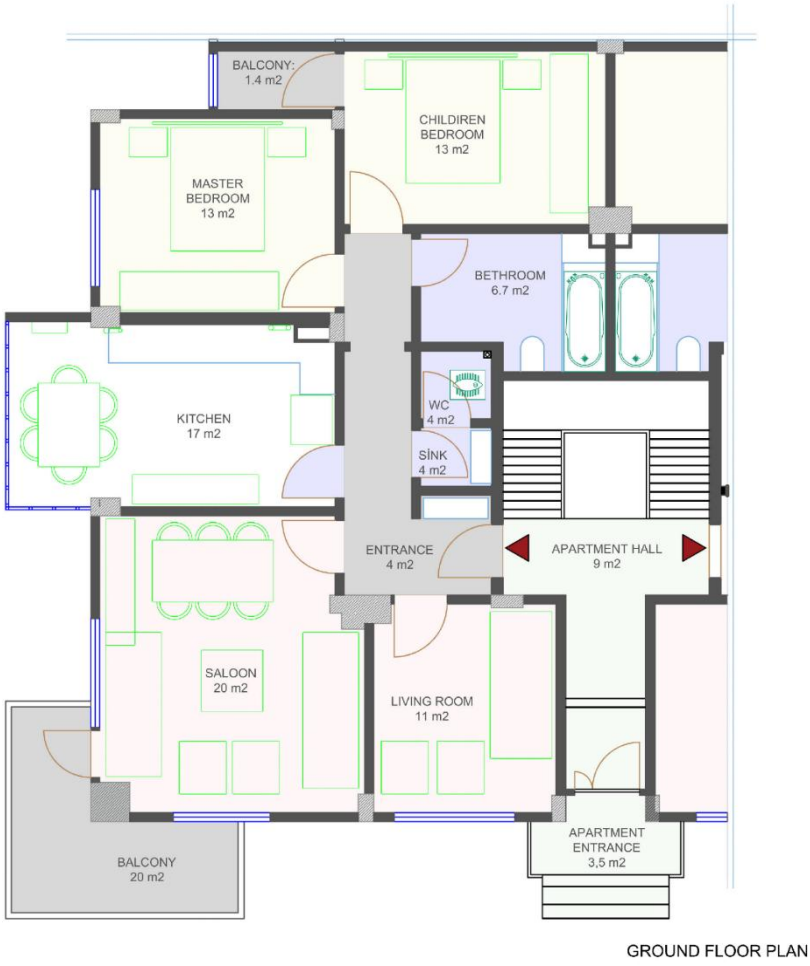

Figure 2 – Ground Floor Plan

The structural assessment revealed that a portion of the floor system in the ground-floor apartment is directly supported by the basement load-bearing elements, while the remainder rests on a compacted soil fill layer (Picture 3). Notably, in the living room, kitchen, and master bedroom, as well as on adjacent wall surfaces above the compacted fill, gradual settlement of the supporting fill material has compromised the stability of the floor system, resulting in structural cracks. The extent and nature of these deformations necessitated comprehensive remedial interventions to restore both the integrity and functional performance of the affected areas.

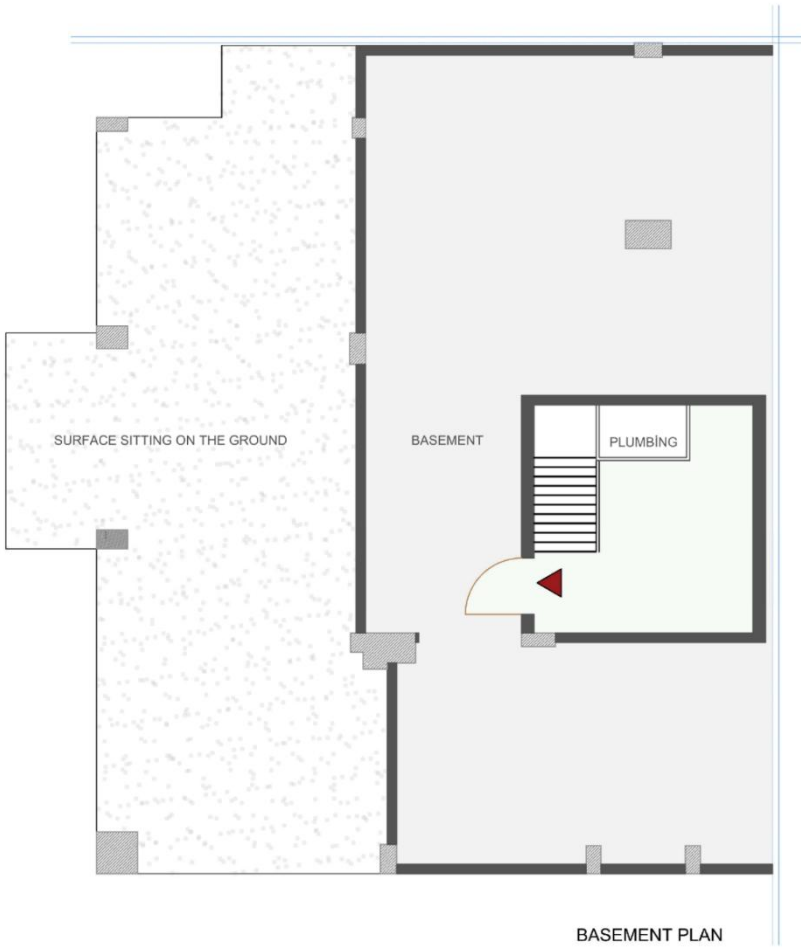

Figure 3 – Basement Floor Plan

Within the scope of the renovation aimed at ensuring floor stability, the replacement of existing utility pipes in the opened floor areas was included in the program to prevent potential future water installation issues that could necessitate reopening the floor and to enhance spatial aesthetics. Accordingly, the pipes of the natural gas heating system, which had been subsequently installed and were running along the wall surfaces—disrupting the visual integrity of the space—were removed from the walls and integrated into the floor structure. Additionally, aged metal water pipes were replaced with modern plastic piping to improve the durability and longevity of the system. In Türkiye, the current regulation governing renovation works is the "Regulation on Zoning of Planned Areas" dated 03.07.2017, and all construction activities are carried out based on this regulation. The Regulation on Zoning of Planned Areas distinguishes between two types of renovations: "substantial renovation" and "minor renovation" (Planlı Alanların İmar Yönetmeliği, 2017). Substantial renovations cover alterations that

affect the building's construction area, the number of independent units, the area of common spaces or independent units, or changes in their intended use. Minor renovations, on the other hand, can be defined as construction activities that do not require a building permit (Ertuğ, 2023). The main distinction between these two types of renovations, as emphasized in Article 59 of the Regulation on Zoning of Planned Areas, is that minor renovations cannot alter the load-bearing system, the exterior façade of an independent unit, or the location and number of wet areas (Planlı Alanların İmar Yönetmeliği, 2017). Accordingly, any modifications carried out under these conditions can be considered minor renovations that do not require a permit (Ertuğ, 2023). According to the Regulation on Zoning of Planned Areas, interior interventions that do not affect the structural system are not subject to inspection. Therefore, there is no obligation to submit any notification for minor renovations.

2.2. Research Method

The purpose of this study is to present the implementation phases and to identify the problems encountered during the application process. The workflow consists of six main stages.

1- Renewal of the Collapsed Floor

A- Opening the collapsed section of the floor

B- Filling the collapsed floor area with reinforced concrete

C- Renewing the old water and heating installations found in the floor

D- Covering the installations by pouring leveling concrete

E- Completing the installation of tiles and laminate flooring

2- Adding and Removing Partition Walls

A- Renewal of electrical lines

3- Repair of Cracked Walls

A- Applying plaster to walls and ceilings

B- Painting the walls

4- Replacement of worn and damaged doors

5- Installation of kitchen cabinets and built-in cupboards

A- Rearranging the kitchen cabinet under the countertop for the oven and dishwasher

B- Installation of the kitchen countertop

C- Installation of the stovetop, sink, and range hood

D- Installation of built-in cabinets such as wardrobes and pantry units

6- Tile installation at the apartment entrance

7- General cleaning

The renovation process began with the removal of the floor coverings (wooden parquet and tiles) in the living room, kitchen, and master bedroom in order to repair the collapsed floors (Picture 4–5).

Picture 4: Living room wooden flooring to be removed

Figure 5: Kitchen Ceramic Flooring to be Removed

In order to prevent the cracks that formed on the floor due to the displacement of the soil fill beneath the slab from reappearing as a result of potential future settlements, structural reinforcement was provided by placing load-bearing rebar in the collapsed areas (Figure 6). Subsequently, the collapsed zones were filled with concrete infill and sealed, completing the repair process of the affected regions.

Figure 6: Application of structural reinforcement to the ground

During the renovation of the collapsed floor areas, the removed old metal water pipes were replaced with new-generation plastic water pipes laid on the repaired floor surface (Figure 7). In addition, following the connection of the natural gas network to the residence in 2004, the heating pipes that had been added later and ran along the wall surfaces were removed, renewed, and placed under the floor (Figure 7). Subsequently, screed concrete was poured to cover the pipes, and the floor level was leveled (Figure 8).

Figure **7**: Renovated and underground water and heating pipes.

Figure 8: Floor leveling applied by pouring screed concrete

After the floor leveling was completed, although there was no technical necessity, an infill wall was constructed through the center of the saloon to create an additional room and to enhance the building's seismic resistance, effectively dividing the space into two separate rooms (Picture 9). This infill wall existed in the building's original plan; however, it was determined that previous occupants had removed it in order to enlarge the living room. This case illustrates that one of the most common types of contemporary building interventions involves the addition or removal of infill walls (Güler, 2021). Such interventions are generally analyzed under three main categories: psychological needs, physical requirements, and economic considerations (Özen, 2018). In the present example, the addition of the infill wall was requested by the users due to physical requirements. According to Article 59 of the Zoning Regulation for Planned Areas dated 03.07.2017, and the amendment added on 25.02.2022, the repair of partition walls and interior design changes that do not affect the structural system or fire safety are not subject to building permits (Planlı Alanlar İmar Yönetmeliği, 2021).

Figure 9: Brick Wall

In reinforced concrete structures, partition walls are not considered primary structural elements. However, research has demonstrated that the presence of partition walls enhances the overall stability of the structural system. Specifically, the placement of infill walls within the frame contributes to increasing the structural stability of the load-bearing system. Especially due to the commercial function on the ground floor, it has been observed that buildings with a reduced number of partition walls sustain damage during earthquakes, with the upper floors collapsing onto the ground floor. This phenomenon is defined as the "soft-story" problem (Ertuğ, 2023). The removal of infill walls compromises the structural system of the building, resulting in the formation of a weak story. The existence of a soft and weak story adversely affects the seismic performance of the structure (İnel et al., 2008). In his study, Bayülke (2003) demonstrated that brick infill walls contribute to the stiffness of reinforced concrete frame systems. Kaplan (2008) experimentally showed that calculating the seismic resistance of structures with and without infill walls yields different results. Baran (2012) examined structures with and without infill walls under lateral and low-load effects, revealing that infill walls increase the load-bearing capacity of the frame by 3.5 times. Similarly, Demirel et al. (2015) found that the shear force in infill walls is 43% higher compared to empty frames. A review of the literature indicates that the seismic behavior of a structural system differs significantly when constructed with infill walls versus an empty frame (Kaplan, 2008). The reconstruction of the mentioned infill wall represents an intervention that will enhance the building's stiffness against seismic loads (Figure 10).

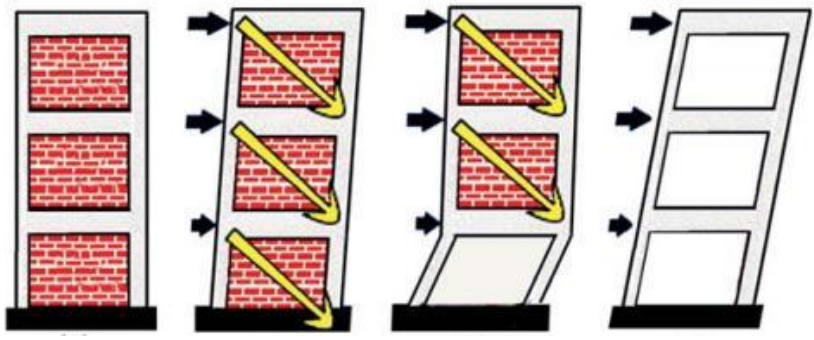

Figure 10: Seismic floor displacement of a reinforced concrete structure depending on the infill condition (Kaplan, 2008).

Concurrently with the construction of the infill wall, gypsum plaster was applied to the walls, preparing them for painting (Figure 11). The primary reason for completing the plastering and painting before the installation of the floor finishes was to prevent plaster and paint residues from reaching and damaging the flooring during these applications.

Figure 11: Plastering and painting applications on the walls.

After the plastering was completed, the interior walls and ceilings of the residence were painted, preparing the surfaces for final finishing touches.

Subsequently, electrical wiring was installed through both the floor and the walls to provide power connections for the relocated boiler in the kitchen and the infill wall constructed at the center of the living room (Figure 12).

Figure 12: Electric lines drawn from the floor and wall

Following the completion of wall and ceiling painting as well as the installation of electrical and plumbing systems, the flooring installation commenced. Initially, ceramic tiles were laid in the entryway, kitchen, bathroom, and toilet areas (Figure 13).

Figure 13: Tile flooring application

After the completion of the tile installation, a floor level mismatch between the rooms was observed during the subsequent laminate flooring application (Figure 14). This height difference was determined to have resulted from laying new tiles directly over the existing ones without removing them (Figure 13). To ensure a uniform level for the laminate flooring across all spaces, leveling concrete was reapplied to the lower areas of the living room, lounge, and bedrooms.

Figure 14: Ground level discrepancy in the place where laminate flooring will be installed

After raising the floor levels of the rooms with low ceiling heights by pouring leveling concrete, it was determined that, due to the floor level being elevated both by the previous faulty tile application and the necessary raising for the laminate flooring installation, some interior wooden door frames remained embedded in the floor, while others absorbed moisture from the poured leveling concrete, causing them to swell and become damaged. As a result of this process, it became necessary to replace all interior doors. The existing doors were removed, and new doors were ordered. Laminate flooring was installed in the rooms whose levels were equalized with leveling concrete (Figure 15). Laminate installation, being generally a practical and rapid method, was completed without encountering significant issues. Prior to installation, a silte underlay was laid on the concrete floor to prevent heat transfer. Subsequently, starting from a corner of each room, the laminate panels were assembled using a sliding method. Following the completion of the floor finishing works, the ordered new doors were installed (Figure 15). Upon completion of the door installation, the installation of wooden skirting boards was carried out (Figure 16).

Figure 15: Lacquer coating door installation

Figure 16: wooden skirting board installation

In the final stage, built-in cabinets, including the kitchen and bathroom cabinets as well as the vestibule and pantry cupboards, were installed in accordance with the interior layout plan (Figure 17-18). After the wooden framework of the kitchen cabinet was completed, the kitchen marble countertop was custom-fabricated on site and integrated onto the cabinet (Figure 17). Subsequently, kitchen fixtures, including the countertop stove, sink, and built-in dishwasher and oven beneath the countertop, were installed in their designated positions as specified in the construction project. This sequential approach not only preserved the visual and aesthetic harmony of the interior but also reflected the meticulous integration of architectural design and technical execution, optimizing both the functional performance and durability of the built environment.

Figure 17: kitchen cabinets and marble

Figure 18: cloakroom and pantry cabinet

Finally, the tile flooring was installed in the apartment entrance (Figure 19). Subsequently, the entire construction site was thoroughly cleaned.

Figure 19: Apartment entrance tile flooring and railing installation.

Following the completion of each implementation phase, it was observed that due to insufficient on-site supervision and the lack of experience of the contractors, structural and execution-related issues arising from previous interventions emerged when progressing to the subsequent phase. These issues are discussed in detail in the following section.

3. RESULT AND DISCUSSION

As stated in the introduction, the primary intervention to correct the ground settlement involved systematically removing the floor coverings located in the collapse area. The wooden parquet flooring in the living room and bedrooms was dismantled, and the kitchen tiles were removed. The wooden parquet panels in the living room and bedrooms were broken during removal without consideration for potential reuse after the floor rehabilitation, rendering them unusable (Picture 19). The main reason for breaking these parquet panels is that the monolithic, interlocking wooden panels have large surface areas, which makes it impractical to store them inside the residence during the collapse-related floor repair. Furthermore, transporting the parquet panels out of the residence in one piece was not feasible, necessitating their disassembly for removal. Once removed, the collapse area beneath the wooden panels was filled with concrete to restore the floor. After stabilizing the surface, laminate flooring was installed. The existing kitchen tiles were broken and removed because reinstalling them was technically unfeasible. However, in the entrance hall, bathroom, and WC areas, which are not located in the collapse zone and do not rest on compacted soil, no floor leveling was required, and therefore the existing tiles were retained. The new tile installation in these areas was planned to be laid directly over the existing tiles.

Figure 19: Wooden parquet flooring that was broken and removed from the house.

Later, concrete was poured into the subsided areas to compensate for the sinkholes in the ground. After the concrete pouring was completed and the floor tiles were laid, it was observed that there were differences in elevation between the rooms and the original doors were hidden within the new floor (tile covering). It was determined that the main cause of this problem was that the old tiles in the entrance hall, bathroom, and toilet were not removed before the new tiles were laid on top of them. This situation caused the ground level of the house to be higher than the old ground level. It was noticed that the higher ground level of

the kitchen, bathroom, and entrance hall resulted in a lower ground level in the living room, bedrooms, and the subsequently added sitting room (Figure 20).

Figure 20: difference in ground level between spaces

In order to eliminate the height differences between floor levels, it became necessary to pour additional leveling concrete in the living room, sitting area, and bedrooms, which were at lower levels. The poured leveling concrete raised the floor level of the residence compared to its original state. Consequently, some door frames were found to be embedded within the new floor level, while others had absorbed moisture from the leveling concrete, causing them to swell and become damaged. For these reasons, it was necessary to remove the original doors and replace them with new ones. While awaiting the delivery of the new doors, it was observed that in certain areas of the walls where plastering had been completed, the plaster was not properly adhered to the surfaces. In these areas, the existing plaster was removed, and a primer was applied to the surfaces to enhance the adhesion of the new plaster during the subsequent reapplication, as part of the repair process (Figure 21). Subsequently, the painting of the walls was carried out.

Figure 21: Primer application before plastering to improve integration.

Following the completion of the painting works, the installation of the new doors was initiated. During the door installation process, it was observed that in some rooms, electrical outlets and light switches did not align with the wide frames of the newly manufactured doors and were partially obstructed (Figure 22). Consequently, the plaster around these areas was removed, the positions of the switches and outlets were adjusted, and subsequent plaster and paint repairs were carried out to restore the surfaces.

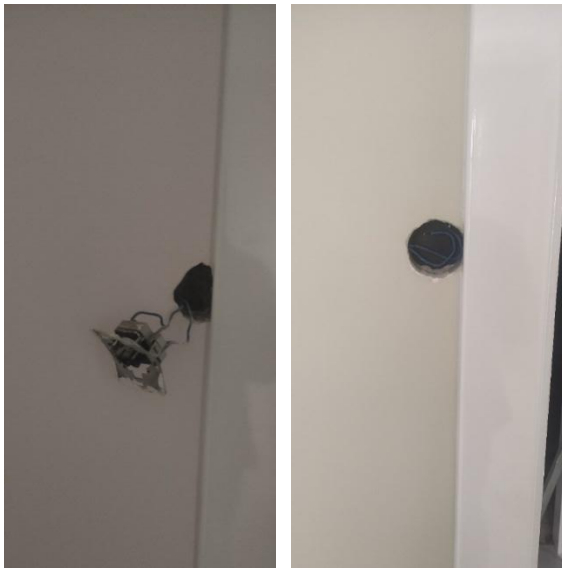

Figure 22: Electrical outlets and switches incompatible with the newly fabricated wide-framed doors

Additionally, due to manufacturing defects, the newly produced doors were shorter than the standard, resulting in gaps of up to approximately 15 cm between the upper door frames and the walls during installation. To eliminate these gaps, the upper frames of certain doors were remanufactured in wider dimensions and subsequently installed.

Figure 23: Gaps between the upper door frame and the wall due to manufacturing defects

However, it was observed that for some doors, the newly produced wider top door frames were broader compared to the original door frames, resulting in misalignment of the doors' upper levels (Figure 24). Correcting this misalignment in the doors' upper levels would only be possible through the costly process of manufacturing new doors; therefore, these discrepancies were not rectified.

Figure 24: Alignment problem at the top of the door

Following the completion of door installations, the application of laminate flooring and wooden baseboards was undertaken.The laminate flooring installation was executed efficiently, owing to the straightforward and modular nature of the system, which minimized constructional disruptions.However, during the installation of the wooden baseboards, it was observed that completing the application along certain long walls with single, continuous baseboard elements was technically unfeasible due to manufacturing dimensions. As a result, the joints between the two baseboard sections became visible and small discontinuities formed. Additionally, the positioning of the water pipes, which extend from the floor and connect to the radiators, was found to be excessively close to the walls during the installation of the plumbing system. This alignment precluded the possibility of maintaining continuous baseboard lines behind the piping (Figure 25). To mitigate the resulting visual disruption, the baseboards were carefully routed around the pipes. Furthermore, weaknesses were identified at the external corner joints of the wooden baseboards, where impact or contact led to accelerated wear and deterioration over time (Figure 26).

Figure 25: Radiator pipes aligned very close to the wall surfaces. **Figure 26**: Wear seen at corner joints of wooden baseboards.

following the completion of the baseboard installation, the assembly of the kitchen cabinets, wardrobes, and bathroom and lavatory furniture commenced. The challenges encountered during the furniture installation phase were largely mitigated due to the inherent flexibility and adaptability of the cabinetry system in practical application.

However, it was observed that cracks began to develop over time on the painted wall surfaces (Figure 27). The primary cause of this deterioration was identified as the absence of a reinforcing mesh during the gypsum plaster application, which prevented the wall from acting as a monolithic structural plane, thereby leading to localized cracking phenomena.

Figure 27: Cracks that form along the joint line in walls constructed without mesh application.

In the final phase of the renovation, the apartment entrance was finished with new tile flooring, providing a durable and visually coherent surface. For enhanced safety and to prevent accidents, protective railings were installed along both sides of the entrance, integrating functional safety measures with the overall architectural design of the building (Figure 19). During the installation of the flooring in the apartment entrance, it was observed that no pre-drilled openings had been provided for the subsequent attachment of protective railings. Consequently, the tiles had to be perforated post-installation to accommodate the anchoring rods of the railings. This corrective intervention revealed localized voids beneath the tile surfaces, which resulted in cracking and minor structural damage in the affected tiles (Figure 28).

Figure 29: Tiles damaged when opening the railing connection points

4. CONCLUSION

In this study, the workflow of a sequential renovation process is presented and illustrated with visual documentation. The interactions and interdependencies between successive interventions are clearly demonstrated, highlighting how each application can influence subsequent stages. The study emphasizes the critical role of expertise, craftsmanship, and on-site supervision throughout the renovation process. Based on these observations, the following recommendations are proposed.

A-) It has been observed that portions of the structure resting partially on soil and partially on the basement have led to the development of cracks within interior spaces over time. Therefore, it is recommended that, in the planning phase, the entire building be designed to rest uniformly on the same foundational level. This approach is expected to prevent future ground settlement issues. Such an approach not only mitigates the risk of localized ground settlement but also ensures a more consistent load distribution, enhancing the overall structural stability and the long-term integrity of the architectural spaces.

B-) It is advisable to replace aging water installations in areas where floorings are removed. This proactive measure helps prevent potential water leakage and avoids the necessity of subsequent interventions on the flooring.

C-) It has been observed that relocating the above-ground natural gas installation, which was later added to the residence, beneath the floor during excavation offers notable visual and aesthetic improvements. Therefore, it is recommended to integrate such installations within the subfloor for enhanced spatial coherence and design integrity.

D-) The precise determination of outlet positions for renewed water and heating systems is essential. As highlighted in this study, radiator outlets positioned too close to walls created complications during the installation of skirting boards. Careful planning of these system terminations is crucial to ensure both functional efficiency and architectural integrity.

E-) The infill wall constructed to divide the living room is recommended not only for its functional advantage—by increasing the number of distinct interior spaces—but also for its structural contribution, as it reinforces the building's resistance to seismic forces, thereby enhancing the overall safety and resilience of the residence.

F-) The use of reinforcing mesh in plaster applications is strongly recommended. As observed in this study, the absence of mesh resulted in areas where the initial plaster failed to adhere properly to the walls, necessitating remedial interventions. Furthermore, shortly after completion, new cracks emerged in the wall surfaces, underscoring the importance of mesh reinforcement to ensure long-term durability and structural integrity of the plastered surfaces.

G-) Plastering operations are recommended to be completed prior to floor installation. This sequence prevents potential damage to newly installed flooring and maintains the integrity and visual continuity of the interior surfaces.

H-) Before the completion of plaster application, the positions of all electrical lines and fixtures, such as switches and sockets, must be carefully checked. Considering future renovation works, any electrical installations that could cause conflicts should be identified and installed prior to plastering to ensure proper integration and avoid interference with subsequent interventions.

İ-) In floor applications, interventions that may alter the established floor levels should be avoided, and particular attention should be paid to this issue. As demonstrated in the study, laying new tiles directly over existing tiled floors led to the necessity of additional leveling concrete and the fabrication of new doors.

J-) When choosing skirting boards, it is recommended to select materials taking into account room dimensions and material durability.

K-) In door fabrication, precise and on-site measurement, as well as supervision during production, is recommended to prevent potential errors in subsequent installation stages.

I-) In scenarios where fixtures, such as railings, will be mounted onto tiled surfaces, it is advisable to install the necessary anchors prior to tiling. This proactive measure prevents the formation of cracks in the tiles in the future.

M-) At the conclusion of each construction phase, it is essential that the work team thoroughly cleans the space. This practice facilitates uninterrupted progress for subsequent construction or installation activities.

This study demonstrates the determining role of process management in architectural renovations by analyzing the problems arising during the successive implementation stages of a residential renovation process through cause–effect relationships. The findings, supported by on-site observations and visual documentation, indicate that isolated application errors directly influence subsequent construction stages, resulting in cumulative structural, functional, and aesthetic deficiencies. In particular, unplanned modifications in floor levels, inadequate foresight in determining mechanical and electrical service outlet locations, errors in construction sequencing, and insufficient site supervision have led to adverse outcomes such as cost overruns, rework, and deterioration of spatial quality. Furthermore, the case study clearly demonstrates the critical impact of non-load-bearing infill walls on the seismic performance of the building.

In conclusion, this study establishes that residential renovations should be regarded not merely as spatial refurbishments but as a complex architectural production process requiring professional expertise, coordination, and an

integrated planning approach. The findings provide an evidence-based and practical reference for architects, contractors, and building users aimed at preventing recurring errors throughout the renovation process.

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CHAPTER 8

Spatial Codes of Theoretical and Practical Conversion in Temporary Settlement Planning

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Introduction

Today, the globe is facing increasingly intense natural, environmental and human problems. Disasters, ecological threats and social crises are not only transforming the socio-economic aspects of daily life, but are also becoming visible at the spatial level through their direct or indirect side effects. The depletion of resources on a global scale, the increase in environmental disasters, and the emergence of urban geographies that have lost their sustainable living conditions for various reasons trigger voluntary or forced population movements, and these mass migrations can be permanent or temporary. The migration, environment and climate change strategy prepared by the International Organisation for Migration (IOM) defines migration not only as a forced movement but also as a mechanism of adaptation and resilience to environmental threats. Migration that becomes necessary due to acute or gradual environmental changes is also seen as an adaptation strategy (IOM, 2021). However, relocations occurring not only in rural but also in urban areas can transform cities into centres of environmental risk and force urban spaces to respond to the socio-spatial needs they bring with them.

According to the UNHCR's Global Trends 2016 Report, the number of refugees worldwide more than doubled during the five-year period between 2011 and 2016. The same report reveals that, for the first time since the Second World War, more than 12 million of the 51 million people with refugee status have begun living in camps (UNHCR, 2017). Indeed, current data shows that once a refugee camp is established, it remains in place for several years, and in some cases, this period can extend to decades. Furthermore, Ataputtu (2010) estimates that, in a scenario where the current conjunctural structure continues for several decades, more than 200 million people will be displaced by 2050 due to climate-related reasons alone. When political conflicts, regional strains, epidemics, water and food crises are added to such large-scale population movements, the issue of temporary settlements emerges as a multi-layered global problem.

The study, based on the concrete facts listed above, aims to discuss the conversion inherent in the theory and practice of temporary settlement design through a comparison with the Refugee Camps and Camp Planning Guide (Cuny, 1977), one of the first guides on the subject, and the Temporary Shelter Area Design Guide (2017), an organisation that is a global humanitarian aid organisation, and aims to discuss the subject through different intervention scales. Thus, the aim is to follow the changes in existing conditions over a half-century period, the spatial solutions developed for these conditions, and the evolution of individual and institutional approaches. The phases of the study are presented in Figure 1.

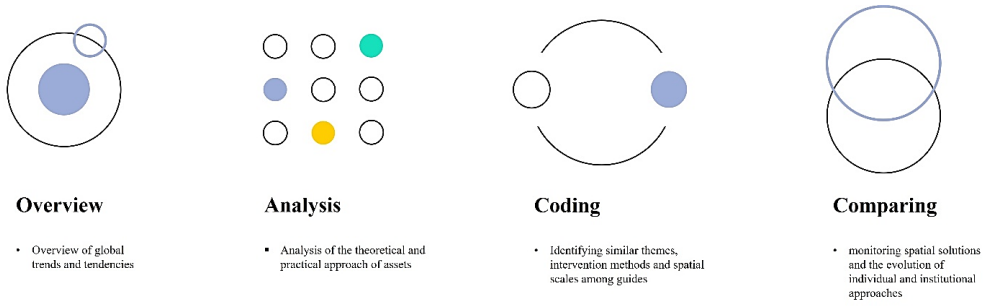

Figure 1. Phases

Overview

The field of disaster and humanitarian response is a multifaceted structure shaped by different organisational levels and interdisciplinary approaches. At the local level, the field takes on an even more diverse and complex nature, depending on site-specific socio-cultural dynamics, geographical conditions, administrative structures and existing network relationships. This situation makes it difficult to analyse two examples at the local level using the same measuring and evaluation methods. For this reason, the initial approach to humanitarian response and temporary settlement planning has been at the level of global organisations that are active, have a wide sphere of influence, and operate in diverse fields.

One of the pioneering organisations in this field, the United Nations High Commissioner for Refugees (UNHCR), was established in 1950 by the United Nations General Assembly to assist people who had lost their homes following the Second World War. Today, the organisation continues its activities in many countries, providing vital and emergency assistance such as shelter, food, water, transport and medical care, while also conducting policy improvement and monitoring work on refugee and asylum laws to ensure the protection of human rights in the long term (UNHCR, 2025). In terms of humanitarian response, the organisation prepares temporary settlement planning studies based on social processes such as population movements, local ecosystems and cultural dynamics (Guiding Principles, 2019). Another global actor, the International Organisation for Migration (IOM), has been active since the mid-20th century and has become one of the leading intergovernmental organisations in the field of migration as part of the United Nations system. IOM has adopted the protection of migrants and the orderly, safe and sustainable management of migration as its key mission (IOM, 2025). The Organisation's 2024–2028 Strategic Plan is structured around three main objectives: protecting the lives of migrants, finding enduring solutions to displacement, and facilitating regular migration pathways (IOM, 2024). Supported by capacity elements such as financing, partnerships, communication, data and human resources, this systematic structure enables IOM to develop spatial interventions and policy approaches that are consistent with sustainable

development goals. Initiated in 1997 as a civil society-led initiative, the Sphere Project aims to improve the quality of humanitarian response in disaster and conflict situations and strengthen accountability. A joint initiative of the Red Cross and Red Crescent Movement and various civil society organisations, the project has developed universal minimum standards for shelter, education, food and disaster scenarios (The Sphere Project, 2011). The Sphere Project brings together the ethical and technical dimensions of humanitarian response and uses collective experience to develop both directly applicable field guidelines (Shelter Design Guidelines, 2017) and comprehensive humanitarian standards (The Sphere Handbook 2000; 2018). This approach brings together the knowledge and experience of different actors, offering a common global reference framework that highlights both the practical and normative aspects of humanitarian response.

The approach that strategically supports the tendency to adapt to local conditions through physical interventions and social policies, rather than individual and hypothetical interventions at the intersection of crisis–migration–space, forms the common ground for all three global actors. However, there are also distinctions between the organisations. UNHCR stands out with its policy development and monitoring expertise in refugee and asylum law, while IOM addresses migration in the context of global development and environmental adaptation, integrating it into its strategic plans. The Sphere Project, meanwhile, appears to have taken on a unique role by offering a civil society-based normative framework that sets standards for the quality and accountability of humanitarian response.

Analysis

In comparing the conversion undergone by the theoretical background and spatial solutions of temporary settlements, settlement planning/design guidelines have been preferred as the data set. In this context, Frederick C. Cuny's (1977) study, one of the first examples on the subject, stands out with its field observation-based approach and site-specific model proposals, and has been determined as the starting point for the analysis phase. However, although other guides suitable for comparison exist in the literature in terms of both approach and application, the Sphere organisation's (2017) temporary shelter design guide was chosen as a comparison option as a current and applicable example. The fact that the preparation process was shaped by site-specific dynamics (with contributions from local authorities, communities, and field feedback) and that standardised principles ensure large-scale applicability were decisive factors in the choice of this guide. On the other hand, as the aforementioned guide focuses directly on shelter and temporary settlement design, the Sphere organisation's Minimum Standards in Humanitarian Response guide (2018) was also included in the analysis process to ensure the contextual integrity of the comparison. This

made it possible to compare both the theoretical background and the implementation processes using the same coding system.

Asset 1: Refugee Camps and Camp Planning Guide (1977)

Frederick C. Cuny's Refugee Camp and Camp Planning Guide (1977) is one of the first comprehensive resources on the design and management of refugee camps, setting out fundamental principles in the context of spatial organisation and sustainability, and providing a data-driven methodological framework for planning temporary settlements following disasters. The guide's approach to temporary settlement planning is structured around three fundamental axes: design, production, and occupancy. In the design phase, alternative settlement plans are developed based on data collected from the field, and the camp's overall physical layout is created, taking socio-economic indicators into account. The production phase represents the physical construction of the camp and covers the longest period during which the spatial decisions envisaged in the guide are transferred to concrete processes. During this process, suitability and functionality are regularly evaluated, and necessary physical adjustments are made as required. The occupancy phase is associated with the settlement of camp residents and the use of social living areas. The guide's content consists of the planning approach, site selection, site plan, and camp development programme phases. However, since the planning approach and camp development programme phases focus on the sustainability of the programme, the supply chain, sponsorship and collaboration processes rather than providing direct spatial references, these phases (Table 1), which are included in the analysis section of the study, have not been addressed separately in the coding section where the guide content is scaled at the spatial level.

Table 1. Asset 1's temporary settlement approach

Phases					
Planning Approach		**Site Selection**	**Design**	**Camp Development**	
Program	▪ Camp size ▪ Location ▪ Budget ▪ iming ▪ Identification of social structure	▪ Topography ▪ Water surfaces ▪ Soil structure ▪ Vegetation ▪ Prevailing winds ▪ Accessibility	▪ Function ▪ Healthcare services ▪ Construction ▪ Drainage ▪ Circulation ▪ Water infrastructure ▪ Fire protection ▪ Waste disposal ▪ Management ▪ Lighting	**Procedure**	▪ Background information ▪ Financial analysis ▪ Expenses
Design	▪ Preparation of alternative plans ▪ Elaboration of the selected plan ▪ Socio-economic data			**Prioritisation**	▪ Urgent ▪ Required ▪ Desired ▪ Can be postponed
Production	▪ On-site assessment ▪ Identification of errors ▪ Feedback ▪ Analysis ▪ Sharing of results			**Examination**	▪ Analysis of requests ▪ Project-camp site suitability ▪ Cooperation ▪ Reporting
Accommodation	▪ Testing the design ▪ Monitoring social changes ▪ Assessing the system's operability ▪ Feedback and updates			**Update**	▪ Monthly monitoring of the programme ▪ Review of resources ▪ Reassessment of priorities

The site selection phase refers to the process of analysing the final plan developed based on socio-economic data and field surveys during the planning approach formulation process using spatial indicators, thereby preparing it for the design phase. The indicators are general land use decisions that determine the physical relationship of the temporary settlement with the urban space and include large-scale arrangements concerning the settlement's wider surroundings. The design phase can be defined as urban design principles that directly define the functional relationships within the temporary settlement and its immediate surroundings. The principles provide a framework for implementation that encompasses basic needs and the sustainability of public life, from the design of shelter units to shared spaces, waste management, and security regulations. The camp development phase involves processes for monitoring, evaluating and

improving the planned and implemented temporary settlement after use. This phase has a management-intensive decision-making structure that seeks to strengthen the adaptation of the camp to its location and conditions.

Aset 2: Sphere Temporary Shelter Design Guide (2017) and Sphere Minimum Standards in Humanitarian Response Guide (2018)

The first part of the integrated analysis, which evaluates Sphere's two guides on temporary settlements together, is the Temporary Shelter Design Guide (Sphere, 2017). The guide can be defined as a set of temporary settlement design principles shaped around needs analyses and stakeholder views. The principles essentially cover indoor solutions for basic needs, storage areas, outdoor designs including multi-purpose activity spaces and common areas, and material selection and construction techniques. In this regard, the guide serves as an implementation-based resource that focuses on spatial solutions at the unit level and directly guides the construction process. The second part of the integrated analysis is the Sphere Humanitarian Standards and the Minimum Standards in Humanitarian Response Guide. First published in 2000 and updated at regular intervals, the guide provides an integrated framework that includes minimum standards for humanitarian assistance, protection principles, and access to basic needs (water, food, hygiene, health, shelter) (Sphere, 2018). The guide's approach to temporary settlement planning addresses the aforementioned standards in the context of shelter, together with the issue of shelter design.

Taken together, the guidelines reveal that the organisation's approach to temporary settlement planning is a hierarchical decision-making mechanism shaped by fundamental standards. The mechanism operates through a network of defined actions for each standard, indicators measuring the success of the action, and guiding decisions for the implementation of the action (Table 2). With this structure, it is possible to say that the guidelines offer a layered and integrated content that consolidates data sets produced at different levels and with different properties.

Table 2. Asset 2's temporary settlement approach

Standarts						
Programming	**Planning**	**Living Space**	**Household items**	**Technical assistance**	**Security of tenure**	**Environmental sustainability**
Actions						
Conformity to requirements and conditions	Reaching agreement with stakeholders on the terms	Determining sufficient living space	Providing suitable items to ensure the continuation of basic household tasks	Understanding pre-crisis planning and construction practices	Understanding the legal framework and the reality on the ground	Environmental impact assessment
Fully meeting requirements	Involving stakeholders in planning	Supporting secure access to activities	Monitoring quality and usage, adapting to conditions	Involving stakeholders in the construction process	Identifying the impact of property regulations on at-risk groups	Sustainable material selection
Formulating holistic and effective solutions in humanitarian intervention	Ensuring access to essential services and facilities	Developing culturally and socially appropriate solutions		Promoting safe construction practices	Supporting tenancy security	Waste management and recycling
	Land use and infrastructure planning in line with functions			Ensuring that people have access to adequate technical assistance	Ensuring protection against forced eviction	Setting up sustainable energy supply systems
				Establishing appropriate project management for legal approval requirements		The protection, recovery and improvement of ecological values
Indicators (%)						
▪ The affected person stated that it reflects the priorities of housing and settlement assistance.	▪ Shelter and/or settlement located in areas where there are no or very few risks and dangers ▪ Shelter and/or accommodation with safe access to essential services within an acceptable time or distance ▪ Those receiving settlement assistance who feel secure in their location ▪ Settlements offering sufficient surface area for special, public outdoor events appropriate to the location	▪ Affected population with sufficient living space for daily activities ▪ Shelter that meets agreed technical and performance standards and is culturally acceptable ▪ Person who feels safe in their shelter	▪ Sufficient and appropriate quality clothing and belongings ▪ Access to adequate, secure and affordable energy sources ▪ The number of incidents causing harm to individuals using stoves, storing fuel or supplying fuel	▪ Programme in which local authorities participate in monitoring construction activities ▪ Construction activities demonstrating the active participation of the affected population ▪ Shelter unit constructed, repaired, or improved in accordance with safe building practices ▪ Household reporting that it received appropriate technical assistance and guidance	▪ Access to housing assistance ▪ Shelter beneficiary accessing legal services	▪ Housing and settlement activities ▪ Number of suggestions implemented ▪ Shelter using low-carbon emission materials ▪ Recycling of solid waste ▪ Temporary settlement area with improved environmental conditions after use

When evaluating the temporary settlement planning approach based on the fundamental components of the assets (phases and standards), it is possible to interpret the second asset (Sphere 2017 and 2018) as an expanded version of the first asset (Cuny, 1977). While the programming and planning standards of the second asset focus on identifying site-specific conditions and needs, it is seen that the spatial decisions responding to these identifications are addressed under living space and facility standards. Within the actions developed through these standards, decisions are made at different levels regarding interior design, shelter design, inner camp organisation, and camp surroundings, in parallel with the first asset. Among the aspects that differ from the previous study are the technical service and safety standards and the indicator package. Accordingly, the technical service standard envisages the direct involvement of stakeholders in the construction process and the provision of legally compliant structures. The safety standard, on the other hand, includes decisions aimed at protecting risk groups against potential threats such as evacuation, property and legal loopholes. The indicator package tests the measurability of implementation by defining the minimum ideal level for each standard. This method explains why the Sphere organisation continuously updates the existing guide at regular intervals to adapt it to different conditions, rather than producing a separate guide for each disaster scenario.

Coding

The coding phase is the phase in which spatial data is scaled to enable the assets examined separately in the previous section to be compared using the same systematic approach. This section compiles studies from the current field literature that anticipate different levels of classification forms, types of spatial intervention, and typologies of shelter units inherent in temporary settlement planning. The data sources for the compilation are: disaster planning (Dayanır et al. 2022), site selection (Şenik and Uzun, 2021) sheltering solutions (Johnson, 2010), (Ritchie et al. 2011), (Eyinç, 2015), (Kikano et al. 2015) , camp design-planning (Dalal, 2014), (Asalı et al. 2019), migration patterns-urban relations (Kotsubo and Nakaya, 2024), systematic comparison (Stocker et al. 2021), and review (Makadi et al. 2025) studies.

Evaluating the classifications presented at the scale of temporary settlement and shelter unit, one encounters a broad and multidimensional set of approaches ranging from the planning of the duration of accommodation to user profiles, from camp density to the legal status of the settlement. On the other hand, when the classification context of the aforementioned studies is closely examined, it is seen that all approaches follow a similar spatial hierarchy, whether they focus on the social dynamics of the space or on measurable physical indicators. This hierarchy begins at the lowest scale with single housing units that provide basic living functions. These units come together in specific arrangements to form

multi-unit clusters where shared spaces and social relationships take shape. Finally, a broader spatial framework emerges where the camp's improvement and sustainability processes are maintained. In this regard, the spatial codes of temporary settlement planning are as follows: the unit level, which represents independent shelter units where basic vital functions are performed; the camp level, which represents the arrangement where independent units come together under specific construction conditions to form community relationships and shared use areas; and the camp neighborhood level, which represents the broader spatial context where physical and social integration with the camp's surroundings is established. (Figure 2).

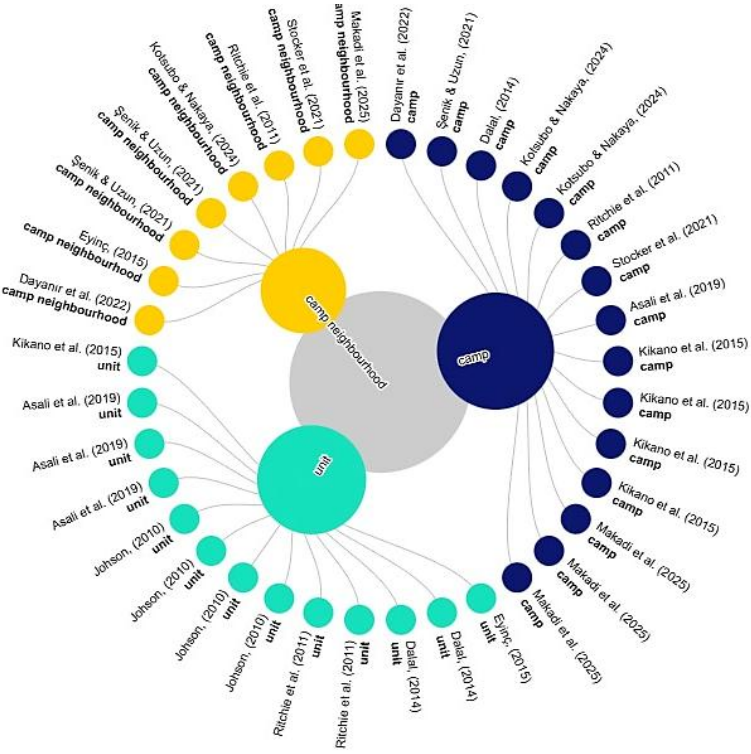

Figure 2. Spatial codes of temporary settlement planning

Codes indicate that the unit level is defined in the literature using concepts such as container, tent, shelter, sub-unit and micro, while the camp level is addressed through community, neighbourhood and formal–informal settlements. The camp level, on the other hand, is classified under the headings of multiple units, city, region, metropolitan area, integration, and higher scale. Systematic comparison and systematic review studies have shown that temporary settlements are predominantly interpreted through the camp level and camp neighborhood level. In the next section of the study, the assets examined in the analysis phase were compared using spatial codes.

Testing

The 1977 Refugee Camps and Camp Planning Guide addresses spatial data under the headings of site selection and design. In contrast, the Sphere Temporary Shelter Design Guide (2017) and the Sphere Minimum Standards in Humanitarian Response Guide (2018), considered as an integrated work, evaluate spatial data within a broader framework under the categories of design, planning, living space, facilities, and sustainability. In a comparison based on codes, the first guide emphasises function, construction and health services at the unit level, while the second guide focuses on these criteria at the same level, in addition to materials, facilities and shelter solutions appropriate to the socio-cultural structure of users. At the camp level, the first asset has developed spatial intervention decisions based on criteria related to infrastructure, superstructure, administrative units, and common areas, while the second asset has centred on the relationship between the user and the outdoor space. In this context, outdoor space design, crime prevention through design, resolution of property issues, and sustainable waste and energy management are prominent topics at this level. At the camp neighborhood level, the first asset addresses the level through spatial analysis tools used in urban planning for site selection, such as terrain structure, prevailing wind direction, and access to surrounding urban functions, while the second asset level shapes design decisions based on the camp's ecological and environmental sustainability, in addition to appropriate land planning. The preservation and improvement of ecological values and the integration of the existing building stock in harmony with the environment are the defining criteria at this level (Figure 3).

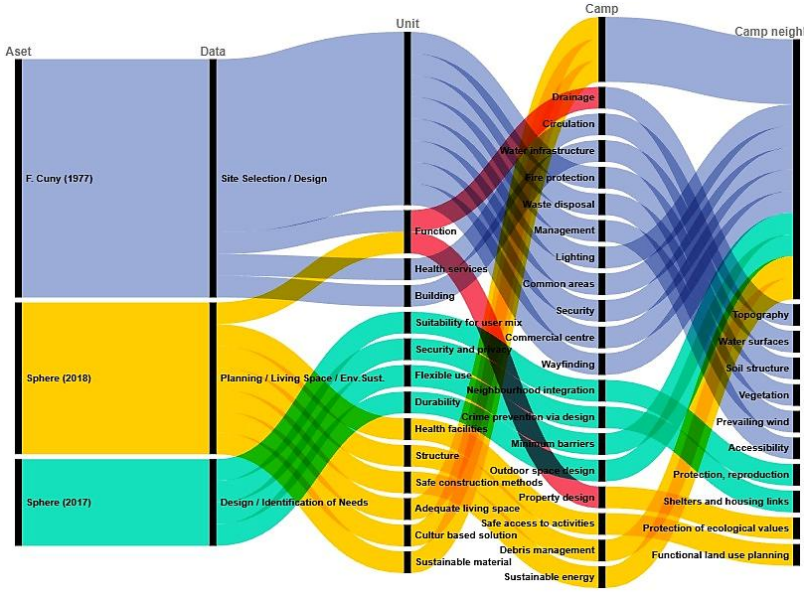

Figure 3. Comparison of assets according to spatial codes

The production of different settlement models according to socio-spatial conditions, the updating of planning decisions based on field usage experiences, and the identification of needs throughout the process to ensure the camp can provide long-term services are the strengths of the temporary settlement planning approach. Furthermore, the idea that well-designed camp infrastructure should be considered not merely as a temporary arrangement responding to emergencies, but as a flexible and adaptable element that can be utilised for various purposes by the host country after the crisis, provides an innovative perspective for the guide.

The guidelines of the Sphere organisation, considered in an integrated manner, can be regarded as an expanded version of Cuny's 1977 study in certain respects. Elements such as user-centred interior and exterior space arrangements, material selection, and consideration of privacy and property structures are directly parallel to the socio-spatial approach in the first guide. Similarly, the reassessment of decisions made during the planning phase in light of field experiences is consistent with the first guide's principle of redefining priorities in the field. In addition, the Sphere Guidelines emphasise a user- and usage-oriented approach by requiring each principle to be monitored using measurable indicators and mandating the active participation of stakeholders before, during and after the planning process. This makes the user-centred conversion that occurs in practice in temporary settlement planning visible. Furthermore, despite being a globally active organisation, the institution's decision to continuously update its existing manifesto and humanitarian response approach based on changing conditions and stakeholder feedback, rather than producing new guides, reinforces the guiding nature of the guide. The fact that the site-specific settlement model proposals in the first guide have been replaced in the current guides by more comprehensive but standardised production techniques also clearly reflects the theoretical conversion in temporary settlement planning.

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CHAPTER 9

The Bibliometric Profile of Urban Polycrisis Literature: Trends, Themes, and Future Projections

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1. Introduction

The term 'polycrisis' was originally conceptualized in the late 1990s by French complexity theorists Edgar Morin and Anne-Brigitte Kern (1999) to describe the intricate interdependence of problems, contradictions, crises, and ungovernable processes. While the concept regained traction within European policy circles during the 2010s, its global proliferation occurred in the early 2020s through scholarly research and the influence of the World Economic Forum (WEF). Notably, its designation as a 'buzzword' during the 2023 Davos Summit marked a significant surge in interest among both policymakers and academics (Mark et al., 2024).

Today, a polycrisis is defined as the causal entanglement of crises emerging across multiple global systems, including the economy, public health, the environment, and security. This phenomenon signifies more than a mere synchronization of events; it represents a dynamic where crises interact to produce cumulative damages far more devastating than the sum of individual disruptions. A consensus in current literature suggests that polycrisis is a process of causally entwined events with cascading effects across various systems (Lawrence et al., 2024a; Rodrigues et al., 2024).

Given the United Nations (2019) projection that two-thirds of the world's population will reside in urban areas by 2050, it is evident that the impact of these crises will be felt most acutely within cities. As arenas where global crises manifest at a local scale, cities are directly linked to processes such as climate change and pandemics. These crises, which carry the risk of becoming a distinct 'trap' of the Anthropocene era, have the potential to erode social trust while heightening the vulnerability of urban systems (Jorgensen et al., 2023).

This study aims to systematically examine academic research that addresses the concept of polycrisis within an urban context. Accordingly, by detailing the theoretical foundations of the polycrisis concept, this research employs R-based bibliometric analysis to reveal prevailing trends, dominant themes, and interdisciplinary correlations. In doing so, it seeks to provide a conceptual framework for understanding the impacts of complex, intertwined crises on urban systems.

2. Theoretical Framework

The concept of polycrisis serves not merely as a descriptive term for the spiral of crises facing the contemporary world, but also offers a novel epistemological perspective. Its theoretical origins are rooted in the "planetary crisis" (crises planétaire) thesis proposed by Edgar Morin and Kern in the 1990s. According to this view, crises are not isolated malfunctions; rather, they are the integrated

outcome of mutually reinforcing, interacting, and ungovernable processes. Consequently, understanding a polycrisis necessitates confronting a "whole" that is fundamentally different and greater than the sum of its individual parts (Henig & Knight, 2023).

2.1. Social Policy and the "Wicked Problems" Paradigm

A cornerstone that solidifies polycrisis discussions within academic discourse is Rittel and Webber's (1973) theory of "wicked problems." Traditional scientific approaches tend to treat issues as "tame" identifiable problems with definitive solutions. In contrast, by its very nature, a polycrisis is a cluster of wicked problems that lack objective definitions, where solutions often trigger secondary issues, and no singular "correct" answer exists. In a pluralistic society, the absence of an objective definition for justice or public interest further complicates policymaking during polycrisis periods. In this context, the polycrisis represents an era where scientific certainty wanes, and the quest for the "optimal solution" is superseded by the search for "systemic resilience" (Collste et al., 2025).

2.2. Creeping Crises and Systemic Vulnerability

The concept of "creeping crises," developed by Boin et al. (2020), provides a vital key to understanding the temporal dimension of a polycrisis. While modern societies typically focus on sudden, eruptive shocks, crises such as climate change, deepening social inequalities, or institutional erosion progress "insidiously" over extended periods. The COVID-19 pandemic demonstrated how these creeping processes, when coupled with a sudden trigger, result in massive systemic vulnerability. At this juncture, a polycrisis manifests as a state of "systemic imbalance" arising from the volatile interaction between slow-moving structural tensions and rapid-onset events.

2.3. Causal Mechanisms and Anthropocene Traps

As emphasized by contemporary scholars such as Lawrence et al. (2024a), Helleiner (2024), and Rakowski (2025), the anatomy of a polycrisis is shaped by three primary causal pathways: common stressors, domino effects, and cross-system feedback loops. In the Anthropocene era, human activities have interconnected Earth's systems so profoundly that a crisis in one domain, such as energy, automatically destabilizes food security, economic stability, and social cohesion. This reality renders "monocausal" explanatory models obsolete (Brosing, 2025).

2.4. Intersection of Crises in Urban Systems

The spatial concentration of crises is the primary element that translates this theoretical framework to the urban dimension. As nodes where systems are most

intricately entangled, cities are both drivers and subjects of the polycrisis. Global economic fluctuations manifest locally as housing crises, while ecological degradation translates into urban heat islands and flash floods; these crises, in turn, force urban administrations into difficult policy trade-offs. The scarcity of resources and the complexity of demands compel local governments to operate on multiple fronts simultaneously, thereby straining institutional capacity.

3. Methodology

To investigate the urban context of the polycrisis concept and decipher the intellectual structure of the existing literature, this study employs bibliometric analysis. Bibliometric analysis provides a robust quantitative perspective by visualizing scholarly accumulation through citation networks, co-authorship dynamics, and conceptual clusters within a specific discipline or conceptual framework.

The data collection process utilized the Web of Science (WoS) database, selected for its high academic impact and comprehensive coverage. To capture the intersection between the terminological diversity of the polycrisis concept and urban nomenclature, a comprehensive search query was formulated. Specifically, the following parameters were applied to the Topic (TS) field:

TS = (polycrisis OR "poly-crisis" OR "multiple crisis" OR "compound crisis" OR "crisis complex" OR "simultaneous crisis" OR "interlocking crisis") AND TS = (urban OR city OR cities OR metropolitan OR municipal OR "local government" OR "urban planning" OR "urban policy" OR "spatial planning" OR "urban governance" OR "urban resilience").

The search yielded 49 documents, a result that reflects the nascent and niche nature of the relationship between polycrisis and urban studies in current academic literature. Given that the volume of the dataset allows for maintaining conceptual depth while facilitating a holistic analysis, no further topical filtering or narrowing was applied. The raw data were processed using the R-based bibliometric analysis software, Bibliometrix (Biblioshiny).

Within the scope of this analysis, various parameters (including annual growth rates of publications, author collaboration networks, and the temporal evolution of keywords) were examined to visualize how polycrisis is reflected in urban policy. Notably, the "Three-Field Plot," which illustrates the interconnections between authors, references, and keywords, was utilized as a primary unit of analysis to understand the theoretical foundations the concept draws upon and the specific urban issues to which it is linked.

4. Findings

The general overview of the bibliometric data retrieved from the Web of Science database is presented in Figure 1. The analyzed dataset spans a significant timeframe, beginning with the earliest publications in 2011 and extending through early-access studies projected into 2026. A total of 49 documents, curated from 45 distinct sources, were included in the analysis. These publications represent the contributions of 194 authors, with a notably small fraction (only 11 researchers) producing single-authored works.

Key technical metrics highlighted in the visualization include the following:

- During the period under review, the annual growth rate of publications was calculated at -4.52%. Despite this, international author collaboration remains substantial at 34.69%, with an average of 4.18 authors per document.
- The analyzed corpus contains a total of 256 author-defined keywords. Furthermore, these articles build upon an extensive scholarly foundation of 2,825 references, averaging 4 citations per document.
- The average document age within the examined literature is remarkably low at 1.57 years. This metric confirms that the intersection of urban studies and the polycrisis concept is an exceptionally contemporary and rapidly evolving field of inquiry.

Figure 1. Overview of the Data

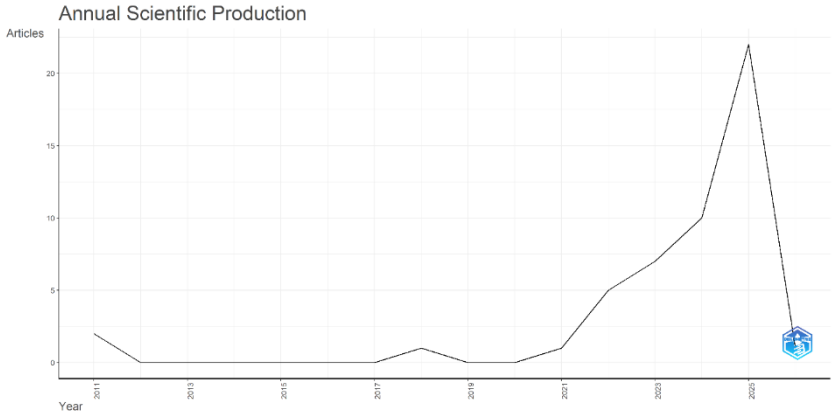
Source: Compiled by the author based on Web of Science data using the Bibliometrix R-package.

4.1. Annual Scientific Production

The temporal evolution of scientific production, illustrated in Figure 2, reveals a compelling upward trajectory in the scholarly discourse surrounding the intersection of polycrisis and urban environments. Following the initial emergence of the concept in the literature in 2011, the volume of publications remained relatively stagnant for nearly a decade. However, beginning in 2021,

the field entered a phase of exponential growth. The peak in publication volume observed particularly in 2024 and 2025 serves as empirical evidence that the compounded impacts of global crises on urban spaces have transitioned from a niche concern to a central frontier of academic inquiry.

Figure 2. Annual Scientific Production Over Time (2011–2026)



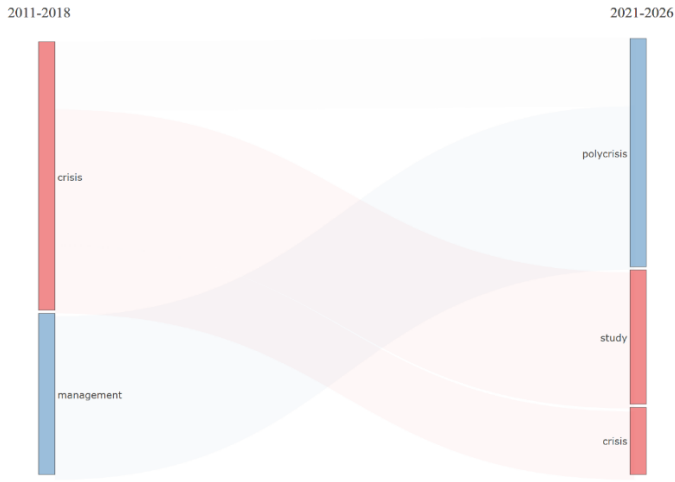
Source: Generated by the author using the Bibliometrix R-package.

While the data point for 2026 appears numerically lower in the graph due to the year not yet being completed, it is essential to recognize that these entries represent articles published under 'early access' status during late 2025. The premature appearance of publications for the forthcoming year in the literature suggests that interest in urban polycrisis research is not merely a transient academic fad; rather, it signifies a sustained and intensifying research trajectory that is poised for further expansion. This temporal landscape further documents a significant paradigm shift: as emphasized by Lawrence (2024), the traditional approach of treating crises as isolated and independent events is increasingly yielding to a more holistic perspective that seeks to decipher the causal pathways and cross-system feedback mechanisms between them.

4.2. Thematic Evolution

The thematic evolution analysis, conducted to understand the conceptual transformation within the bibliometric landscape, strikingly reveals the shifting focus of the literature over time (Figure 3). Due to technical constraints in keyword data, where a limited number of documents precluded a keyword-based transition, this analysis was constructed using document abstracts. This methodological choice documents how urban crisis studies have undergone a qualitative metamorphosis alongside their numerical growth.

Figure 3. Thematic Evolution Analysis



Source: Generated by the author using the Bibliometrix R-package.

According to the analysis results, the initial phase spanning 2011–2018 was predominantly shaped around the concepts of "crisis" and "management." Research during this period tended to treat crises as isolated, operational processes requiring specific interventions and governance. However, transitioning into the 2021–2026 period (the post-pandemic era), this conceptual framework has been decisively superseded by a "polycrisis" perspective. This evolution from "crisis" to "polycrisis" proves that risks in urban areas are no longer perceived as disjointed issues; rather, as Morin and Kern (1990) articulated, they are understood through the complex interdependence of contradictions and ungovernable processes.

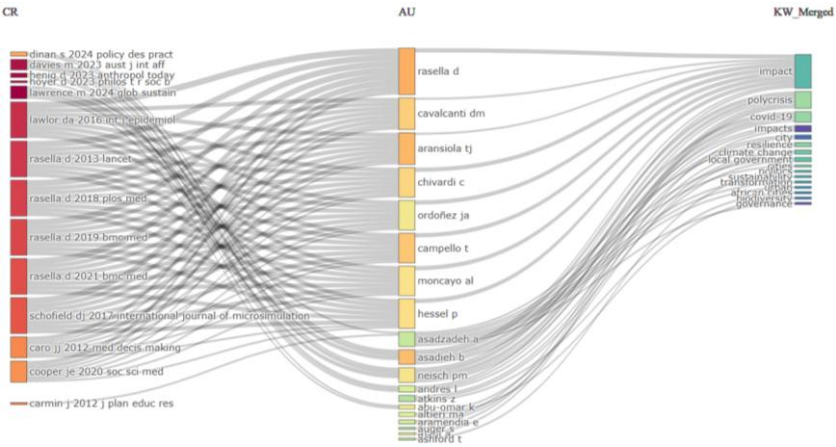
This thematic shift implies a significant paradigm shift for urban policymakers and scholars alike. Academic interest, which initially focused on "mitigation" and "traditional management" methods, has now pivoted toward understanding how crises become entangled and trigger systemic collapse. The mapping performed through abstract texts statistically confirms that the polycrisis concept now forms the backbone of urban studies, replacing a narrow, management-oriented viewpoint with a more comprehensive, systemic analysis model.

4.3. Three-Field Plot Analysis

One of the most comprehensive visualizations in bibliometric analysis, the "Three-Field Plot," summarizes the intellectual flow of the literature within a single integrated framework. As presented in Figure 4, this graph reveals the "genealogy" of the field by interconnecting three key elements: the primary

foundational sources (references) in the left column, the active authors contributing to the field in the middle column, and the core themes (keywords) on which the research is concentrated in the right column.

Figure 4. Three-Field Plot



Source: Generated by the author using the Bibliometrix R-package.

An examination of the graph yields the following key findings:

- Foundational Roots and Theoretical Continuity: The works of figures such as Rasella D. (2013, 2018), Lawlor DA. (2016), and Lawrence M. (2024), located on the left side of the plot, constitute the main intellectual arteries from which the urban polycrisis literature draws its strength. The dense network of connections between the active authors in the middle column and these foundational references proves that current research is not coincidental but is built upon a robust theoretical heritage.
- Thematic Convergence: When the output of the researchers in the middle column is analyzed, it is evident that interest converges on the concepts of "impact," "polycrisis," "COVID-19," and "resilience," represented by the largest nodes in the right column. This indicates that the literature does not merely define crises; it focuses on the tangible impacts generated by these crises and the urban resilience tools required to mitigate them.
- Institutional and Spatial Correlation: Within the conceptual clustering of the right column, the presence of terms such as "local government," "climate change," and "urban" documents that polycrisis discussions are directly associated with the jurisdictional responsibilities of local authorities and the future of urban spaces.

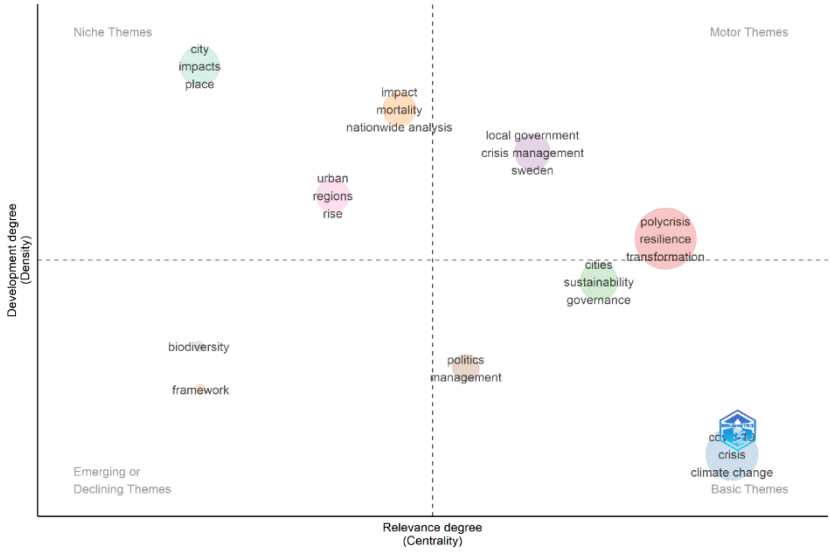
In summary, this triple flow confirms that the urban polycrisis literature possesses an integrated academic structure. It draws momentum from historical

health and systemic risk studies to seek solutions for contemporary, multidimensional challenges such as climate change and pandemics.

4.4. Thematic Map Analysis

The thematic map, which reveals the strategic dimensions of the bibliometric analysis, summarizes the current position and scientific depth of the polycrisis concept within urban studies across four distinct quadrants (Figure 5). In this visualization, the position of concepts along the horizontal axis reflects their centrality (relevance) within the literature, while their vertical placement signifies their density (internal development or academic maturity).

Figure 5. Thematic Map



Source: Generated by the author using the Bibliometrix R-package.

Within this framework, the concepts of "polycrisis," "resilience," and "transformation," situated in the upper-right quadrant, constitute the "motor themes" of the literature. This clustering documents that the polycrisis has moved beyond a purely theoretical debate to become a primary guiding force for how cities should structurally transform. Furthermore, the inclusion of "local government" and "crisis management" in this quadrant clearly demonstrates that the subject has directly entered the practical implementation sphere of municipalities and local actors.

Conversely, the terms "climate change," "COVID-19," and general "crisis," located in the lower-right quadrant, represent the "basic themes" upon which the literature is built. These concepts are recognized as the primary triggers of the urban polycrisis and form the bedrock of current discussions. In the upper-left

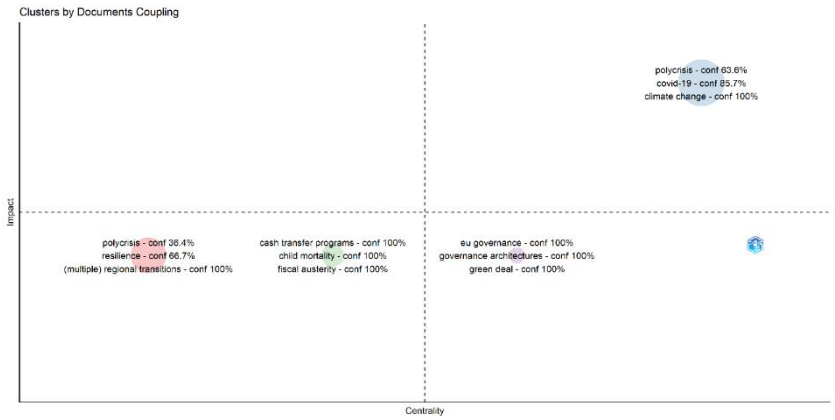
quadrant, the region of "niche themes", local impact analyses and national-scale statistical studies indicate a shift toward specialized sub-fields that require specific expertise rather than a general framework. Finally, concepts such as "biodiversity," appearing in the lower-left corner, stand out as emerging topics or those newly integrating into polycrisis discourse.

In summary, this strategic map provides concrete evidence that urban polycrisis research is not a random collection of concepts; rather, it has achieved substantial academic maturity centered on local governance and urban resilience.

4.5. Document Coupling Map Analysis

The results of the "Document Coupling Map," representing one of the most technical yet explanatory segments of this bibliometric study, explicitly clarify the shared conceptual denominators within the urban polycrisis literature. This analysis enables a deeper understanding of the proximity between disparate research focuses and identifies the primary "nodal points" around which the scholarship clusters.

Figure 6. Coupling Map



Source: Generated by the author using the Bibliometrix R-package.

The blue cluster, situated in the upper-right quadrant of Figure 6, exhibits the highest values for both impact and centrality, thereby providing statistical reinforcement for the study's core thesis. Within this cluster, it is particularly noteworthy that the concepts of "polycrisis," "COVID-19," and "climate change" co-occur with remarkably high confidence intervals of 63.6%, 85.7%, and 100%, respectively. This data serves as scientific evidence that urban polycrisis is far more than a theoretical abstraction; it is the manifestation of two colossal crises (the pandemic and climate change) converging to exert simultaneous and inescapable pressure on urban systems.

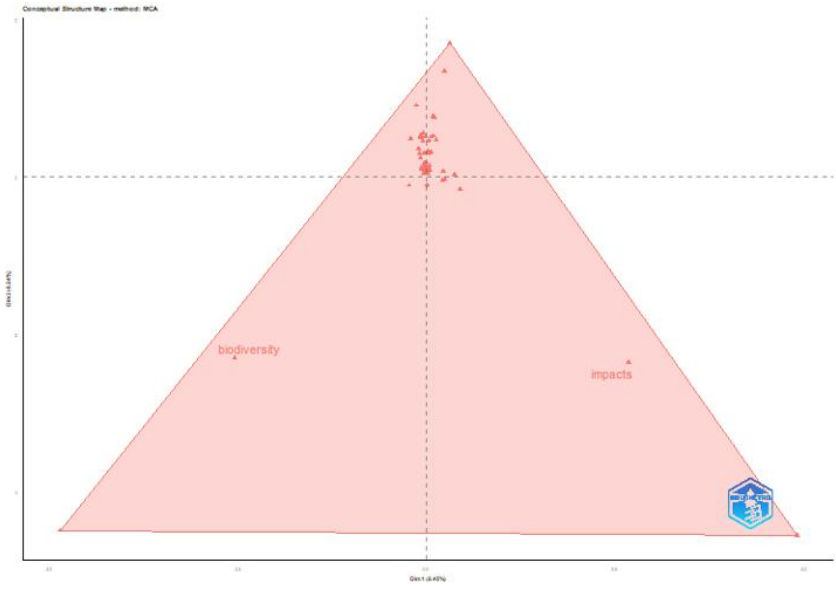
In contrast, the red cluster, located in the lower-left region with lower impact and centrality scores, represents the broader, transformation-oriented dimension of the literature. The coupling of "polycrisis" with "resilience" and "multiple regional transitions" within this group suggests a scholarly pivot: research is increasingly focusing not only on the destructive impacts of crises but also on the spatial and structural transformation opportunities these processes might catalyze. Furthermore, the purple and green clusters integrate political-economic and administrative mechanisms (such as "EU governance," "Green Deal," and "fiscal austerity") into the polycrisis framework.

In summary, this coupling map confirms that while urban polycrisis research is fueled by a core intersection of climate and health crises, it is surrounded by a multi-layered academic discourse ranging from governance models to fiscal policies.

4.6. Conceptual Structure: Multiple Correspondence Analysis (MCA)

The Multiple Correspondence Analysis (MCA), utilized to clarify the conceptual dimensions of the bibliometric data, presents the semantic distance between terms in the polycrisis literature on a statistical plane. The distribution observed in Figure 7, where a significant majority of terms are clustered at the apex of a pyramid-like structure, provides critical insights into the intellectual architecture of urban polycrisis research.

Figure 7. Factor Analysis (MCA)



Source: Generated by the author using the Bibliometrix R-package.

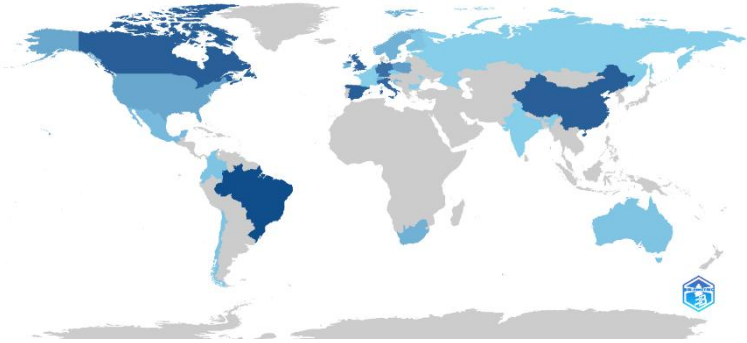
The close proximity of terms at the top of the pyramid, forming what resembles a conceptual "knot," indicates a powerful consensus within the literature regarding fundamental concepts such as polycrisis, urban resilience, governance, and sustainability. This dense clustering documents that academic studies addressing the urban polycrisis discuss these terms as an inseparable whole. In other words, all sub-topics (ranging from climate change to local government, and from the pandemic to urban transformation) are articulated within this dominant center of gravity formed by the polycrisis framework.

Conversely, the concepts that diverge from this central nodal point toward the base of the pyramid represent more specialized research focuses that are beginning to branch out from the mainstream. For instance, the positioning of "biodiversity" on the far left suggests that the ecological dimension of the polycrisis is beginning to differentiate itself from general administrative discussions onto a more technical ground. Similarly, the term "impacts" on the far right points to the emergence of an empirical vein that prioritizes tangible and measurable outcomes over theoretical depth. Ultimately, this factor analysis confirms that the field of urban polycrisis remains a cohesive discipline, integrated around a central theoretical body that emphasizes the "interpermeability" of crises.

4.7. Global Scientific Production: A Geographical Overview

The map reflecting the global dimension of this bibliometric analysis illustrates the worldwide dispersion of polycrisis discourse and its primary geographical concentrations. The distribution of colors across the map documents that the polycrisis has transitioned from being a localized regional issue to a global urban concern.

Figure 8. Country Scientific Production



Source: Generated by the author using the Bibliometrix R-package

An examination of the color intensities in Figure 8 reveals that countries such as Italy, China, Germany, and Brazil stand out with the darkest tones. This pattern confirms that polycrisis discussions are not confined to advanced Western economies; rather, they have proliferated across diverse geographies facing rapid urbanization and climatic pressures. For instance, the academic momentum observed in China and Brazil underscores the sensitivity of urban systems and the transboundary nature of modern crises.

The varying shades of blue observed throughout the rest of the map demonstrate that this subject has entered the local agendas of a vast area, ranging from Canada to Australia. This widespread distribution indicates that the urban polycrisis has become a common and urgent matter for nations across different levels of development. In essence, the multidimensional risk spiral facing cities has found a comprehensive academic response on a global scale.

5. Discussion

The bibliometric findings derived from the Web of Science database strikingly validate the rise and theoretical evolution of the polycrisis concept within the field of urban studies. When examining the temporal development of the literature, the transition from a period of stagnation between 2011 and 2021 to a rapid surge in publications starting in 2022—peaking in 2024–2025—proves that the subject is far more than an academic "buzzword." This momentum, which accelerated following the 2023 Davos summit, demonstrates that crises are no longer perceived as isolated failures but rather as processes intricately linked through complex dependencies, as originally suggested by Morin and Kern (1999).

The thematic evolution analysis documents a fundamental shift in the literature from a focus on "singular crisis management" toward a more holistic "polycrisis" perspective. This transformation aligns with Rittel and Webber's (1973) theory of "wicked problems." The fact that factor analysis and dendrogram results show concepts intertwined at the apex of a pyramid—forming a conceptual "knot"—statistically reflects the difficulty of objectively defining the urban polycrisis; it highlights how a solution in one domain (e.g., climate mitigation) can trigger unintended consequences in another (e.g., economic costs).

Furthermore, the document coupling map results, where polycrisis, COVID-19, and climate change cluster with a confidence interval of up to 100%, provide bibliometric evidence for the "cross-system feedback" mechanisms emphasized by Lawrence et al. (2024a). This finding substantiates how slow-moving processes—defined by Boin et al. (2020) as "creeping crises"—converge with sudden shocks like the pandemic to generate immense destructive force upon

urban systems. Given the United Nations' (2019) projections for urban population growth by 2050, the central role of cities in this crisis spiral necessitates that local governments shift from mere crisis management toward building systematic resilience.

The prominence of countries such as Italy, China, and Brazil on the geographical distribution map indicates that the urban polycrisis has evolved into a global "trap" characteristic of the Anthropocene era, regardless of a nation's development level. The central positioning of "local government" in the three-field plot confirms that cities are the primary arenas where global crises manifest at a local scale. Ultimately, the synthesized data reveal that the risks facing urban systems are no longer disjointed; instead, they represent a multidimensional state of systemic imbalance that strains institutional capacity and defies traditional problem-solving methods.

6. Conclusion

The bibliometric analyses and theoretical evaluations conducted in this study demonstrate that contemporary cities are no longer merely spatial settlements; they are massive, complex systems composed of tightly interconnected sub-systems. As nodes where economic networks, social fabrics, infrastructure systems, and ecological processes are most densely entwined, cities inherently exhibit a structure prone to generating "wicked problems." The high correlation between concepts observed in the analyses, forming a visual "consensus" or knot, confirms that urban challenges have become so integrated that they can no longer be explained through singular disciplines.

The thematic evolution from "crisis management" to "polycrisis" signals a radical paradigm shift for the discipline of urban planning. The complex nature of cities has transformed into a polycrisis landscape where a disruption in one system (e.g., a transport failure) can trigger a cascading effect that destabilizes food supplies, public health, and social trust. The clustering of climate change, the pandemic, and the polycrisis as an inseparable entity in the coupling analyses documents that planning processes can no longer be executed without accounting for these intertwined risks. In the Anthropocene era, cities stand as both the perpetrators and the most vulnerable victims of these multidimensional crises.

Ultimately, the polycrisis concept opens a new epistemological window into the creeping and mutually reinforcing crises within urban planning literature. The "tame" solutions offered by traditional planning approaches prove inadequate against the "wicked" and uncertain nature of the polycrisis. Consequently, it is an imperative to reconfigure urban systems through the lens of "systemic resilience," not only physically but also administratively and socially. The future of cities

depends on flexible and transformative planning strategies capable of comprehending the polycrisis spiral and managing the feedback mechanisms between concurrent crises.

Planning Recommendations for the Future

- Instead of managing departments such as transportation, housing, and energy in isolation, local governments must adopt an integrated planning model that analyzes how these systems interact during a polycrisis.
- Considering the uncertain nature of climate change and creeping crises, "flexible zoning" and "temporary use" models that can be rapidly adapted to crisis scenarios should be encouraged over rigid, static plans.
- By monitoring urban resource flows (water, food, energy) with real-time data, early warning systems should be established to identify specific nodes where a polycrisis trigger might occur.
- Given the devastating impact of polycrises on disadvantaged urban groups, it is essential to ground resilience strategies in social policy that strengthens communal trust and justice, rather than focusing solely on physical infrastructure.

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CHAPTER 10

Land Surface Temperature as an Indicator of Urban Thermal Environment

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1. Introduction

Urban areas worldwide are experiencing increasingly intense thermal stress as a combined result of rapid urbanization, land cover transformation, and global climate change. Over the past decades, the expansion of impervious surfaces such as asphalt, concrete, and rooftops has significantly altered the surface energy balance of cities. These materials exhibit high heat storage capacity and low evaporative potential, leading to elevated surface temperatures, particularly during summer months (Oke, 1982; Voogt & Oke, 2003). As a result, urban populations are increasingly exposed to extreme heat conditions that adversely affect human health, energy consumption, ecosystem functioning, and overall urban livability (Bowler et al., 2010).

The intensification of heat-related risks has made urban thermal environments a central focus of contemporary environmental research and urban planning. Heat waves have become more frequent and severe, especially in Mediterranean and semi-arid regions, where climatic conditions already favor high summer temperatures. Cities located in these regions, such as Adana in southern Türkiye, are particularly vulnerable to compounded heat stress due to both climatic and anthropogenic drivers. Understanding the spatial distribution and underlying mechanisms of urban heat is therefore essential for developing effective mitigation and adaptation strategies (Peng et al., 2012; Zhou et al., 2014).

Traditionally, urban climate studies have relied on in-situ air temperature measurements obtained from meteorological stations. While these measurements provide accurate point-based observations, they are inherently limited in their ability to represent the spatial heterogeneity of urban environments. A single weather station may reflect atmospheric conditions over a relatively small area and fails to capture fine-scale thermal contrasts caused by variations in land cover, surface materials, vegetation density, and urban morphology (Voogt & Oke, 2003). As cities become increasingly complex, there is a growing need for spatially continuous data sources capable of capturing surface-level thermal variability across entire metropolitan areas (Weng, 2009).

Remote sensing has emerged as a powerful tool for addressing these limitations by enabling large-scale, spatially explicit monitoring of land surface conditions. Satellite-based observations provide consistent, repeatable, and objective measurements that are particularly well suited for urban climate analysis. Among the various remotely sensed variables, Land Surface Temperature (LST) has become one of the most widely used indicators for assessing urban thermal environments (Weng, 2009; Li et al., 2013). Derived from thermal infrared satellite sensors, LST represents the radiative skin temperature of the Earth's surface and responds directly to surface energy exchanges (Sobrino et al., 2004).

LST is fundamentally different from near-surface air temperature, yet it is closely linked to the processes that govern urban heat dynamics. While air temperature reflects atmospheric conditions at a specific height, LST captures the thermal behavior of surface materials themselves. This distinction is especially important in urban areas, where surfaces with contrasting thermal properties coexist within short distances. Asphalt roads, concrete buildings, bare soil, vegetated parks, and water bodies all exhibit distinct thermal responses to incoming solar radiation, resulting in pronounced spatial variability in LST (Voogt & Oke, 2003; Chen et al., 2006). As such, LST provides a physically meaningful and spatially detailed representation of urban thermal patterns.

The use of LST has been particularly prominent in studies of the Urban Heat Island (UHI) phenomenon, which describes the tendency of urban areas to be warmer than their surrounding rural environments (Oke, 1982). When analyzed using satellite-derived surface temperatures, this phenomenon is commonly referred to as the Surface Urban Heat Island (SUHI). LST-based SUHI studies have demonstrated that surface thermal contrasts are strongly influenced by land cover composition, vegetation abundance, and surface moisture availability (Weng et al., 2004; Imhoff et al., 2010; Buyantuyev & Wu, 2010). These findings have reinforced the value of LST as a diagnostic tool for identifying urban heat hotspots and evaluating the effectiveness of heat mitigation measures.

One of the most critical components of urban heat mitigation is the presence and spatial configuration of urban green spaces. Parks, urban forests, street trees, and other vegetated areas play a key role in regulating urban thermal environments by modifying the surface energy balance. Vegetation reduces surface temperatures through multiple mechanisms, including shading, increased albedo in some cases, and evapotranspiration, which dissipates energy as latent heat rather than sensible heat (Spronken-Smith & Oke, 1998). Numerous studies have shown that urban green spaces exhibit significantly lower LST compared to surrounding built-up areas, particularly during daytime under clear-sky conditions (Bowler et al., 2010; Ziter et al., 2019).

Despite the growing body of research on urban green space cooling effects, important questions remain regarding the extent to which LST alone can capture and represent these thermal interactions. While LST provides valuable spatial information, it also has limitations related to atmospheric influences, observation timing, and its indirect relationship with human thermal comfort (Voogt & Oke, 2003; Li et al., 2013). These limitations highlight the need for careful interpretation of LST-based results and for studies that explicitly acknowledge both the strengths and constraints of using LST as a proxy for urban thermal environments.

In this context, this chapter aims to critically examine the role of Land Surface Temperature as an indicator of urban thermal conditions, with a particular focus

on the interaction between LST and urban green spaces. Rather than integrating multiple thermal or climatic variables, this chapter deliberately adopts a single-variable approach, relying exclusively on LST derived from satellite observations. This approach allows for a focused and transparent evaluation of what LST can and cannot reveal about urban thermal environments (Weng, 2009).

The chapter places special emphasis on daytime thermal conditions, as observed by the Landsat 9 satellite during its daytime overpass. Daytime LST is especially relevant for understanding surface energy exchanges, material heat storage, and vegetation-driven cooling processes (Imhoff et al., 2010; Zhou et al., 2014). While nighttime urban heat dynamics are also important, they are beyond the scope of this chapter due to data availability constraints.

The main objective of this chapter is to demonstrate how Land Surface Temperature can serve as a robust, spatially explicit indicator of urban thermal environments and to illustrate its applicability for assessing the cooling effects of urban green spaces. By combining theoretical discussion with a real-world case study, the chapter seeks to bridge the gap between conceptual understanding and practical application. The findings are intended to support urban planners, environmental scientists, and policy makers in developing climate-resilient cities through informed, data-driven decision making (Oguz, 2017).

2. Physical Meaning of Land Surface Temperature

Land Surface Temperature represents the radiative skin temperature of the Earth's surface as sensed by thermal infrared satellite sensors. Physically, LST corresponds to the temperature that controls the longwave radiation emitted from the surface and is therefore directly linked to the surface energy balance (Oke, 1982; Voogt & Oke, 2003). Unlike air temperature, which is measured within the atmospheric boundary layer, LST reflects the thermal state of the uppermost surface layer and responds rapidly to changes in solar radiation, surface materials, and moisture availability.

The physical basis of LST is rooted in the surface energy balance, which describes how incoming and outgoing energy fluxes interact at the land–atmosphere interface. Net radiation is partitioned into sensible heat flux, latent heat flux, and ground heat flux, and the relative magnitude of these components determines surface temperature (Oke, 1982). Surfaces with low moisture availability and high heat storage capacity tend to convert a larger portion of absorbed energy into sensible heat, resulting in higher LST values. Conversely, surfaces with abundant moisture and vegetation dissipate more energy through latent heat flux, leading to lower surface temperatures (Weng et al., 2004).

Land Surface Temperature is strongly influenced by surface material properties, including albedo, thermal conductivity, heat capacity, and emissivity.

Urban materials such as asphalt, concrete, and roofing surfaces typically have low albedo and high thermal inertia, enabling them to absorb and store large amounts of solar energy during the daytime (Voogt & Oke, 2003). These characteristics result in elevated LST values, particularly under clear-sky summer conditions. In contrast, natural surfaces such as soil and vegetation generally exhibit higher albedo and greater evaporative capacity, contributing to lower surface temperatures (Chen et al., 2006).

Surface emissivity plays a critical role in the physical interpretation of LST. Emissivity defines the efficiency with which a surface emits thermal radiation and varies substantially across different land cover types (Li et al., 2013). Vegetated surfaces typically exhibit high emissivity, while built-up areas show greater variability due to diverse construction materials. Accurate representation of emissivity is therefore essential for obtaining physically meaningful LST values, especially in heterogeneous urban environments (Sobrino et al., 2004; Jiménez-Muñoz & Sobrino, 2003).

It is important to distinguish Land Surface Temperature from near-surface air temperature, as these variables respond to different physical processes. While air temperature reflects atmospheric conditions influenced by advection and turbulence, LST responds primarily to radiative forcing and surface characteristics (Voogt & Oke, 2003). As a result, strong spatial gradients in LST can occur over short distances, particularly in urban areas where land cover changes abruptly. This sensitivity makes LST especially suitable for detecting fine-scale thermal variability associated with land use and surface composition (Weng, 2009).

Vegetation exerts a strong moderating influence on LST through shading and evapotranspiration. Numerous studies have demonstrated a robust inverse relationship between vegetation abundance and surface temperature, often quantified using vegetation indices such as NDVI (Weng et al., 2004; Buyantuyev & Wu, 2010). Areas with dense vegetation cover consistently exhibit lower LST values, highlighting the importance of biophysical surface properties in regulating urban thermal environments.

From a temporal perspective, LST varies substantially throughout the diurnal cycle, reaching maximum values during daytime hours when solar radiation is strongest. Satellite-based LST measurements therefore represent instantaneous thermal conditions at the time of overpass rather than daily averages (Li et al., 2013). This characteristic reinforces the interpretation of LST as a snapshot of surface energy balance rather than a direct indicator of long-term thermal exposure.

In summary, Land Surface Temperature is a physically grounded variable that reflects the interaction between surface materials, moisture conditions, and radiative forcing. Its strong linkage to surface energy processes and land cover

characteristics makes LST a powerful indicator for analyzing spatial patterns of urban heat (Oke, 1982; Voogt & Oke, 2003; Weng, 2009). When interpreted within its physical context, LST provides critical insight into the mechanisms driving thermal variability in urban environments.

3. Satellite Based Retrieval of Land Surface Temperature

Satellite-based retrieval of Land Surface Temperature has become a standard approach in urban climate studies due to its ability to provide spatially continuous and physically consistent measurements (Voogt & Oke, 2003; Weng, 2009). Among available satellite platforms, the Landsat program offers a unique combination of moderate spatial resolution, long-term data continuity, and freely accessible imagery, making it particularly suitable for city-scale thermal analysis (Weng et al., 2004). Landsat 9, launched as the latest mission in the Landsat series, continues this legacy by providing improved radiometric performance and reliable thermal observations (Li et al., 2013).

Landsat 8 and 9 are equipped with the Thermal Infrared Sensor (TIRS), which acquires thermal data in two spectral bands located in the thermal infrared region. These bands are specifically designed to capture the thermal emission of the Earth's surface, enabling the estimation of surface temperature (Sobrino et al., 2004). Although the native spatial resolution of TIRS is 100 m, the data are resampled to 30 m to ensure spatial compatibility with the multispectral bands, allowing integrated analysis with land cover and vegetation indices (Weng et al., 2004).

The retrieval of Land Surface Temperature from Landsat 8/9 imagery involves a sequence of processing steps that transform raw satellite measurements into physically meaningful surface temperature values (Jiménez-Muñoz & Sobrino, 2003; Li et al., 2013). The first step consists of converting digital numbers (DNs) recorded by the sensor into spectral radiance values using radiometric calibration coefficients provided in the image metadata. This conversion accounts for sensor-specific gain and bias parameters and ensures consistency across different scenes (Sobrino et al., 2004).

Following radiance conversion, spectral radiance values are transformed into at-sensor brightness temperature. Brightness temperature represents the temperature of a hypothetical blackbody that would emit the same amount of radiance at the observed wavelength (Jiménez-Muñoz & Sobrino, 2003). This step is based on the inverse of Planck's law and provides an initial estimate of surface thermal conditions. However, brightness temperature does not yet account for the emissivity of real-world surfaces and therefore cannot be directly interpreted as Land Surface Temperature (Voogt & Oke, 2003).

Surface emissivity correction is a critical component of LST retrieval, particularly in heterogeneous urban environments. Emissivity varies with surface

material composition and significantly influences the relationship between emitted radiance and actual surface temperature (Li et al., 2013). In this study, surface emissivity is estimated using an NDVI-based approach, which assumes that emissivity can be inferred from vegetation cover (Weng et al., 2004). Pixels with higher vegetation density are assigned higher emissivity values, while built-up and bare surfaces are assigned lower values. This approach has been widely adopted in urban thermal studies due to its simplicity and effectiveness (Sobrino et al., 2004; Oguz, 2017).

Once emissivity is estimated, brightness temperature is corrected to obtain Land Surface Temperature. The resulting LST values represent the radiative temperature of the surface under clear-sky conditions at the time of satellite overpass (Li et al., 2013). To ensure the reliability of the LST product, cloud-contaminated pixels are excluded from the analysis using quality assessment information provided with the Landsat imagery. Cloud masking is particularly important in thermal studies, as clouds significantly alter observed radiance and can lead to substantial errors in temperature estimation (Weng, 2009).

Temporal consistency is another important consideration in satellite-based LST retrieval. Landsat 8/9 follows a fixed daytime overpass schedule, typically acquiring images in the late morning local time. This consistent acquisition time minimizes variability related to diurnal temperature cycles and allows meaningful spatial comparisons within a single scene (Oke, 1982; Voogt & Oke, 2003). The use of a single, cloud-free image acquired during peak summer conditions further ensures that observed thermal patterns primarily reflect surface characteristics rather than short-term atmospheric fluctuations (Peng et al., 2012).

Spatial preprocessing steps, including geometric correction and subsetting to the study area boundary, are applied to ensure accurate spatial alignment and efficient analysis. All processing steps are implemented within a geographic information system environment, allowing seamless integration of LST with other spatial datasets such as land use, vegetation cover, and urban infrastructure (Weng, 2009).

In summary, Landsat 8/9 provides a robust and reliable platform for retrieving Land Surface Temperature at the urban scale. Through careful radiometric calibration, emissivity correction, and quality control, satellite-derived LST offers a physically grounded representation of surface thermal conditions (Li et al., 2013; Oguz, 2017). When applied to urban environments, this approach enables detailed analysis of spatial thermal variability and forms a solid methodological foundation for assessing urban heat island patterns and the cooling effects of urban green spaces (Voogt & Oke, 2003; Zhou et al., 2014).

4. Urban Heat Island Concept Through LST

The Urban Heat Island (UHI) phenomenon refers to the systematic temperature difference between urban areas and their surrounding rural environments (Oke, 1982). This temperature contrast arises primarily from land cover transformation, urban morphology, and anthropogenic heat emissions associated with urban development. While the UHI has traditionally been quantified using near-surface air temperature measurements, advances in remote sensing have enabled the characterization of urban heat patterns using satellite-derived Land Surface Temperature (Voogt & Oke, 2003).

When analyzed using thermal infrared satellite data, the UHI is commonly referred to as the Surface Urban Heat Island (SUHI). SUHI represents the spatial contrast in surface temperatures between urban and non-urban areas and provides a surface-based perspective on urban thermal environments (Weng, 2009). Unlike air temperature-based UHI measurements, which are limited to discrete observation points, SUHI analysis offers spatially continuous information across entire metropolitan regions, making it particularly valuable for urban-scale assessments (Imhoff et al., 2010).

Land Surface Temperature is especially well suited for capturing the physical mechanisms underlying SUHI formation. Urban surfaces such as asphalt, concrete, and roofing materials absorb and store large amounts of solar radiation during the daytime. Due to their high thermal inertia and limited moisture availability, these surfaces release stored heat primarily as sensible heat, resulting in elevated LST values (Oke, 1982; Buyantuyev & Wu, 2010). In contrast, rural and vegetated surfaces dissipate a larger portion of absorbed energy through latent heat flux, leading to comparatively lower surface temperatures (Peng et al., 2012).

Daytime satellite observations play a critical role in SUHI analysis. During daylight hours, differences in surface energy balance between urban and non-urban areas are most pronounced, producing clear thermal contrasts in LST (Voogt & Oke, 3). Landsat-based daytime imagery captures the maximum thermal response of surface materials to solar heating, making it particularly effective for identifying urban heat hotspots and evaluating land cover-related temperature variations (Weng et al., 2004). These patterns are often spatially complex, reflecting the heterogeneous nature of urban landscapes (Chen et al., 2006).

LST-based SUHI assessments typically involve the comparison of surface temperatures between urban core areas and reference rural zones. The magnitude of the SUHI can be quantified by calculating the temperature difference between these zones or by classifying LST values into relative temperature categories (Zhou et al., 2014). Such classifications facilitate the identification of high-temperature zones and allow for visual interpretation of urban thermal structure.

Importantly, SUHI intensity is not uniform across a city but varies in response to land use, building density, vegetation cover, and proximity to water bodies (Imhoff et al., 2010; Buyantuyev & Wu, 2010).

One of the key advantages of using LST to study SUHI is its sensitivity to land cover composition. Numerous studies have demonstrated strong relationships between LST and indicators such as vegetation indices and impervious surface fraction (Weng et al., 2004; Chen et al., 2006). Areas with high vegetation density consistently exhibit lower LST, while densely built-up zones tend to show elevated surface temperatures (Zhou et al., 2014). These relationships highlight the critical role of land cover in shaping urban thermal environments.

Despite its strengths, the interpretation of SUHI based on LST requires careful consideration. LST represents surface conditions rather than atmospheric temperature, and the relationship between surface and air temperatures can vary depending on meteorological conditions and urban morphology (Voogt & Oke, 2003; Weng, 2009). Moreover, SUHI intensity derived from LST is influenced by the time of satellite overpass and prevailing weather conditions (Peng et al., 2012). As a result, LST-based SUHI should be viewed as a complementary perspective rather than a direct substitute for air temperature-based UHI measurements.

In the context of urban planning and environmental management, LST-based SUHI analysis offers practical advantages. It enables the identification of spatial patterns of heat accumulation at fine spatial scales and supports the evaluation of land cover-based mitigation strategies (Weng, 2009). By revealing where and why surface temperatures are elevated, SUHI mapping provides valuable information for prioritizing urban greening efforts and designing climate-resilient cities (Zhou et al., 2014; Oguz, 2017).

5. Cooling Role of Urban Green Spaces

Urban green spaces play a fundamental role in regulating thermal environments by modifying surface energy exchange processes (Oke, 1982; Bowler et al., 2010). In the context of increasing urban heat stress, green infrastructure has emerged as one of the most effective and sustainable strategies for mitigating surface and atmospheric warming (Gill et al., 2007). Parks, urban forests, street trees, agricultural lands, and riparian corridors contribute to cooling by altering surface properties and enhancing latent heat flux through evapotranspiration (Spronken-Smith & Oke, 1998; Peng et al., 2012). Land Surface Temperature provides a direct and spatially explicit means of assessing these cooling effects at the urban scale (Voogt & Oke, 2003; Weng, 2009).

The cooling capacity of urban green spaces is primarily driven by two interrelated mechanisms: shading and evapotranspiration (Oke, 1982; Bowler et

al., 2010). Vegetation canopies intercept incoming solar radiation, reducing the amount of energy absorbed by underlying surfaces. At the same time, vegetation facilitates evapotranspiration, a process by which water is transferred from the surface to the atmosphere, consuming energy in the form of latent heat (Peng et al., 2012). This dual mechanism significantly reduces sensible heat flux and results in lower surface temperatures compared to impervious urban surfaces (Ziter et al., 2019).

LST-based analyses consistently demonstrate that vegetated areas exhibit lower surface temperatures than built-up zones, particularly during daytime under clear sky conditions (Spronken-Smith & Oke, 1998; Zhou et al., 2014). Satellite observations reveal distinct thermal contrasts between urban green spaces and surrounding impervious surfaces, with temperature differences often reaching several degrees Celsius (Imhoff et al., 2010). These contrasts are most pronounced during summer months, when solar radiation is intense and moisture availability becomes a critical determinant of surface temperature (Peng et al., 2012).

The spatial configuration and size of green spaces strongly influence their cooling effectiveness (Buyantuyev & Wu, 2010; Ziter et al., 2019). Large, contiguous parks tend to generate more pronounced cooling effects than small, fragmented green patches. However, even relatively small vegetated areas can contribute to localized cooling, particularly when strategically distributed across dense urban districts (Chen et al., 2006). LST allows for the quantification of these effects by enabling comparisons between green spaces of different sizes and surrounding land cover contexts (Weng et al., 2004).

Beyond their internal cooling effect, urban green spaces also influence the thermal environment of adjacent areas. This phenomenon, often referred to as the "cool island effect," describes the extent to which reduced surface temperatures within green spaces propagate into surrounding urban fabric (Spronken-Smith & Oke, 1998; Bowler et al., 2010). LST-based buffer analyses have shown that surface temperatures generally increase with distance from green spaces, indicating a spatially limited but measurable cooling influence (Zhou et al., 2014). The magnitude and extent of this effect depend on factors such as vegetation density, irrigation practices, surrounding building density, and prevailing meteorological conditions (Peng et al., 2012).

While the cooling benefits of urban green spaces are well documented, LST-based assessments also reveal important limitations and trade-offs. The effectiveness of vegetation in reducing surface temperatures is strongly influenced by water availability (Peng et al., 2012). Under drought conditions or insufficient irrigation, the cooling potential of green spaces may be reduced, leading to elevated LST values even within vegetated areas (Oguz, 2017). This

underscores the importance of integrated water and green space management, particularly in water-limited regions.

From an urban planning perspective, LST-based evaluation of green space cooling effects provides actionable insights for climate-resilient city design (Weng, 2009). Identifying areas with elevated surface temperatures and limited vegetation coverage enables targeted interventions aimed at maximizing thermal benefits (Imhoff et al., 2010). Moreover, spatial analysis of LST supports evidence-based decisions regarding the placement, size, and connectivity of urban green spaces to enhance their cooling efficiency (Ziter et al., 2019; Zhou et al., 2014).

6. Limitations of LST-Based Analysis

Despite its widespread use and clear advantages, Land Surface Temperature–based analysis has several inherent limitations that must be acknowledged to ensure accurate interpretation of results (Voogt & Oke, 2003; Weng, 2009). While LST provides spatially continuous and physically meaningful information on surface thermal conditions, it represents only one component of the urban thermal system and does not fully capture the complexity of urban heat dynamics (Oke, 1982).

One of the primary limitations of LST is its indirect relationship with human thermal comfort. LST reflects the radiative temperature of surfaces rather than the temperature of the air experienced by urban residents. Human heat stress is influenced by multiple atmospheric variables, including air temperature, humidity, wind speed, and radiation, which are not directly represented by LST (Voogt & Oke, 2003). Consequently, areas with high surface temperatures may not always correspond to locations of maximum thermal discomfort, particularly under conditions of strong ventilation or shading (Weng, 2009).

Temporal constraints also limit the interpretability of LST-based analyses. Satellite-derived LST represents an instantaneous snapshot of surface conditions at the time of satellite overpass. Landsat 8/9 acquires imagery during a fixed daytime window, typically in the late morning. As a result, LST observations do not capture the full diurnal cycle of surface temperatures, including nighttime cooling processes that are critical for understanding heat retention and nighttime urban heat island intensity (Oke, 1982; Peng et al., 2012). The absence of nighttime observations restricts the ability to assess thermal persistence and recovery in urban environments.

Atmospheric effects introduce additional sources of uncertainty in LST retrieval. Although standard correction procedures are applied, residual atmospheric absorption and emission can influence thermal infrared measurements, particularly under conditions of high atmospheric water vapor (Li et al., 2013; Sobrino et al., 2004). These effects may lead to over- or

underestimation of surface temperatures if not properly accounted for. Furthermore, cloud contamination and subpixel cloud effects can compromise LST accuracy, emphasizing the importance of rigorous cloud masking and quality control (Jiménez-Muñoz & Sobrino, 2003).

Surface heterogeneity presents another challenge, especially in complex urban landscapes. A single LST pixel may contain a mixture of land cover types, such as buildings, vegetation, and bare soil, resulting in a composite temperature signal (Buyantuyev & Wu, 2010; Chen et al., 2006). This mixed-pixel effect can obscure fine-scale thermal variability and reduce the accuracy of LST estimates in highly heterogeneous areas (Weng et al., 2004). While higher spatial resolution data can mitigate this issue, they often come at the cost of reduced temporal coverage.

The estimation of surface emissivity constitutes a further source of uncertainty. Emissivity values are typically inferred using simplified approaches, such as NDVI-based methods, which assume uniform emissivity characteristics for broad land cover categories (Sobrino et al., 2004; Li et al., 2013). In reality, urban surfaces exhibit substantial material diversity, and emissivity can vary significantly within the same land use class. These assumptions may introduce systematic biases in LST retrieval, particularly in densely built-up areas (Oguz, 2017).

Finally, LST-based urban heat analysis is sensitive to short-term meteorological conditions. Variations in soil moisture, recent precipitation, and wind conditions can influence surface temperatures independently of land cover (Peng et al., 2012; Zhou et al., 2014). As a result, LST patterns observed on a single date may not fully represent long-term thermal behavior. This limitation highlights the importance of cautious generalization and, where possible, the use of multi-temporal analyses to capture more robust thermal patterns (Imhoff et al., 2010).

In summary, while Land Surface Temperature is a powerful indicator for assessing urban thermal environments, its limitations necessitate careful methodological choices and cautious interpretation (Voogt & Oke, 2003; Weng, 2009). Recognizing these constraints does not diminish the value of LST-based analysis; rather, it enhances its scientific rigor and supports more informed application in urban climate research and planning (Oguz, 2017).

7. Conclusions and Implications for Urban Planning

This chapter has demonstrated the value of Land Surface Temperature as a spatially explicit and physically meaningful indicator for assessing urban thermal environments (Voogt & Oke, 2003; Weng, 2009). By focusing on satellite-derived LST, the study provides insights into how land cover composition and surface properties shape urban heat patterns, with particular emphasis on the cooling role of urban green spaces (Li et al., 2013; Zhou et al., 2014).

Urban green spaces emerge as a critical component of thermal regulation within the city (Bowler et al., 2010). LST-based analysis reveals that parks, riparian zones, and irrigated agricultural areas generate localized cooling effects that extend into surrounding urban neighborhoods (Spronken-Smith & Oke, 1998; Ziter et al., 2019). The magnitude and spatial extent of these cooling effects depend on the size, density, and spatial configuration of vegetation, as well as on surface moisture availability (Peng et al., 2012; Buyantuyev & Wu, 2010). These findings highlight that both the quantity and quality of urban green infrastructure are essential for effective heat mitigation (Bowler et al., 2010).

From an urban planning perspective, the results provide several important implications (Weng, 2009). First, LST mapping offers a practical tool for identifying heat hotspots at fine spatial scales, enabling planners to prioritize interventions in the most thermally vulnerable areas (Imhoff et al., 2010; Zhou et al., 2014). Second, the spatial relationship between green spaces and surface temperature supports the strategic placement of vegetation to maximize cooling benefits, particularly in densely built districts (Ziter et al., 2019). Integrating green corridors and preserving existing agricultural and riparian areas can enhance thermal connectivity and reduce overall urban heat stress (Chen et al., 2006; Buyantuyev & Wu, 2010).

In hot climate cities, urban planning strategies must explicitly account for surface thermal conditions to improve resilience to extreme heat (Oke, 1982). The incorporation of LST-based evidence into planning processes can support climate-sensitive land use decisions, including zoning regulations, green space allocation, and urban redevelopment initiatives (Weng et al., 2004; Oguz, 2017). Moreover, LST analysis can inform the evaluation of alternative design scenarios by providing quantitative benchmarks for thermal performance (Li et al., 2013).

While this chapter adopts a single-variable approach centered on Land Surface Temperature, the results demonstrate that LST alone can provide meaningful insights into urban thermal environments when interpreted within its physical and methodological context (Voogt & Oke, 2003). Future urban climate assessments may benefit from integrating LST with complementary indicators, such as evapotranspiration and urban morphology, to further enhance understanding of heat dynamics (Peng et al., 2012; Zhou et al., 2014).

In conclusion, Land Surface Temperature represents a powerful and accessible indicator for urban heat assessment and planning (Weng, 2009; Oguz, 2017). By revealing the spatial structure of surface heat and the cooling role of green spaces, LST-based analysis supports evidence-based urban planning aimed at creating more climate-resilient, thermally comfortable, and sustainable cities (Bowler et al., 2010; Ziter et al., 2019).

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CHAPTER 11

Landscape Restoration in the Development of Climate-Oriented Resilient Urban Form

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1. Introduction

Climate change is a global crisis that affects the ecological, economic, and social structure of today's cities in multifaceted ways (Dinç, 2024). The increase in temperature observed as a result of rising greenhouse gases in the atmosphere, irregularities in rainfall patterns, heat waves, floods, droughts, and biodiversity loss threaten the sustainability of cities (Abdulrahman Hamad & Oguz, 2020; HamaSharef & Oguz, 2020; Pandey & Ghosh, 2023; Tuğluer & Çakır, 2021). In particular, the proliferation of impermeable surfaces resulting from rapid and unplanned urbanization prevents the absorption of rainwater by the soil, increasing the risk of urban flooding (Çorbacı & Ekren, 2025). At the same time, dense construction and insufficient green space alter the microclimate of cities, increasing the urban heat island effect. This shows that climate change is not only an environmental problem but also a critical issue in terms of urban quality of life, public health, economic sustainability, and social justice (Baş & Partigöç, 2022; Kaymaz & Arslan, 2022; Leichenko, 2011; Tan & Kordon, 2024).

The concept of a resilient city refers to the capacity of urban systems to continue functioning without disruption in the face of shocks and stresses, and to recover quickly if damaged. Resilience requires an approach that is not limited to post-disaster response processes but also includes risk prediction, mitigation of impacts, increased adaptation capacity, and strengthening community participation (Meerow et al., 2016). Therefore, making cities resilient requires a planning approach that is not limited to physical spatial arrangement but encompasses energy, environment, infrastructure, society, economy, and governance dimensions together (Tyler & Moench, 2012; Ekren, 2021). Furthermore, when considering the effects of spatial perception on sustainability, studies on the impact of landscape components on human behavior and the spatial relationship established with green spaces show that the perceptual dimension should not be overlooked in how urban ecosystems are perceived and in developing climate-friendly urban forms (Kordon et al., 2022).

Ecological planning forms a crucial foundation for the creation of resilient cities. Ecological planning refers to an approach where natural processes, ecosystem services, and the carrying capacity of the land are considered, and human settlements are designed in harmony with the environment. Design criteria for urban green spaces are determined by taking into account the ecological tolerance of plants (Ekren et al., 2024). The theoretical foundations of this approach are based on the principle of "design with nature" as defined in McHarg's (1969) work, Design with Nature. This perspective envisages the joint evaluation of natural and cultural components such as soil, water, climate, flora, fauna, and cultural landscape in the urbanization process (Yang & Li, 2019). In

this context, green-blue infrastructure systems, urban forests, green corridors, sustainable rainwater management, protection of natural soil and vegetation, use of renewable energy, and strengthening ecosystem services have become fundamental components of resilient urban planning. Integrating these systems into the urban fabric reduces the urban heat island effect, lowers flood and inundation risks, increases carbon sequestration, and improves quality of life. It also supports social cohesion and environmental responsibility by increasing the environmental awareness of the local population (Fan et al., 2024; Semeraro, 2022).

In this context, the concept of landscape restoration comes to the forefront in ensuring resilient cities. Landscape restoration is the process of restoring ecosystems that have been disrupted as a result of climate change, urbanization, industrial activities, and improper land use, ensuring the continuity of natural processes, and strengthening ecosystem services. Soil improvement, water cycle restoration, reforestation with local plant species, erosion prevention, and ensuring the continuity of natural habitats are the main applications of this process (Özbey, 2005; Yörüklü, 2021). Creating resilient cities in the face of climate change requires a multi-dimensional strategy that includes ecological planning principles, nature-based solutions, and landscape restoration processes. This strategy expresses an urban transformation approach that aims at environmental sustainability, the concept of social justice, economic resilience, and improving the quality of urban life. Approaches to landscape planning aimed at creating a resilient city are still limited (Dinç & Gök, 2024). Developing this issue through scientific studies is important for urban planning.

2. Ecological Planning Approaches and Nature-Based Solutions

Ecological planning is an approach that focuses on shaping cities in harmony with natural systems. Urban space is considered not only as a built physical environment, but also as a living ecosystem where the water cycle, soil structure, vegetation, climate characteristics, and human interaction operate together. Nature-based solutions are among the fundamental components of this approach (McHarg, 1969). The European Commission (2021) defines nature-based solutions as practices that utilize natural processes, strengthen ecosystems, and aim to produce ecological, social, and economic benefits. This understanding aims to create healthier and more livable environments in cities (Dinç et al., 2025; Dinç and Gül, 2022).

In ecological planning, the protection of natural resources and the reduction of the pressure of urbanization on ecosystems are priorities. Ensuring the continuity of ecosystem services is directly related to vital processes such as clean air, water cycles, soil fertility, and microclimatic regulation. Therefore, it is

important that land use decisions and construction are guided in a way that does not harm ecological cycles (Ahern, 2011; Forman, 2014; Millennium Ecosystem Assessment, 2005).

Organizing energy and matter cycles within the city in a way that creates a closed system as much as possible is also among the aims of ecological planning. In this context, practices such as waste recycling, on-site energy production, and water retention and reuse are gaining importance (UNEP, 2015). Thus, the city becomes a system that reduces its dependence on external sources and can sustain its own resource cycles (Beatley, 2011). Ecological planning is not only a process where technical decisions are made, but also includes a governance approach that requires the participation of the community in decision-making processes (Healey, 1997). The sustainability and success of nature-based practices are supported by social awareness and ownership (European Commission, 2021).

Nature-based solutions are implemented through interventions such as rain gardens, green roof systems, permeable surface use, urban afforestation, recreational ecological corridors, urban wetland arrangements, and urban community gardens. These community-based green spaces and applications in different typologies contribute to reducing the urban heat island effect, making rainwater manageable, supporting carbon sequestration, fostering social solidarity, and improving the microclimate (Kordon, 2024). They also enhance the quality of public open spaces, strengthening social interaction and supporting the development of urban identity. Thus, ecological planning serves as a tool that makes cities environmentally balanced, socially livable, and resilient. Bibliometric studies examining sustainable urban application approaches in Turkey also show that nature-based urban restoration processes are increasingly prominent in the literature and are recognized as a strategic and widespread approach in urban planning (Karcı & Kordon, 2025).

3. The Role of Landscape Restoration in Creating Climate-Resilient Cities

Landscape restoration aims to restore lost natural processes in degraded urban ecosystems (Hobbs & Harris, 2001; Aronson et al., 2006). The goal is not merely to improve the appearance of vegetation, but to restore functions such as water cycling, soil health, biodiversity and habitat continuity, microclimate regulation, climatic comfort, and social participation (Clewell & Aronson, 2012; Gill et al., 2007). This approach strengthens the capacity of cities to adapt to climate change.

3.1. Hydrological cycle restoration and nature-based restructuring of water management

The increase in impermeable surfaces in cities leads to precipitation quickly turning into surface runoff and increases the risk of flooding. Landscape restoration aims to reduce this effect through ecological water management approaches (Çakır & Dönmez, 2018). Examples of these approaches include the reuse of permeable surfaces (stone block pavements, grass retaining grids, biological drainage surfaces), slowing runoff and infiltration into the soil with rain gardens and rain ditches, temporarily retaining and filtering water through wetland restoration, and dissipating flood energy by transforming stream beds from channel cross-sections back to their natural forms (Fletcher et al., 2015; European Commission, 2021).

Thanks to nature-based practices, water ceases to be a rapidly disappearing risk factor within the city and becomes a slow-cycled and regenerative ecological resource (Gill et al., 2007; Ahern, 2011). Thus, the risk of flooding is reduced, groundwater is replenished, and the urban water cycle operates more closely to natural processes (Millennium Ecosystem Assessment, 2005; Fletcher et al., 2015). This makes a significant contribution to water security and hydrological resilience at the city scale. The literature indicates that nature-based solutions are effective in urban water management. Furthermore, there are studies that strongly address the relationship between water security and climate adaptation (Dunlop et al., 2024).

3.2. Enhancing biodiversity and re-establishing ecological connection networks

Habitat fragmentation in urban landscapes weakens the genetic diversity and continuity of living communities. Landscape restoration aims to address this degradation by re-establishing ecological networks. Examples of applications include creating urban ecological corridors (riverside strips, linear park systems), identifying ecological connections by following natural topography such as slopes and valley lines, prioritizing the use of local and compatible plant species, and planning urban forests and shrublands to ensure continuity within the habitat matrix (Ahern, 2011; Benedict & McMahon, 2006; Forman, 2014).

Thanks to these interventions, species movements, pollinator activities, soil microorganism cycles, and wildlife corridors are reactivated within the city. The ecosystem goes beyond visual green spaces and acquires a vibrant and self-renewing quality. The literature indicates that nature-based restoration practices have positive effects on biodiversity and ecological connections at the urban scale (Frantzeskaki et al., 2019). Furthermore, there is an increasing number of studies evaluating the social and environmental dimensions of nature-based solutions in urban planning (Corgo et al., 2024).

3.3. Microclimate regulation and modeling of climatic comfort through ecological design

The urban heat island effect is a significant problem that reduces living comfort and increases energy consumption. Landscape restoration aims to reduce this effect through processes such as evaporation (evapotranspiration), shading, and surface reflectivity (albedo) management. Shading areas created with trees with wide canopies can reduce pedestrian-scale temperatures by 3–7 °C. The evapotranspiration capacity of vegetation regulates the moisture-heat balance in the air, and light-colored or highly reflective surface materials reduce surface temperature by reflecting solar energy back. Green roof and vertical garden applications can reduce the heat load in buildings, resulting in a 10–25% reduction in energy consumption (Oguz, 2022a; Oguz, 2022b).

When these elements are considered together, a self-balancing microclimate system develops within the city. The literature emphasizes that nature-based solutions have an impact on microclimates. Furthermore, there is evidence that nature-based approaches increase the adaptation capacity of cities to climate change (Adams et al., 2023).

3.4. Ecosystem-Based strengthening of soil health and carbon cycle

In urban areas, soil becomes poor in organic matter, impermeable, and weak in terms of biological activity due to the effects of dense construction and surface compaction. Landscape restoration includes interventions aimed at restoring the functionality of the soil ecosystem. Carbon sequestration in the soil is increased, water retention capacity is improved, and a sustainable environment for plant root development is created through organic matter supplementation, composting applications, biochar use, artificial soil mixtures, and support of mycorrhiza-rhizosphere interactions. This process supports plant growth and allows for the long-term storage of atmospheric carbon in biomass and soil organic matter. The literature indicates that soil restoration strengthens carbon sequestration capacity and ecosystem services (Lal, 2004; Lal, 2020; Pouyat et al., 2006). Maintaining soil microbial diversity contributes to increasing ecosystem resilience and buffering capacity against environmental stresses.

3.5. Increasing community participation, ecological literacy, and social resilience

Landscape restoration is a transformative area that affects not only ecological processes but also social processes (Ahern, 2011; Aronson et al., 2017). Green public spaces, community gardens, co-production areas, and participatory design processes strengthen the ecological awareness of urban dwellers and their sense of belonging to urban ecosystems (Tidball & Krasny, 2010; Kingsley &

Townsend, 2016). Such participatory processes demonstrate that resilient cities can exist not only with technical infrastructures but also with resilient communities (Meerow et al., 2016). The literature states that citizen participation in landscape restoration practices increases social cohesion, collective memory, and a sense of environmental responsibility, and that this enhances the capacity for societal resilience against disasters and climate-related shocks (Tidball, 2014; Aldrich & Meyer, 2015). Therefore, landscape restoration offers an urbanization approach that links environmental improvement with social resilience. Landscape restoration serves as an infrastructure that reorganizes the ecological, spatial, and social structure in creating cities that can adapt to changing climate conditions. Reorganizing the hydrological cycle, strengthening biodiversity and ecological connections, improving microclimate conditions, increasing soil health and carbon sequestration capacity, and supporting social participation and ecological literacy strengthen the adaptation capacity of cities within both an ecosystem-based and social resilience-focused framework. Thus, landscape restoration transforms the city into an ecosystem structure that can renew itself, ensure continuity, and act as a buffer against crises. Therefore, considering landscape restoration as a fundamental component in climate adaptation policies, urban design, and land-use planning is considered important for creating resilient cities of the future.

4. Conclusion

Climate change is making living conditions more difficult in cities through effects such as rising temperatures, flood risk, drought, and ecosystem loss. Traditional engineering solutions are insufficient to alleviate the pressure created by these effects alone. Therefore, strengthening ecosystem processes has gained a decisive position in the future planning of cities. Landscape restoration is an approach that meets this need and aims to restore the functionality of natural cycles in cities. Strengthening the urban water cycle is one of the fundamental application areas of landscape restoration. Reducing impermeable surfaces, infiltrating rainwater into the soil, increasing temporary water storage areas, and ensuring natural flow in stream beds reduce the risk of urban flooding and support the replenishment of groundwater resources. Making these interventions a standard practice in planning and implementation processes will mitigate the hydrological stresses that cities may face in the future. Ensuring habitat continuity is also important for the resilience of urban ecosystems. The protection and restoration of ecological corridors, prioritizing the use of local plant species, and planning urban forests in a way that ensures continuity support species mobility and ecosystem health. Initiating the evaluation of green spaces in cities not only

for recreational functions but also for ecological functions is among the fundamental goals of landscape restoration.

Reducing the urban heat island effect is directly related to quality of life. Afforestation, increasing shading surfaces, the use of highly reflective paving materials, and green roof applications reduce the heat load in the city and decrease energy consumption. Defining these practices as mandatory standards in new development areas and gradually expanding them in existing urban fabrics will strengthen the climatic comfort of cities.

Improving the soil ecosystem is also an important component of landscape restoration. Compost and biochar applications, artificial soil mixtures, and supporting microbial interactions increase the soil's water and nutrient retention capacity, support plant growth, and contribute to carbon sequestration. Improving urban soils is not only a physical arrangement but also a fundamental step in ensuring the long-term functioning of the ecosystem.

The social dimension of landscape restoration has a significant impact on the relationship between individuals living in the city and their environment. Shared production areas, community gardens, and public green spaces encourage urban dwellers to experience, own, and protect ecological processes. Strengthening social participation shows that the urban environment will be supported not only by technical regulations but also by social solidarity and a sense of shared responsibility. Integrating these approaches into urban planning policies will ensure that landscape restoration creates lasting effects. Land use decisions should be made with an understanding that considers ecosystem functions, green space systems should be organized in a way that can establish ecological connections, and water-soil-plant interactions should be accepted as a fundamental indicator in planning. The absence of landscape restoration in the future spatial design of cities carries the risk of increasing the level of vulnerability to the effects of climate change.

In conclusion, landscape restoration offers an approach that makes cities resilient to climatic and environmental pressures, strengthens ecosystem processes, and supports quality of life. This includes the restructuring of the water cycle, ensuring habitat continuity, protecting microclimate balance, strengthening soil health, and supporting social participation. It increases the capacity of cities to adapt to changing climate conditions. Therefore, considering landscape restoration as a fundamental element in urban planning, design, implementation, and management processes is regarded as a necessary step in creating livable and resilient cities of the future.

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CHAPTER 12

How Do Trees Store Carbon? An Overview of Measurement and Estimation Methods

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1. Introduction

Climate change has become a global environmental problem, with effects felt on a global scale as a result of the rapid increase in greenhouse gas accumulation in the atmosphere (IPCC, 2021). Carbon dioxide (CO_2) has the highest share among these gases and is continuously added to the atmosphere through human-induced processes such as energy production, industrial activities, transportation, and land-use changes (Friedlingstein et al., 2022; Le Quéré et al., 2018). The increase in the amount of carbon in the atmosphere leads to rising temperatures, disruption of ecological balances, and a decrease in the predictability of the climate system (IPCC, 2021). Therefore, the natural capture and storage of carbon is considered one of the fundamental strategies in combating climate change (Griscom et al., 2017).

Trees are living systems that convert CO_2, which they take from the atmosphere through photosynthesis, into organic compounds and store it as carbon in their trunks, branches, roots, and leaves (Pan et al., 2011; Nowak & Crane, 2002). This process works similarly in both natural forest ecosystems and urban green spaces; however, the amount of carbon sequestration varies depending on many factors such as species characteristics, age, growth rate, soil conditions, climate characteristics, and maintenance practices. In natural forests, trees determine ecosystem productivity and biomass accumulation as a key component of the carbon cycle; while in urban areas, the carbon sequestration function is evaluated together with multiple ecosystem services such as improving air quality, reducing the heat island effect through shading, and increasing living comfort (Çorbacı et al., 2023; Nowak et al., 2013; Pretzsch et al., 2017). In this context, ensuring that the amount of green space reaches an adequate level is of great importance (Gül et al., 2024).

Determining how much carbon trees store is important not only as an ecological indicator but also for planning and management processes (Birdsey et al., 2006). Decisions regarding species selection, maintenance strategies, green space development, and natural area conservation can become more sustainable when considering the carbon storage capacity of trees (Çakır et al., 2022; Gül, 2024). Furthermore, determining the amount of carbon storage is necessary for creating carbon budgets in the fight against climate change, developing green infrastructure policies at the city level, and making the economic value of forests more visible in the context of ecosystem services (FAO, 2020). Similarly, the importance of approaches that draw attention to the economic potential of the issue, such as "sinks," "carbon credits," "carbon markets," and "carbon pricing," is emphasized in the Turkish Climate Law No. 7552 (Ekren and Kordon, 2025).

The aim of this study is to explain the carbon sequestration capacity of trees from ecological and functional perspectives, to reveal why the amount of carbon should be calculated, and to evaluate the methods and approaches used in determining this amount, within the framework of their differences, advantages, and limitations.

2. Rationale for Determining the Amount of Carbon in Trees

Calculating the amount of carbon sequestered in trees contributes to understanding the effects of atmospheric CO_2 accumulation on the environment and climate. Knowing how much carbon a tree or an area sequesters allows for a clear expression of the area's value in terms of climate regulation (Stephenson et al., 2014). The amount of sequestered carbon is related to species, age, wood density, growth pattern, and the characteristics of the tree's environment. Therefore, studies aimed at determining carbon sequestration affect afforestation and maintenance decisions in both natural and urban areas (Anderegg et al., 2020; Gül et al., 2024). The intended use of an area is important in the selection of species to be planted. For example, fast-growing species can produce more biomass in a short time, while long-lived species can provide more stable carbon sequestration over time (Shimamoto et al., 2014). Therefore, carbon sequestration information can guide the evaluation of the results of planting plans, maintenance practices, and land use decisions.

Researchers state that global climate change is one of the most significant threats to ecosystems (Dinç, 2023; Dinç, 2024). In this context, international climate policies also require the calculation of carbon stored in trees. Under the Paris Agreement and greenhouse gas inventory systems, countries monitor and report the amount of carbon sequestered in natural and urban green spaces (UNFCCC, 2015). This agreement therefore makes it mandatory for countries to measure carbon sequestration and storage.

Information on carbon accumulation in urban areas is used in planning processes related to the protection and renewal of green spaces (Uçar, 2021). In forest ecosystems, this information is used in evaluating the development of the forest and in long-term monitoring studies (Brown, 2002; Oğuz & Bozali, 2014). Therefore, calculating the carbon stored in trees is not only a scientific assessment but also a data point used in environmental management and planning.

3. Carbon Sequestration and Storage Process in Trees

The structure of a tree is essentially composed of four main parts: the trunk, branches, leaves, and root system. The majority of this structure is made up of woody tissue, responsible for the transport of water and nutrients and the mechanical support of the trunk. At the microscopic level, woody tissue is made

up of cell walls, the main components of which are known as cellulose, hemicellulose, and lignin (Dönmez & Dönmez, 2013; Uraki & Koda, 2015; Zhang, Li, & Xu, 2022). All of these substances are carbon-containing organic compounds; therefore, what we see when we look at the trunk of a tree is largely plant-based building blocks that hold carbon. Cellulose is the fibrous structure that forms the skeleton of the cell wall; hemicellulose is the more flexible matrix surrounding this skeleton; and lignin is the component that increases the strength of this structure and protects the cell wall from external influences (Zhang, Li, & Xu, 2022). These three main components are long-chain organic structures containing carbon atoms, and together they provide mechanical strength and chemical resistance in the wood cell wall. Therefore, wood tissue acts as a storage area for carbon, holding a significant portion of the carbon dioxide absorbed from the atmosphere throughout the tree's life (Paladinić et al., 2009).

The tree takes up carbon through photosynthesis. In this process, which takes place in the leaves, carbon dioxide is converted into organic matter and oxygen using water and sunlight (Wu et al., 2025). These organic substances produced both meet the plant's energy needs and enable the formation of new cells; thus, carbon accumulates in the trunk, branches, roots, and leaves. The trunk is the region in the tree where the most carbon is found because woody tissue constitutes the largest component by volume. Branches contain less carbon than the trunk; leaves contain the least biomass and therefore the least carbon; also, because leaves are short-lived, the carbon held in the leaves returns to the atmosphere more quickly in the ecosystem cycle. Roots, especially thick roots, are the parts where longer-term carbon storage occurs, particularly when anchored to the soil (Paladinić et al., 2009).

Carbon accumulation depends on the age of the tree. A young tree grows rapidly and adds new tissue to its trunk and branches each year, resulting in a high annual carbon uptake. As age increases, the growth rate may decrease, but the total amount of carbon stored increases; because large and old trees have a much greater storage capacity in terms of biomass (Luyssaert et al., 2008; Woodall et al., 2015). Therefore, young trees bind carbon faster, while older trees reach higher values in terms of total accumulated carbon (Stephenson et al., 2014).

Environmental conditions have a significant impact on this process. Water, light, temperature, and soil characteristics directly affect the growth rate (Onwuka & Mang, 2018). Studies evaluating the ecological tolerance of plants to environmental conditions have revealed that different plant species exhibit varying growth performances depending on environmental factors such as air pollution, drought, wind, temperature, cold, and salinity (Ekren et al., 2024). Such

studies highlight the importance of appropriate species selection in terms of carbon sequestration potential. In urban areas, factors such as limited root space, soil compaction, or drought can reduce carbon sequestration (Day et al., 2010). In forest areas, competition, shading, and soil structure are determining factors (Pretzsch, 2014). Pruning, damage, diseases, or drought slow down growth, reducing the amount of carbon sequestration. In contrast, a healthy tree continues to store carbon throughout the year thanks to its sustained growth (Marx et al, 2021; Trugman et al, 2018).

4. Calculating Carbon Sequestration and the Methods Used

To calculate the amount of carbon stored in trees, it is first necessary to correctly understand the concept of biomass. Biomass is the amount of organic matter containing carbon obtained from living or recently living organisms (Demirbaş, 2001). Plants, animals, and microorganisms, as well as all organic residues and by-products derived from them, fall under the scope of biomass. In energy and carbon calculations, biomass is often considered as dry matter after removing water content; because the carbon in biomass is stored in organic compounds such as cellulose, hemicellulose, lignin, and protein. Therefore, to determine the amount of carbon stored in trees, dry biomass after removing water content is considered, not wet weight (McKendry, 2002; Rowell, 2012).

The most accurate method of determining the actual dry biomass of a tree is to harvest the tree, separate all its components, and dry it to a constant weight under laboratory conditions; however, this method is time-consuming, costly, and not suitable for widespread applications (Chave et al., 2005). Therefore, in field studies, carbon sequestration is calculated through models that estimate dry biomass rather than directly by logging. This shows that determining carbon sequestration in trees is mostly based on estimation (Henry et al., 2011).

Once dry biomass is determined, it is assumed that a certain percentage of this biomass contains carbon; because carbon is located in the organic components of the woody tissue. It is generally accepted that approximately 45–50% of dry biomass contains carbon (Thomas & Martin, 2012). Therefore, the carbon sequestration is calculated based on the carbon ratio in the structural components of the dry biomass. What is important here is knowing that carbon is a chemical component stored in the organic tissue of the tree.

Some calculation methods have been developed to determine the carbon sequestration of trees. In these methods, the mass of the tree or group of trees and, consequently, the carbon sequestration are calculated using measurements taken from the tree or imaging data representing large areas (Tuğluer & Dönmez, 2022). These calculations can be applied to a single tree in some cases, to a piece of

forest in others, or to a green area within a city. The methods used for calculating carbon sequestration in trees are described below.

4.1. Direct harvesting (destructive) method

The direct harvesting method is the most accurate method for determining the carbon content of a tree (Brown, 1997). In this method, the tree is cut down and its parts, such as the trunk, branches, leaves, and roots, are separated. Each part is weighed separately, then dried under constant temperature in laboratory conditions and weighed again. The drying process removes water from the tissues, thus obtaining the dry weight of the tree (Parresol, 1999).

The percentage of carbon in the dry weight depends on the chemical composition of the tree. All organic compounds such as cellulose, hemicellulose, lignin, and protein, which make up the majority of the wood tissue, contain carbon (Pettersen, 1984). The carbon content of these compounds can vary in different species and tissues. The carbon content is determined by laboratory analysis, and the generally accepted average value is that approximately 47–50% of the dry weight is carbon (Lamlom & Savidge, 2003).

The direct harvesting method gives the most reliable results because the measurements are made from physical values; however, it has various limitations in practice. Cutting down trees for measurement is not feasible, especially in urban areas and natural ecosystems that need protection. Furthermore, in large-scale studies involving numerous trees, processes such as cutting, drying, and weighing are quite challenging in terms of time and labor (Clark et al., 2001).

Therefore, the direct harvesting method is mostly used in research areas, for sampling purposes, in developing estimation models, and as reference data in validation studies. The carbon estimation methods commonly used in the field are estimation-based methods that do not require cutting down trees.

4.2. Biomass and carbon estimation using allometric equations

Because direct harvesting methods are impractical, allometric equations have been developed to determine the mass and carbon content of trees. Allometric equations establish a mathematical relationship between biomass and carbon content, which are difficult to measure directly, and easily measurable characteristics of the tree. The most frequently used measurement in these equations is stem diameter (DBH). Diameter is usually measured at breast height (1.30 m). Some equations also take into account tree height and wood density (ρ) (Chave et al., 2014). These measurements are placed into formulas created using reference datasets previously obtained by direct harvesting (Basuki et al., 2009; Chave et al., 2005; Jenkins et al., 2003; Zianis et al., 2005):

1) Biomass = a x $(DBH)^b$

or

2) Biomass = a x $(DBH^b \times Height^c)$

The coefficients (a, b, c) here are determined from data obtained from specific species and groups of trees with similar growth characteristics. Since the chemical composition of trees (cellulose, hemicellulose, lignin) does not vary significantly between species, the carbon content is generally calculated by multiplying the estimated dry biomass by the carbon ratio (Lamlom & Savidge, 2003; Tuğluer, 2019):

3) Carbon Content = Estimated Biomass x (0.47–0.50)

The advantage of this method is that it allows carbon estimation without requiring tree felling. Field measurements are relatively easy, applicable to large areas, and make it possible to conduct studies of varying sizes, from individual trees to forest scale (Henry et al., 2011). Therefore, it is one of the most frequently used methods in scientific research and practical applications. However, allometric equations have limitations that must be considered. The equations are primarily based on trunk dimensions; crown structure and branching density are not directly taken into account. Yet, two trees of the same species, with the same diameter and height, may have different biomass if grown under different growing conditions, especially due to crown width, number of branches, and lateral branch volume (Goodman et al., 2014). A tree grown in an open area may develop a wider crown, while a tree grown in a cramped or shaded area may have a narrower crown. This creates a certain margin of error due to the estimatory nature of the equation. Furthermore, the validity of an allometric equation is closely related to the species, age range, and ecological conditions under which it was developed. Applying coefficients taken from different ecological regions to other regions can reduce the accuracy of calculations (Litton & Kauffman, 2008). Therefore, it is important for the reliability of carbon estimation that the equation used is appropriate to the study area and the species (Chave et al., 2005).

4.3. Software-based computing tools

One method used to estimate the amount of carbon in trees is software-based calculation tools. These tools work by combining basic measurements obtained from the field with models, allowing for the rapid calculation of biomass and carbon amounts for different tree species. The software matches variables such as species information, trunk diameter, height, and location with allometric equations in the database and makes carbon estimations based on this information. This method significantly speeds up the calculation process,

especially in areas with a large number of trees (Nowak, 2024; Tuğluer & Çakır 2018).

One of the best-known examples of these software programs is i-Tree. i-Tree makes carbon storage estimations based on the biophysical properties of urban trees and performs these estimations through mathematical models created for different species. The software has a large database of allometric equations and species; However, since a large part of this database consists of harvesting studies and measurements carried out in the United States, its compatibility with local conditions needs to be evaluated before it can be used in different regions and species (Nowak et al., 2013; Nowak, 2024).

In Türkiye, KARBİYOSİS (CARBIOSYS), developed by Tuğluer (2009), is used as a tool for estimating the biomass and carbon storage amounts of urban trees. The system can calculate trunk, bark, branch, and leaf components separately and determine the total carbon amount using non-destructive measurement data. Its Turkish interface and simple data entry make it practical to use in field studies. In addition, the ability to add new species and update the existing database allows the software to be used for more comprehensive studies over time.

A significant advantage of software-based methods is that estimates based on individual inventories can be made with high accuracy. With this method, the carbon storage levels of different species in the same study area can be compared on a species basis, and the user can obtain results immediately after taking measurements. The ability to record data entries makes it possible to conduct long-term monitoring studies regularly. Furthermore, the updatable nature of the software supports the addition of new equations and new species to the system. However, software-based methods also have some limitations. Measuring individual trees one by one can be time-consuming in large areas. Such software relies on allometric equations and databases developed for specific species and regions. As equations for new species are generated over time, existing models need to be updated. Similarly, obtaining local data reflecting different climates and growing conditions necessitates the reorganization and calibration of the software databases. In areas with high species diversity, some species may not be defined in the system or may have limited representation, making updating with new datasets necessary. Therefore, while software-based methods generally produce fast and detailed results, they are considered dynamic tools that require periodic review and updating of model contents, type coverage, and databases (Kirteke & Oguz, 2022; McPherson et al., 2017; Nowak et al., 2013; Nowak, 2024; Tuğluer 2019).

4.4. Remote sensing and three-dimensional volume-based prediction

Another group of methods used in estimating carbon content is based on remote sensing techniques. In these methods, without touching the trees, the crown structure, volume, and structural characteristics are determined using image and measurement data obtained from different sensors, and biomass and carbon content are estimated using this information (Lefsky et al., 2002). Remote sensing data can be obtained from different sources such as satellite images, aerial photographs, photogrammetric data obtained with unmanned aerial vehicles (UAVs), and LiDAR (Light Detection and Ranging) measurements (Popescu et al., 2011; Utla, 2025).

Three-dimensional volume estimation forms the basis of this method. With drone or LiDAR data, the crown height, crown width, and crown volume of trees can be modeled in detail; thus, metrics that directly reflect the structural characteristics of the tree are obtained (Jucker et al., 2017). These metrics are converted into biomass estimation using volume-biomass relationships found in the literature. The ability to model crown architecture in detail makes it possible to account for branching and structural differences, especially where allometric equations are limited. Therefore, three-dimensional volume-based approaches can yield more realistic results, especially in species with complex crown structures (Disney et al., 2019).

A significant advantage of remote sensing methods is that they allow for the evaluation of large areas in a short time. Forest areas, parks, and entire cities can be scanned at once with satellite images or LiDAR data, and the height, crown volume, and location information of trees can be automatically extracted (Dubayah & Drake, 2000). This significantly speeds up the data collection process for large-scale studies. In addition, being a non-contact method eliminates the physical limitations that may arise in field studies. Drone and LiDAR applications provide high detail at the individual tree level, thus allowing for the three-dimensional comparison of trees with different growth patterns (Disney et al., 2019).

However, remote sensing methods have some limitations. The resolution of satellite images does not always allow for species differentiation, therefore the accuracy of carbon estimation can vary depending on the quality of the image used (Zolkos et al., 2013). Although LiDAR and drone-based applications offer high accuracy, data processing processes require expertise, and image processing may require additional analysis stages. Furthermore, since biomass estimation in these methods is based on volume-biomass relationships in the literature, model-region fit needs to be evaluated. Regular use of remote sensing data requires updating databases at regular intervals and adapting new measurement techniques

to the system (Disney et al., 2019; Jucker et al., 2017; Oguz, H., 2022a; Oguz, H. 2022b).

Remote sensing is used as an important method in carbon calculation due to its non-contact measurement logic and its capacity to evaluate large areas in a short time. Thus, detailed analyses based on three-dimensional data can be performed both in large-scale areas and at the individual tree level.

4.5. Uncertainties, limitations, and sources of error

Studies aimed at estimating the amount of carbon in trees rely on different methods and data sources, and each method has its own uncertainties and limitations (Chave et al., 2014). Some of these uncertainties stem from the measurement process, some from the models used, and some from the environmental conditions of the study area. Since carbon calculations are fundamentally based on estimation, the characteristics of the data and approaches used are decisive in determining the results. A significant portion of the uncertainties arises from the variability in the natural structure of trees. Even within the same species, growth patterns, crown density, branch distribution, and root structure can show significant differences (Goodman et al., 2014). This variability can cause differences in mass and carbon amounts, especially in equation-based estimations, among trees with the same trunk dimensions. Differences in crown architecture and branching density create variations in volume and mass estimates. This situation is particularly pronounced in species with complex crown structures (Disney et al., 2019). Uncertainties based on models are related to the scope of the equations and conversion coefficients used. Since allometric equations are developed based on specific species and specific growth conditions, using the same equation in different geographies or under different growing conditions can lead to variations in the results (Sileshi, 2014). Similarly, the fact that the volume-biomass relationships used in remote sensing methods do not perfectly correspond to every study area necessitates the evaluation of model fit from time to time (Jucker et al., 2017). The fact that the databases used in software-based tools are based on specific species and specific coefficients can also create some limitations in areas with high species diversity (Nowak et al., 2013).

Uncertainties related to data sources also affect carbon estimates. Factors such as the resolution of satellite images, the processing stages of drone and LiDAR data, and the point density used in three-dimensional models directly affect the accuracy of the results (Zolkos et al., 2013). In the evaluation of large areas, image quality can vary, and shading, lighting conditions, or topography can sometimes lead to a loss of detail. In three-dimensional volume-based calculations, the level of detail of the model, the characteristics of the sensor used,

and the data processing methods are decisive factors in the result (Chen et al., 2015).

In addition to these limitations, it should be remembered that the conversion coefficients used in carbon calculations also vary within a certain range. Although the carbon content of dry weight does not differ greatly between species, changes in chemical composition can cause limited differences in estimates (Thomas & Martin, 2012). Therefore, it is important to regularly update carbon coefficients, add new measurement studies to the literature, and make local data available.

Studies aimed at estimating carbon amounts produce more robust results when evaluated with an awareness of all these uncertainties and limitations. The use of different data sources together, the regular updating of models, and the selection of methods appropriate to the field of study reduce uncertainties and make calculations more reliable.

5. Conclusion

Trees are among the important natural components that enable the biological sequestration of carbon dioxide in the atmosphere. Organic compounds such as cellulose, hemicellulose, and lignin, which make up a large part of tree tissue, allow for the long-term storage of carbon. Therefore, the structure of trees, their growth characteristics, and their interaction with environmental conditions are key factors in determining the amount of carbon. The methods used to determine the amount of carbon are based on different data sources and measurement levels. The direct harvesting method can reveal the amount of carbon most accurately; however, it has a limited area of use due to application conditions and time requirements. Methods based on allometric equations make it possible to estimate carbon from measurements that can be easily obtained in the field and are widely used in both natural and urban ecosystems. Software-based tools allow for the rapid evaluation of inventory-based data, enable detailed comparisons at the species level, and facilitate calculations by using large databases. Remote sensing and three-dimensional volume-based methods offer an important option, especially in terms of rapid data generation in large areas and evaluating details related to crown structure. However, since all methods are based on estimation, environmental conditions, growth patterns, crown structure, and model-region fit can affect the results. Therefore, carbon estimates need to be interpreted according to the measurement level and data structure of the method used. The combined use of different methods makes it possible to obtain more balanced and reliable results in both individual tree and large-scale area assessments. Several suggestions are put forward to strengthen the assessment process in carbon sequestration studies. Developing allometric equations for local species, updating databases, and increasing regional measurements support the accuracy of the

methods. Expanding software-based tools to include new species and regularly using remote sensing data facilitates rapid assessment, especially in urban areas. In studies conducted over large areas, the combined use of different data sources and the support of three-dimensional volume-based measurements contribute to reflecting the structural differences of trees in the calculations. In conclusion, determining the amount of carbon sequestration in trees can be done through different methods, and each method offers significant contributions under specific conditions. Choosing the right methods, regularly updating data sources, and considering information specific to the study area ensures that more reliable carbon estimates are obtained.

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CHAPTER 13

Digital Twin-Based Salutogenous Landscape Design: A Holistic Approach For Healthy Cities

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1. INTRODUCTION

1.1. Global Urbanization, Environmental Pressures, and Public Health

Accelerated urbanization on a global scale, while generating significant advantages in terms of economic opportunities and access to services, also intensifies environmental, social, and spatial pressures, creating new risk areas that directly affect public health. According to projections by the United Nations, by the year 2025, the majority of the global population will be residing in urban areas, with this proportion expected to rise further by the middle of the century (Statistisches Bundesamt [Destatis], 2025). The percentages in urbanization indicators are subject to variation due to methodological differences in the definitions of "city" and "urban area." For instance, some readings that prioritize the definition of "city" may indicate a lower share, while the "urban area" approach may reveal a higher share (Copernicus, 2025; Destatis, 2025). This situation demonstrates that discussions on urban health should pay attention not only to population growth, but also to how urbanization is measured and which spatial units are considered “urban.”

The relationship between urbanization and health should be understood not as a single environmental problem, but rather as an accumulation of interacting risks. Air pollution (pollutants such as PM2.5, PM10, NO_2, O_3) can place a significant burden on the respiratory and cardiovascular systems in urban cores dominated by heavy traffic and industrial activity (Tian et al., 2019). Increased impermeable surface area, combined with wastewater management and water quality problems, can increase the risk of infectious diseases (Almeida et al., 2020). Furthermore, the urban heat island effect engenders a critical risk area regarding heat stress and heat-related mortality/morbidity, particularly during periods of high temperature, and the disruption of thermal comfort can have multifaceted consequences, ranging from sleep quality to cognitive performance (Karimi et al., 2021; Taylor et al., 2023a). Noise pollution, with its effects extending beyond hearing -including sleep disturbances, stress responses, and increased cardiovascular risk- is another key determinant affecting urban quality of life and health (Münzel et al., 2014). This framework reveals that the "health" agenda in cities is closely related not only to the capacity of healthcare services but also to the quality of the built environment and open-green space systems.

1.2. Conceptual Framework of the Healthy Cities Approach

The healthy cities approach offers a holistic framework that addresses health indicators not solely through the absence of disease, but through environmental and governance conditions that support physical, mental, and social well-being. The fundamental idea highlighted in the World Health Organization (WHO)'s Healthy Cities perspective is that the city itself, as a "health-producing" system, supports societal well-being through continuously improved physical and social environments (Coşkun, 2022). This approach necessitates the consideration of

urban health as a system in which numerous sectors, including transportation, housing, environmental management, quality of public spaces, and social equity, operate in conjunction (Ziafati Bafarasat & Sharifi, 2024).

This holistic approach leads to two critical conclusions. Firstly, the goal of healthy cities is achievable not through a single intervention, but through consistent policies and design decisions across different scales and sectors. Secondly, the measurement and improvement of urban health necessitate a combined consideration of environmental indicators (air quality, temperature, humidity, wind, noise) and user experience indicators (accessibility, perception of safety, spatial readability, social interaction). Consequently, the healthy cities approach necessitates data, methodologies, and evaluation instruments to facilitate "evidence-based" planning and design decisions.

1.3. The Role of Urban Landscape on Health and Green Infrastructure

Open green spaces and green infrastructure systems are regarded as spatial carriers of the goal of healthy cities. Green infrastructure produces multiple ecosystem services at the urban scale through components such as parks, urban forests, green corridors, blue-green systems, and permeable surfaces, and these services are directly or indirectly related to human health (Tzoulas et al., 2007; European Commission, 2013). Urban landscape components fulfill multifaceted functions such as microclimate regulation, enhancement of thermal comfort through shading and evaporation-transpiration, contribution to air pollutant dilution, rainwater management, support for biodiversity, and provision of recreational opportunities (Bowler et al., 2010; Demuzere et al., 2014).

However, the positive effects of green infrastructure on health do not occur spontaneously; the direction and magnitude of these effects are closely related to spatial and technical decisions regarding landscape design. Design parameters such as the location, size, spatial continuity, plant composition, surface materials, accessibility level, and user safety of the area determine the quality of the ecosystem services produced and the level at which users benefit from these services (Kabisch et al., 2017; WHO, 2016). In this context, not only the existence of green space but also how it is designed and managed stands out as a decisive factor in terms of health outcomes.

Consequently, landscape architecture should be regarded not solely as an aesthetic or recreational element within the healthy cities approach, but as a strategic intervention area that mitigates environmental risks and fosters physical, mental, and social well-being (Jennings, Larson, & Yun, 2016). Indeed, green infrastructure can offer multiple health-related benefits, such as reducing the urban heat island effect, promoting physical activity, lowering stress, and strengthening social interaction (Hartig et al., 2014; Markevych et al., 2017).

However, the current literature mostly addresses the relationship between green infrastructure and health through "outcome-oriented" measurements. Although the relationships between exposure to green spaces and health indicators have been statistically established, it is often not clearly defined which design decisions produce these relationships, which spatial parameters correspond to which health effects, and how these effects change over time (Kabisch et al., 2015; van den Bosch & Sang, 2017). This situation, particularly in the current context of climate change, extreme weather events, and deepening urban inequalities, makes the need for evidence-based assessment of the health performance of landscape design even more visible. In this context, the role of urban landscape in the context of healthy cities necessitates holistic design and evaluation approaches that consider environmental performance, user experience, and spatial equity together, in addition to increasing the amount of green space.

1.4. Integration of Digital Twin and Salutogen Design

The multifaceted and dynamic nature of current urbanization dynamics and environmental and health-related risks necessitate higher-resolution, integrated, and feedback-driven assessment approaches in planning and design processes. It is emphasized that static analyses and one-off assessments are insufficient to support decision-making processes, particularly in urban contexts where climate change, extreme temperature events, air pollution, and intra-urban inequalities have a combined impact (Batty, 2018; Sharifi, 2021). In this context, the digital twin approach offers a framework that allows for the dynamic representation of physical urban systems in a digital environment and the continuous updating of these representations with real-time or up-to-date data (Grieves & Vickers, 2017).

Digital twins can address the spatial and temporal behavior of urban systems by bringing together multi-layered data streams fed by sensor networks, remote sensing data, and geographic information systems (GIS). In this respect, a digital twin is not only a modeling tool that visualizes the current situation, but also a decision support infrastructure that systematically supports design and planning decisions through scenario generation, intervention testing, and performance verification (Batty, 2018; Deren et al., 2021). In particular, the simultaneous evaluation of health-related indicators such as urban microclimate, thermal comfort, air quality, and usage density makes the digital twin approach a critical tool for the healthy cities agenda (Sharifi, 2021).

However, while the measurement and modeling of technical environmental indicators (such as heat, air pollution, and noise) hold a relatively strong place in the healthy cities literature, the systematic inclusion of user experience and psychosocial well-being in design processes remains more limited. In this regard, the salutogenic design approach offers an important theoretical framework because it addresses health not only through risk reduction but also through spatial conditions that support the well-being of individuals (Antonovsky, 1996;

Lindström & Eriksson, 2005). The concept of sense of coherence, central to the salutogenic approach, explains individuals' relationships with their environment and their capacity to cope with stressors through the components of meaningfulness, manageability, and perceptibility. These components are directly related to how users perceive space in urban and landscape settings, the extent to which they experience controllable experiences, and the degree to which they find the environmental order understandable. However, in the literature, the "operationalization" of these concepts at the landscape and urban design scale—that is, their transformation into tangible design inputs and measurable evaluation parameters—is described as a still developing research area (Sternberg, 2010; Lengen, Kistemann, & Hagen, 2017). This situation can lead to salutogenic design often being limited to qualitative discussions and providing a limited evidence base for comparing design alternatives.

This study aims to integrate the analytical capabilities offered by the digital twin approach with the human-centered theoretical components of salutogenic design, thereby addressing the gap. Digital twin-based assessment allows for the consideration of salutogenic components together with environmental performance indicators and user behavior data, enabling the development of health-oriented landscape design decisions in a more transparent, verifiable, and scenario-based manner. Within this framework, the study:

(i) discusses the literature on healthy cities and green infrastructure at the landscape scale,

(ii) explains the role of digital twin technology in urban health and landscape performance assessments,

(iii) addresses salutogenic design principles with their spatial counterparts, and

(iv) presents a conceptual integration model in which salutogenic components are paired with digital tools.

2. LANDSCAPE AND GREEN INFRASTRUCTURE IN THE CONTEXT OF HEALTHY CITIES

2.1. Green Infrastructure and Open-Green Space Systems

Green infrastructure is defined as an integrated network of natural and semi-natural areas designed to support ecological processes and ecosystem services at the city scale. This network encompasses various spatial components such as parks, urban forests, green corridors, stream beds, shorelines, green roof and wall systems, rain gardens, and permeable surfaces, aiming to ensure the continuity of ecological functions within the urban system (Benedict & McMahon, 2006; European Commission, 2013). The key feature that distinguishes green infrastructure from individual green spaces is that it offers a strategic planning

approach that aims to extend ecosystem services throughout the city through spatial connectivity and continuity, going beyond fragmented green areas (Tzoulas et al., 2007).

Open-green space systems are considered components of green infrastructure that particularly highlight the dimensions of public space, accessibility, and recreation. Public open spaces such as parks, squares, pedestrian and bicycle paths, recreation areas, and coastal arrangements are directly related to urban quality of life, physical activity level, and social interaction (Hartig et al., 2014; Jennings et al., 2016). These systems facilitate urban residents' access to green spaces in their daily lives, thus creating a critical spatial infrastructure for achieving the goal of healthy cities.

From a healthy cities perspective, green infrastructure is considered not merely as an approach of “adding nature” or aesthetic enhancement, but as a multi-functional planning and design strategy that reduces health-related risks and enhances well-being in the urban environment (WHO, 2016). Effects such as microclimate regulation, mitigation of the urban heat island effect, improvement of air quality, rainwater management, promotion of physical activity, and support for mental rejuvenation are among the key contributions of green infrastructure in the context of healthy cities (Demuzere et al., 2014; Kabisch et al., 2017).

Therefore, the design of green infrastructure components requires a comprehensive consideration of principles such as spatial hierarchy (from neighborhood scale to regional scale), connectivity (green corridors and active transport networks), ecological suitability (habitat continuity and use of local species), and managerial sustainability (maintenance, water management, safety, and operation) (Benedict & McMahon, 2006; European Commission, 2013). Evaluating green infrastructure not only during the design phase but also in conjunction with long-term management and operation processes is critical for the continuity of the ecosystem services it provides.

With increasing heat waves, droughts, and sudden rainfall events due to climate change, the resilience dimension of green infrastructure is becoming even more prominent. In this context, the blue-green infrastructure approach aims to produce both ecological and health-oriented benefits by integrating solutions related to the water cycle (rainwater harvesting, flood management, permeable surfaces, and natural drainage systems) with the components of landscape design (Fletcher et al., 2015; Kabisch et al., 2017). Thus, green infrastructure is positioned as a strategic urban system that reduces environmental risks, supports climate adaptation, and strengthens the well-being of users, in line with the goal of healthy cities.

2.2. The Relationship Between Urban Landscape and Physical, Mental, and Social Health

The effects of urban landscapes on human health are generally explained in the literature through three main mechanisms: (i) reducing environmental risks, (ii) promoting health-promoting behaviors, and (iii) strengthening psychosocial well-being. These three pathways are not independent of each other; rather, they are often considered to be processes that operate simultaneously and reinforce each other through the same spatial arrangements (Hartig et al., 2014; Markevych et al., 2017).

In terms of mitigating environmental risks, it is widely accepted that urban landscape components improve thermal comfort by regulating the microclimate and reduce health risks associated with the urban heat island effect. Tree canopies reduces the risk of heat stress by lowering surface and air temperatures through shading and evaporation-transpiration; this can have a protective effect on mortality and morbidity during heat waves (Bowler et al., 2010; Karimi et al., 2021; Taylor et al., 2023a). Similarly, it is stated that vegetation can influence air currents, particulate matter accumulation, and pollutant dispersion at the urban scale, thereby playing a complementary role in managing respiratory and cardiovascular health risks associated with air quality (Tian et al., 2019; Nowak et al., 2014). In the context of noise pollution, landscape elements can reduce exposure through physical barrier effects and improvements in the acoustic environment, and it is emphasized that this has significant consequences on sleep disorders, stress responses, and cardiovascular risks (Basner et al., 2014; Münzel et al., 2014).

Behavioral pathways are defined through the capacity of urban landscapes to promote physical activity, active transportation, and daily mobility. The presence of green spaces can contribute to reducing health risks associated with sedentary lifestyles by offering opportunities for physical activities such as walking, running, and cycling. However, the literature shows that this effect is strongly dependent not only on the amount of space but also on design and management qualities such as accessibility, spatial continuity, perception of safety, lighting, seating and resting facilities, and ease of navigation (Giles-Corti et al., 2016; Sallis et al., 2016). Therefore, the supportive effect of green spaces on physical activity is directly related to the spatial quality and usage conditions of landscape design.

Psychosocial approach examines the effects of urban landscapes on stress reduction, mental rejuvenation, improved concentration, and strengthening of social bonds. There is strong theoretical and empirical evidence suggesting that contact with nature supports mental well-being, reduces stress levels, and contributes to the recovery of cognitive functions, particularly in urban dwellers living under dense construction and high stimuli (Kaplan & Kaplan, 1989; Hartig

et al., 2014). Furthermore, it is emphasized that public open-green spaces provide spatial environments that support social interaction, a sense of belonging, and social cohesion, and that this is important for social health and quality of life (Jennings et al., 2016; Kuo, 2015).

However, the literature frequently emphasizes that these positive effects are not evenly distributed at the urban scale. Spatial inequalities in access to green space can deepen urban health inequalities for low-income groups, children, the elderly, and vulnerable communities (Wolch, Byrne, & Newell, 2014). Therefore, the healthy cities approach necessitates evaluating urban landscape and green infrastructure decisions not only through environmental performance but also through accessibility, social inclusion, and the needs of vulnerable groups.

2.3. The Strategic Position of Landscape Architecture in the Healthy Cities Process

Landscape architecture holds a strategic position in the healthycities agenda as a discipline capable of generating “multiple scales” and “multiple benefits.” Historically, discipline carries a tradition linked to urban interventions related to public health; current approaches emphasize that landscapes can contribute to health and well-being through planning, design, and management decisions (Landscape Institute, 2013). This strategic contribution is visible in practice at three complementary levels: planning, design, and management/operation.

The first level (planning scale) involves the positioning of the green infrastructure network, the establishment of connectivity, and the integration of blue-green systems with urban water management. In this context, blue-green infrastructure is considered an approach that supports both ecological functions and urban quality of life through the integration of rainwater management, increased permeable surfaces, and water retention solutions into the urban space (Pochodyła et al., 2021). The second level (design scale) involves translating the components of environmental exposures such as microclimate, thermal comfort, air quality, and noise, which are reflected in user experience, into concrete spatial decisions. At this point, the "evidence-based landscape architecture" approach argues that design decisions should be justified by relating them to health and well-being outcomes, and that the design should be structured with measurable performance goals (Brown, 2020). The third level (management/operational scale) is based on the understanding that processes such as maintenance, irrigation, risk management, and usage intensity determine the continuity of design performance, and therefore the health impacts of the landscape should be evaluated not only at the “design moment” but also in conjunction with operational decisions over time (Landscape Performance Series, n.d.).

This strategic role also highlights a crucial need: evidence-based testing and validation of the health-related impacts of landscape design decisions. Urban landscapes are dynamic systems due to the variability of seasonality and usage

patterns. Therefore, not only the initial design but also its performance over time needs to be evaluated. In this context, approaches such as post-occupancy evaluation (POE) offer a powerful toolset for systematically evaluating designed public open spaces through user behavior and spatial performance (Torun, 2020). In health-focused landscapes, diagnostic POE applications can test the extent to which design goals are achieved by considering environmental performance components such as rainwater management together with user experience (Jiang, 2018).

In recent years, the "landscape performance" literature has addressed this need by aiming to report the environmental, social, and economic outcomes of landscape solutions using measurable indicators. This approach supports the comparison of design alternatives, makes benefits visible, and allows policy/investment decisions to be based on more rational foundations (Landscape Architecture Foundation, n.d.; Yang, 2016). Therefore, landscape design compatible with the goal of healthy cities requires measurement and evaluation tools that combine environmental indicators (microclimate/thermal comfort, air quality, noise), ecosystem services (rainwater management, shading, biodiversity), and user indicators (accessibility, spatial readability, continuity of use, perception of safety) within the same evaluation framework (Landscape Performance Series, n.d.).

The framework presented in this section provides a direct basis for explaining why the digital twin approach is critical in the next stage. This is because digital twins have the potential to offer a decision support infrastructure that allows for the comparison of health-focused decisions with scenario-based design tests, enabling simultaneous monitoring of the landscape's environmental performance and its interaction with the user (Brown, 2020; Landscape Performance Series, n.d.).

3. DIGITAL TECHNOLOGIES AND THE DIGITAL TWIN CONCEPT IN URBAN HEALTH

3.1. Smart City Approach and Health-Focused Digitalization

The health-related risks of cities (heat stress, air pollution, noise, water management problems, accessibility, and security) are often spatially heterogeneous, temporally variable, and interconnected. This multi-dimensional structure necessitates that the healthy cities approach not remain solely at the level of normative principles but transform into a governance capacity supported by measurable data collected from the field, generating feedback, and integrating into decision-making processes (Batty et al., 2012; WHO, 2016). In this context, the smart city approach offers a holistic framework for monitoring, analyzing, and managing urban processes through digital infrastructures (Albino et al., 2015).

Smart city applications aim to dynamically monitor urban systems by bringing together sensor networks and the Internet of Things (IoT), communication infrastructures, big data analytics, geographic information systems (GIS), and decision support tools. The fundamental promise of this approach is to generate more efficient, flexible, and evidence-based decisions based on high-resolution data regarding the physical and social processes of the city (Batty et al., 2012; Kitchin, 2014). However, the literature also critically emphasizes that when the smart city discourse focuses solely on technical efficiency and infrastructure optimization, it can relegate the dimensions of social benefit and quality of life to a secondary role (Kitchin, 2014; Hollands, 2015).

A critical point for health-focused digitalization is that urban data should not be collected solely for "technical operation" or infrastructure performance purposes but should also be interpreted in a way that feeds spatial decisions to support human health and well-being. In this context, digitalization can be addressed at two complementary levels. The first level is the monitoring of environmental exposures—such as air temperature, humidity, wind, radiation, PM2.5/PM10, NO_2, O_3, and noise -with high spatial and temporal resolution and the correlation of these exposures with health risks (Tian et al., 2019; Basner et al., 2014; WHO, 2016). Such data makes it visible where and when risks are concentrated within the city, enabling targeted interventions. The second level is the use of indicators related to user experience and behavior -usage intensity, route preferences, spatial readability, accessibility, perceived safety, and comfort- in the evaluation of design performance. In recent years, smart city literature has emphasized that data-driven approaches that disregard human behavior and perceptions have been limited, and therefore, "human-centered" and "spatially sensitive" digitalization models need to be developed (Gehl, 2010; Sharifi, 2021). The healthy cities approach also requires the joint consideration of environmental exposure data and user experience data, aiming to transform smart city technologies from merely measuring tools into a means of supporting decisions aimed at improving quality of life.

In this context, the smart city approach offers a significant digital infrastructure for monitoring environmental risks, understanding user experience, and evaluating these two dimensions in an integrated manner within health-focused planning and design processes. However, realizing this potential depends on transforming data from a purely technical output into a human-centered and evidence-based evaluation system directly integrated into spatial decision-making.

3.2. Sensor Technologies, Remote Sensing and Geographic Information Systems

Monitoring and evaluating environmental and spatial indicators related to urban health requires the combined use of different data sources. In the literature,

these digital data sources are generally addressed in three main groups: (i) ground-based sensor and Internet of Things (IoT) systems, (ii) remote sensing data, and (iii) geographic information systems (GIS)-based spatial data infrastructures. These three approaches complement each other in terms of the spatial and temporal resolution levels they offer (Batty et al., 2012; Kitchin, 2014).

Ground-based sensors and IoT-based measurement systems enable the monitoring of microclimate and environmental quality indicators with high temporal resolution. Air temperature, relative humidity, wind speed and direction, solar radiation, noise level, particulate matter (PM2.5, PM10), and some gaseous pollutants (such as NO_2, O_3) can be continuously measured through these systems. Such data captures intraday and short-term fluctuations, revealing "at what times" and "at what points" health risks such as heat stress, air pollution, and noise exposure are concentrated (Karimi et al., 2021; Tian et al., 2019).

In this respect, ground-based sensors play a critical role in evaluating micro-scale environmental conditions that are directly related to user experience. Remote sensing data, on the other hand, offers the advantage of spatial continuity and comparability by covering wider areas at the urban scale. Data obtained through satellite and aerial platforms allow monitoring of surface temperature, vegetation density and health (indicators such as NDVI), impermeability rate, land cover classes, and some atmospheric parameters. This approach is widely used for analyzing the spatial patterns of the urban heat island effect, monitoring the distribution and temporal changes of green infrastructure components, and scalably assessing potential ecosystem services (Weng, 2009; Demuzere et al., 2014; Taylor et al., 2023a). Remote sensing is a powerful tool, especially at the urban scale, for comparative analyses and revealing long-term trends.

Geographic information systems (GIS) enable multi-layered analyses by combining different data sources, including ground-based sensors and remote sensing data, within a common spatial reference framework. In health-focused landscape and urban planning studies, GIS forms the basic infrastructure for analyses such as data integration, spatial statistics, accessibility analysis, exposure mapping, inequality assessment, and scenario comparisons (McLafferty, 2015; Kabisch et al., 2017). In this respect, GIS makes it possible to evaluate environmental data together with information on population, socio-demographic structure, and user behavior. The combined use of these three data sources provides a strong foundation for evaluating the performance of green infrastructure and open-green space systems through both environmental and user-oriented indicators. However, as emphasized in the literature, simply collecting and mapping data is not sufficient to produce health-focused design decisions. Data needs to be integrated into design and planning processes through dynamic modeling, scenario generation, and feedback mechanisms (Batty, 2018;

Sharifi, 2021). At this point, the digital twin approach offers a framework that integrates sensor, remote sensing, and GIS-based data to simultaneously monitor the environmental performance of urban landscape systems and their interaction with users, creating a critical infrastructure for testing and comparing health-focused decisions.

3.3. Definition and Key Components of Digital Twin Technology

A digital twin is an approach based on the digital representation of a physical system, object, or spatial whole, and the continuous updating of this representation with real-time or semi-real-time data streams as much as possible. Initially developed in the fields of manufacturing and engineering, the digital twin concept aims to monitor the current state of the system, analyze its behavior, and test possible interventions in a virtual environment by establishing a bidirectional data relationship between the physical system and its digital representation (Grieves & Vickers, 2017). In this respect, unlike static three-dimensional models or singular simulations, the digital twin offers a dynamic and feedback-driven structure (Batty, 2018).

In an urban context, the digital twin is considered not only as a geometric representation of the built environment but also as a multi-layered decision support infrastructure fed by sensor data, remote sensing products, and geographic information systems (GIS). In the literature, the primary function of urban digital twins is defined as monitoring the state of urban systems, conducting scenario-based analyses, and evaluating the potential impacts of planning and design decisions in advance (Deng et al., 2021; Kitchin et al., 2019).

This approach transforms the digital twin from merely a visualization tool into a holistic system supporting the measurement, analysis, scenario, and evaluation cycle.

The concept of digital twins is addressed in literature through four main elements, in line with component-based approaches. The first component is the spatial and component-level description of the physical system. This component includes the spatial modeling of landscape components such as land use, topography, vegetation, surface materials, shading elements, water features, furnishings, and access networks. This detailed representation of the physical environment forms the basis of the digital twin's analysis and simulation capacity (Boje et al., 2020).

The second component is the data layers that feed the digital twin. This layer includes microclimate and environmental quality data obtained from ground-based sensors, remote sensing-based land cover and surface temperature indicators, GIS-based spatial data, and, when necessary, user-generated information (surveys, mobile application feedback, voluntary geographic information). In the literature, the reliability and functionality of digital twins are

largely linked to the continuity and accuracy of these data layers (Lu et al., 2020; Kitchin, 2014).

The third component is analysis and simulation engines. This component encompasses tools that enable the modeling of physical and environmental processes. Microclimate and thermal comfort simulations in the context of urban landscapes, urban heat island analyses, ecosystem service assessments, rainwater management scenarios, and user mobility models are included in this group. Analysis and simulation engines allow for scenario-based testing of the environmental and functional consequences of design decisions and strengthen the decision support capability of the digital twin (Batty, 2018; Deng et al., 2021).

The fourth component is the decision support and visualization layer. This layer aims to make the analysis results understandable to designers, planners, and decision-makers. Performance indicator panels, scenario comparisons, temporal change visualizations, and reporting tools are considered within this scope. In the literature, it is emphasized that for digital twins to be effective in planning and design processes, it is critical that technical analyses, as well as their transparent and interpretable presentation, are presented (Kitchin et al., 2019; Boje et al., 2020).

This four-component structure adapts to the dynamic characteristics of the urban landscape, such as seasonality, variability in climatic conditions, and the time-dependent differentiation of user patterns, making it possible to monitor and evaluate design performance not only at the "design moment" but also over time. In this respect, the digital twin offers a strong methodological infrastructure that can address the environmental and user-oriented impacts of landscape design together in the context of healthy cities.

3.4. The Potential of Digital Twins in the Context of Urban Landscapes and Healthy Spaces

The fundamental potential of the digital twin approach in the context of urban landscapes and wellness spaces lies in its ability to evaluate environmental exposures and user experience together within the same analytical framework. While environmental risks (heat stress, air pollution, noise) are often addressed through physical indicators in the urban health literature, the analysis of how these risks intersect with user behavior and spatial usage patterns is limited. The digital twin infrastructure, by simultaneously monitoring these two dimensions through sensor data and spatial models, makes it possible to make visible the critical health-related intersections in landscape design (Batty, 2018; Kitchin et al., 2019).

For example, the spatial distribution of thermal comfort in a park area can be modeled in relation to shading elements, surface materials, vegetation, and topography. Behavioral indicators such as user density, route preferences, seating

area usage, and duration of stay at specific points can also be integrated into the digital twin environment for the same space. Such integrated analyses go beyond simply identifying the "hottest" or "coolest" areas and allow for the uncovering of more design-critical situations, such as areas that are "exposed to high heat stress but heavily used." The literature emphasizes that considering environmental exposure and usage patterns together offers a significant methodological advantage for health-focused spatial prioritization (Deng et al., 2021; Lu et al., 2020).

Another important contribution of digital twins is the ability to test landscape design decisions on a scenario-based approach. Interventions such as increasing shading elements, changing surface materials, rearranging planting compositions, or adding water features can be compared through pre- and post-intervention environmental performance indicators. This scenario-based approach allows the health-related impacts of design alternatives to be evaluated not only based on predictions but also on measurable data. Batty (2018) and Deng et al. (2021) state that digital twins strengthen the capacity for "evidence-based decision-making" in planning and design processes by supporting such comparative analyses.

Considering the expected increase in heat waves, droughts, and extreme weather events in the context of climate change, the importance of digital twins in healthy landscape design is further enhanced. Microclimate simulations and climate scenarios allow testing the performance of shading, planting, and blue-green infrastructure components under different climatic conditions. In this way, water management, irrigation regimes, and maintenance scenarios can also be evaluated as an integral part of design performance. Literature particularly emphasizes the need for dynamic and scenario-based tools to address climate adaptation and urban health goals together (Taylor et al., 2023b).

When considered together with the salutogenic design approach described in the following section, the digital twin infrastructure supports health-oriented landscape design not only in reducing environmental risks but also in strengthening spatial qualities that generate meaningfulness, manageability, and perceptibility for the user. By enabling the monitoring of these qualities through environmental and behavioral indicators, the digital twin prepares the ground for addressing salutogenic design principles within a more operational and verifiable framework.

4. SALUTOGEN DESIGN APPROACH AND SPATIAL DIMENSION

4.1. Theoretical Foundations of Salutogenic Theory

The dominant approach in urban health literature is based on defining health problems through specific risk factors and developing preventive strategies to reduce these risks. While this pathogenic approach is important in terms of identifying and limiting environmental stressors such as air pollution, extreme

temperatures, noise, and infectious diseases, it provides only limited answers to the question of how health is produced and maintained (Antonovsky, 1979). In this context, salutogenic theory offers a complementary theoretical framework to urban health discussions by shifting the focus from the causes of disease to the conditions that enable health.

First developed by Aaron Antonovsky, the salutogenic approach views health not as a dual "healthy-sick" state, but as a health continuum in which individuals are located at different points throughout their lives (Antonovsky, 1987). The fundamental element determining the movement towards health on this continuum is not the complete elimination of stressors, but the existence of generalized resistance resources that support the individual's capacity to cope with these stressors. These resources are shaped at individual, social, and environmental levels and directly affect an individual's capacity to make sense of, control, and predict their life.

The concept of sense of coherence, central to salutogenic theory, is defined as a holistic orientation expressing the extent to which an individual finds their life understandable, manageable, and meaningful (Antonovsky, 1987). Literature has shown that this concept is strongly associated with maintaining health and well-being, even under stress (Eriksson & Lindström, 2006). In this respect, salutogenic theory considers health not only in terms of reducing environmental risks but also in conjunction with structural and contextual conditions that strengthen an individual's relationship with their environment.

This theoretical framework makes it possible to rethink the role of urban space, and especially public spaces, in health production. Beyond reducing stressors encountered in daily life, the spatial environment can produce experiences that foster a sense of coherence. Indeed, the literature emphasizes that public spaces and urban landscape areas have the potential to encourage social interaction, support physical activity, and enhance mental renewal through contact with nature (Hartig et al., 2014; Ward Thompson, 2011). These effects are considered, as predicted by salutogenic theory, as environmental resources that support individuals' coping capacity and well-being. Therefore, the salutogenic approach allows us to consider the urban landscape not merely as a spatial arrangement that limits environmental risks, but as a health production environment where individuals can develop meaningful, manageable, and understandable experiences. Because of these characteristics, salutogenic theory offers a strong theoretical foundation for landscape design and public space studies in the context of healthy cities.

4.2. Concepts of Meaningfulness, Manageability, and Perceivability

At the heart of salutogenic theory lies the sense of coherence, defined as a holistic orientation that expresses the extent to which an individual finds their life understandable, manageable, and meaningful (Antonovsky, 1987). This concept,

developed to explain individuals' capacity to move toward health on the health continuum when faced with stressors, consists of three fundamental components: meaningfulness, manageability, and comprehensibility (Antonovsky, 1979; Antonovsky, 1987). Literature shows that these three components work together to strengthen an individual's coping capacity and are strongly associated with health (Eriksson & Lindström, 2006).

Meaningfulness is related to an individual's perception of situations encountered in their life as "worth investing in" emotionally and cognitively, and their development of intrinsic motivation towards these situations (Antonovsky, 1987). In a spatial context, meaningfulness is shaped through the emotional connection an individual forms with a space, their place identity, and sense of belonging. In urban and landscape literature, this dimension is addressed through concepts such as sense of place, spatial identity, richness of experience, and interaction with nature (Relph, 1976; Tuan, 1977; Ward Thompson, 2011). Research shows that public spaces that users can relate to and connect with the social context have the capacity to produce meaning that supports psychosocial well-being (Hartig et al., 2014).

Manageability refers to an individual's perception of having access to the necessary resources to cope with the demands they face. These resources are not limited to individual skills but also include social support mechanisms and environmental conditions (Antonovsky, 1979). In the context of the spatial environment, manageability is associated with physical and functional qualities such as perceived safety, accessibility, ease of navigation, adequacy of facilities, climatic comfort, and continuity of maintenance. In urban landscape literature, it is emphasized that areas where users can develop a sense of control and predictability over the space support longer-term and more diverse uses (Gehl, 2011; Carmona, 2019). This reveals that manageability can be indirectly strengthened through spatial design.

Perceptibility refers to the extent to which an individual finds their environment understandable, orderly, and predictable. Antonovsky (1987) associates this component with the cognitively structured and coherent nature of the stimuli and individual encounters. In a spatial context, perceptibility is directly related to the “readability” of the urban environment. Lynch (1960) defined urban readability through the perceptual clarity of spatial elements such as roads, edges, zones, nodes, and foci, and revealed that this quality strengthens users' spatial orientation and sense of security. In landscape and public space design, perceptibility is supported through design components such as the clarity of spatial hierarchy, the continuity of routes, the definition of boundaries, signage systems, and lighting (Kaplan & Kaplan, 1989; Carmona, 2019).

These three components are not considered as independent variables in terms of health production, but rather as parts of a whole that function in interaction

with each other. The literature shows that a space being environmentally high-quality alone is not sufficient; It is emphasized that user experience, and consequently salutogenic effects, can be limited if qualities such as accessibility, safety, and perceptual clarity are poor (Hartig et al., 2014; Ward Thompson, 2011). Therefore, the salutogenic design approach offers a multidimensional evaluation framework that considers both the physical performance of the landscape and the user experience.

4.3. Salutogenic Design Principles at the Urban Landscape Scale

Salutogenic design, as an interpretation of salutogenic theory adapted to the spatial environment, aims to produce physical and perceptual conditions through design that support individuals' sense of coherence. In the literature, this approach assumes that space should be considered not only as a tool for reducing environmental risks, but also as an active source of health that strengthens the individual's coping capacity and well-being (Antonovsky, 1987; Dilani, 2008). At the scale of urban landscapes, salutogenic design is discussed in environmental psychology, public space, and landscape planning literature through two complementary design lines.

The first line is the reduction of environmental stressors and the provision of comfort conditions. This approach aims to reduce factors such as thermal stress, noise, air pollution, and physical fatigue that individuals are exposed to in the urban environment, and to enable users to experience the space in a more manageable way. In the context of landscape design, improving thermal comfort, enhancing shading and evaporation-transpiration effects, regulating wind conditions, providing resting areas, and strengthening accessible pedestrian routes are identified as key components of this approach (Hartig et al., 2014; Ward Thompson, 2011). It is emphasized that such interventions contribute to users developing a sense of control and predictability over the space, particularly by supporting the manageability component (Gehl, 2011; Carmona, 2019).

The second approach focuses on strengthening the capacity of space to produce meaning and its perceptual legibility. Within the context of salutogenic theory, meaningfulness and perceptibility are directly linked to an individual's ability to relate to space at both emotional and cognitive levels (Antonovsky, 1987). In urban landscape literature, this dimension is addressed through place identity, continuity, the use of local ecological and cultural references, diversity of experiences, and clarity of spatial focus (Relph, 1976; Tuan, 1977). Furthermore, spatial legibility, ease of navigation, consistency of routes, and perceptual clarity of signage systems support the perceptibility component by enabling users to experience the environment in an understandable and predictable way (Lynch, 1960; Kaplan & Kaplan, 1989).

These two design approaches are not considered independent of each other, but rather as processes that work together and complement each other. Literature

has shown that environmentally high-performing but perceptually complex or socially exclusionary spaces have limited salutogenic effects (Hartig et al., 2014). Similarly, areas with a strong capacity for generating identity and meaning but lacking in thermal comfort or accessibility can negatively impact user experience and health-related benefits. This highlights the need for a holistic approach to salutogenic design at the urban landscape scale, addressing both physical performance and user experience simultaneously.

However, salutogenic design principles present a significant methodological challenge in urban landscape studies. Since components such as meaningfulness, manageability, and perceptibility are largely shaped by user perception and experience, direct and continuous measurement of these principles remains limited. The literature indicates that these dimensions are mostly assessed through surveys, interviews, and observational methods, making comparisons of design alternatives and scenario-based evaluations difficult (Eriksson & Lindström, 2006; Dilani, 2008). At this point, the digital twin approach, which can track environmental performance indicators and user behavior patterns simultaneously, stands out as a methodological tool that can allow for a more operational and comparable approach to salutogenic design principles.

5. DIGITAL TWIN-BASED SALUTOGEN LANDSCAPE DESIGN: A HOLISTIC MODEL

5.1. Conceptual Integration of Digital Twin and Salutogen Design

In line with the healthy cities approach, the role of urban landscape is being redefined as an active spatial system supporting health production, moving beyond being merely a passive infrastructure that mitigates environmental risks. This transformation necessitates evaluating the impacts of green infrastructure components on health not only through qualitative observations but also through visible, measurable indicators that can generate feedback for design decisions (Hartig et al., 2014; Kitchin et al., 2019). In this context, the combination of the digital twin approach and salutogenic design principles offers a holistic framework for health-oriented landscape design at both analytical and theoretical levels.

The digital twin, as a dynamic infrastructure fed by sensor data, remote sensing products, and geographic information systems, allows for monitoring and scenario-based analysis of health-related indicators such as microclimate, air quality, noise, and occupancy density at high spatial and temporal resolution (Batty, 2018; Deng et al., 2021). The salutogenic design approach provides a theoretical framework explaining how these environmental performance outputs are integrated with user experience and psychosocial well-being. Therefore, this integration positions the digital twin not merely as a technical monitoring tool, but as a decision support system that links the conceptual components of salutogenic design to spatial design decisions.

The digital twin-based salutogenic landscape design model proposed in this study is built upon three fundamental principles derived from digital twin and health-focused design approaches in literature (Figure 1). The first principle is *multi-layered data integration*. Indicators related to the environmental performance of the urban landscape (microclimate, thermal comfort, air quality, noise) and user-related data (usage intensity, mobility patterns, feedback) are combined within a common spatial reference framework, allowing both the physical and experiential dimensions of the landscape to be evaluated within the same system. The literature emphasizes that such integrated data structures provide a critical methodological advantage in urban health analyses (Kitchin et al., 2019; Lu et al., 2020).

The second principle is *feedback-based evaluation* and *scenario-based design testing*. The digital twin infrastructure allows for the comparison of design decisions (shading, vegetation, surface materials, water features, access arrangements) through pre- and post-intervention performance indicators. This approach makes it possible to analyze the health-related impacts of landscape design through alternative scenarios instead of static evaluations. The digital twin literature clearly states that this feedback loop strengthens evidence-based decision-making capacity in planning and design processes (Batty, 2018; Deng et al., 2021).

The third principle is *human-centered health production*. Beyond reducing environmental risks, this principle aims to support the components of meaningfulness, manageability, and perceptibility predicted by salutogenic theory through spatial design (Antonovsky, 1987). The digital twin, by considering environmental performance indicators and user behavior patterns together, allows for the monitoring of these components through indirect indicators and the comparison of the potential impacts of design alternatives on health. Thus, the model transforms into a decision support approach that integrates the relationship between environmental performance and psychosocial well-being within the context of landscape design.

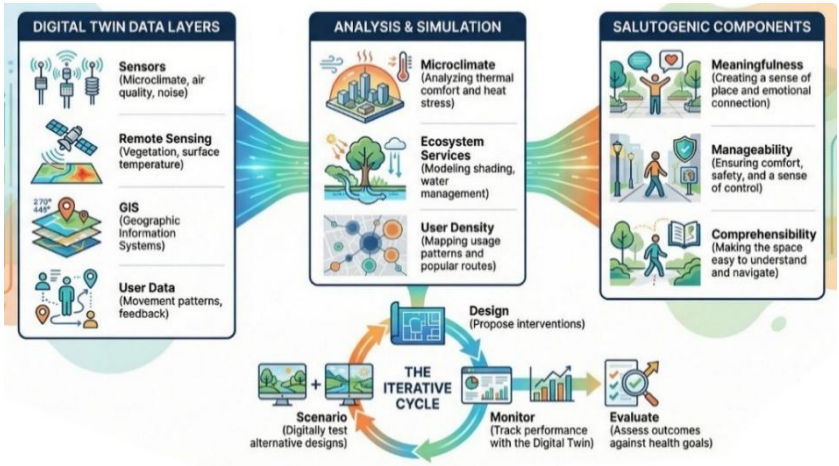

Figure 1. Conceptual model of digital twin–driven salutogenic landscape design for healthy urban environments

5.2. Salutogenic Components, Digital Tools, and the Context of Landscape Design

The core of the digital twin-based salutogenic landscape design approach is the integration of the three fundamental components of salutogenic theory (meaningfulness, manageability, and perceptibility) into the spatial design process through digital data sources and analytical tools (Table 1).

This approach does not aim at the direct and reductionist quantification of salutogenic concepts; rather, it aims to allow for the discussion of these components indirectly, comparablely, and verifiably through environmental and behavioral indicators (Antonovsky, 1987; Eriksson & Lindström, 2006). In this respect, the proposed framework transforms salutogenic design from an approach based solely on qualitative evaluations into a design performance evaluation system supported by a digital twin infrastructure.

Table 1. Relationship between salutogenic components, spatial design, and digital indicators

Salutogenic Component	Landscape / Spatial Correspondence	Digital Twin Indicators
Meaningfulness	Sense of place, spatial identity, experience diversity, preferred routes	Wayfinding analysis, usage intensity, dwell time, route preference
Manageability	Thermal comfort, accessibility, shading, resting areas, safety	Microclimate simulations, heat stress maps, scenario testing
Comprehensibility	Spatial legibility, hierarchy, entrances, lighting, signage	User feedback, VGI, navigation difficulty reports

5.2.1. Meaningfulness: Spatial Readability, Wayfinding, and User Behavior

The meaningfulness component is shaped by the emotional and cognitive connections individuals establish with a space and is related to whether the space offers a "worthwhile" experience (Antonovsky, 1987). In the context of urban landscapes, meaningfulness is frequently addressed in literature through concepts such as sense of place, identity, diversity of experience, and user preferences (Relph, 1976; Tuan, 1977; Ward Thompson, 2011).

The digital twin approach can support the meaningfulness dimension in two complementary ways. First, it involves the analytical evaluation of indicators related to spatial readability and wayfinding performance. Spatial parameters such as the continuity of the pedestrian network, the density of decision points, field of view analysis, the distribution of focal points, route complexity, and the consistency of signage systems generate indirect indicators of the extent to which the environment presents an “intentional” and meaningful arrangement for the user (Lynch, 1960; Kaplan & Kaplan, 1989).

The second aspect is the monitoring and interpretation of user behavior patterns. Indicators such as usage intensity, preferred routes, duration of stay in specific areas, repeat visit patterns, and intraday usage variations offer important clues about the quality of users' relationship with the space. Digital twin infrastructure can analyze this behavioral data within a spatial context, revealing which landscape components generate experiential value and which areas are avoided by users (Kitchin et al., 2019; Deng et al., 2021). Such analyses allow for a reassessment of design decisions in a way that strengthens the space's capacity to generate meaning.

5.2.2. Manageability: Microclimate Simulations and Environmental Scenario Testing

Manageability refers to individuals' perceptions of having the necessary environmental and functional resources to cope with spatial demands (Antonovsky, 1979). In the context of urban landscapes, this component is shaped through elements such as thermal comfort, recreational facilities, accessibility, safety, and continuity of maintenance (Gehl, 2011; Carmona, 2019).

Digital twin infrastructure can concretize the manageability dimension through environmental performance simulations and scenario-based analyses. Microclimate and thermal comfort simulations reveal the spatial distribution of heat stress risk, showing where interventions such as shading, vegetation, or surface material changes are necessary (Karimi et al., 2021; Taylor et al., 2023). Furthermore, under climate scenarios such as heat waves and drought, the performance of design decisions such as increasing shading, positioning water features, or protecting wind corridors can be compared.

Similarly, infrastructure components such as rainwater management, permeable surfaces, and automated irrigation systems are considered elements that support manageability in terms of both climate adaptation and user comfort. Digital twin allows these decisions to be analyzed together with environmental performance, water consumption, and maintenance requirements, establishing a holistic evaluation framework between design and operation processes (Batty, 2018; Deng et al., 2021).

5.2.3. Perceptibility: Participatory Technologies and User Feedback

Perceptibility is related to the environment being understandable, orderly, and predictable to the user, aiming to keep cognitive load low (Antonovsky, 1987). In landscape spaces, perceptibility is directly linked to design components such as the clarity of spatial hierarchy, the legibility of entrances and exits, the continuity of routes, and the consistency of lighting and signage systems (Lynch, 1960; Kaplan & Kaplan, 1989).

The digital twin approach can support the perceptibility dimension through participatory technologies and user feedback mechanisms. Through mobile applications, QR-based feedback points, voluntary geographic information (VGI), and short user surveys, difficulties with wayfinding, perception of safety, areas found to be complex or unclear, and undesirable routes can be identified (Goodchild, 2007; Kitchin et al., 2019). This data provides direct input for design improvements by revealing in which sections of the spatial layout perceptual uncertainty increases. Thus, perceptibility becomes a dimension of evaluation that is not solely based on the designer's foresight but supported by evidence derived from user experience.

5.3. Microclimate, Ecosystem Services, and User Density Analyses

Indicators monitored within the scope of digital twins aim to evaluate health-related environmental performance and user behavior together. Microclimate and thermal comfort analyses reveal the spatial distribution of heat stress risk and its relationship with green infrastructure components (Karimi et al., 2021). Ecosystem service assessments make it possible to analyze functions such as shading, evaporation-transpiration, rainwater retention, and biophysical cooling effects through design components (Hartig et al., 2014). User density and mobility analyses, on the other hand, make visible how environmental performance outputs coincide with or conflict with user experience, allowing for a reassessment of design priorities.

5.4. Evaluating Health-Focused Design Decisions Through Digital Twins

The key outcome of a digital twin-based approach is that health-focused design decisions become verifiable and comparable. This evaluation is typically conducted through "alternative design scenarios." For example, interventions such as increasing shading elements in a park, changing the plant species composition, increasing the permeable surface area, repositioning seating/resting units, or improving the wayfinding system can be tested in a digital twin environment in terms of both environmental and user behavior indicators. By comparing pre- and post-intervention indicators, it can be determined which intervention contributes more to which health goals.

This process ensures that design transcends being merely a "well-intentioned" or "normative" proposal, transforming into a decision set supported by measurable performance indicators. Simultaneously, the model reduces the distance between theoretical frameworks and practical tools in health-focused landscape design, as it makes the components of salutogenic design (meaningfulness, manageability, perceptibility) debatable through a digital twin infrastructure. The holistic model proposed in this section, as will be discussed in the next section, offers a methodological innovation to planning and design processes in developing healthy, resilient, and sustainable urban landscapes.

6. CONCLUSION AND RECOMMENDATIONS

This study proposes a holistic conceptual and methodological framework to strengthen the health-producing potential of urban landscapes within the scope of the healthy cities approach. The fundamental originality of the proposed approach lies in its ability to connect the dynamic, data-driven analytical capacity offered by digital twin technology with the human-centered theoretical components of salutogenic design, addressing health-oriented landscape design not only through the reduction of environmental risks but also through user experience and psychosocial well-being. In this respect, the study moves the relationship between green infrastructure and urban landscape and health beyond static outcome

indicators to a traceable, comparable, and scenario-based decision-support process.

The digital twin-based approach has the potential to make visible the temporal and spatial variability of health-related indicators of urban landscapes such as thermal comfort, air quality, noise, and usage intensity. This makes it possible to base design decisions not only on normative standards or designer predictions but also on measurable data specific to a particular space. At the same time, the digital twin infrastructure promotes an adaptive design approach that supports the sustainability of healthy landscapes by allowing the evaluation of the design's performance not only during production but also its impact over time, including use, maintenance, and operation.

The salutogenic design approach, however, elevates this technical infrastructure to a human-centered evaluation level. The components of meaningfulness, manageability, and perceptibility provide a crucial framework explaining the relationship between the urban landscape and its users, its spatial readability, controllability, and experiential value. The model proposed in this study, without directly claiming to quantify salutogenic concepts, makes them discussable indirectly through environmental performance indicators and user behavior patterns. Thus, salutogenic design moves beyond being solely a qualitatively based approach, becoming a more operational framework that allows for the comparison of the health-related impacts of design alternatives.

An important contribution of the proposed approach is the ability to consider design and operational decisions together. The performance of healthy landscape spaces is shaped not only by spatial arrangements but also by management processes such as maintenance, irrigation, user capacity, safety, and response to climatic extremes. The digital twin makes it possible to evaluate these processes in relation to health goals, transforming landscape design from a static product into a continuously monitored and improved system. In this respect, the approach offers a powerful tool for developing resilient and adaptable urban landscapes, especially in the face of increasing uncertainties under climate change. However, there are some limitations and points to consider in the application of the digital twin-based salutogenic landscape design approach. Data quality, data continuity, and technical infrastructure capacity are fundamental elements that directly affect digital twin performance. Furthermore, adherence to ethical principles, privacy, and representational fairness in the data collection processes related to user behavior and feedback is critically important. Given the context-sensitive and multidimensional nature of salutogenic concepts, it must be clearly acknowledged that digital indicators do not represent all of these concepts precisely but rather provide approximate indicators that support design discussions. Therefore, the proposed model needs to be considered in conjunction with interdisciplinary collaboration and a strong governance infrastructure. For

future research, testing the digital twin-based salutogenic landscape design framework in different spatial contexts is a crucial requirement. Different urban landscape types such as parks, green corridors, squares, coastal areas, and campuses can offer suitable pilot areas for evaluating the model's contextual sensitivity and the validity of its indicators. Furthermore, the use of digital analytics in conjunction with qualitative methods and participatory approaches will contribute to a more holistic understanding of user experience. From an application perspective, three key recommendations stand out for local governments and planning-design units: establishing a minimum data infrastructure capable of monitoring health-related environmental indicators; developing decision-support processes that enable scenario-based comparison of design alternatives in green infrastructure projects; and establishing participatory mechanisms that integrate user feedback into continuous design improvement. These steps will support the transformation of the digital twin-based approach from a purely technical innovation into a transformative tool with institutional and societal implications in line with the goal of healthy cities.

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CHAPTER 14

Urban Acupuncture as a Tool for Public Space Sustainability

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1. INTRODUCTION

"Public spaces are all places publicly owned or of public use, accessible and enjoyable by all for free and without a profit motive" (The Biennial of Public Space & UN-Habitat, 2013). As vital organs of the city, they are designed to function as "nodes which bring people together for various activities," forming an essential "infrastructure for social life" (Madanipour, 1999, p. 882). Moreover, they form the crucial connective tissue for a sustainable city, providing the "nested" network of green features necessary for ecological health and human well-being (Beatley, 2010, p. 83). Despite their profound importance, "the value of public spaces is often overlooked or underestimated by policy makers, leaders, citizens, and urban developers" (United Nations Statistics Division [UNSD] 2025, para. 1). This neglect is not merely an oversight but a significant urban sustainability challenge, stemming from a "lack of resources, or understanding or capacity to use public space as a complete, multi-functional urban system," which is often compounded by "the lack of appropriate enabling frameworks, weak political will and the absence of the means of public engagement" (UNSD, 2025, para. 1).

The expected response to this challenge has often been to rely on large-scale urban projects and policy reforms. While this macro-level approach is important for setting a strategic direction, it depends on the same entities that often overlook the value of public space and can obscure the transformative potential of smaller, community-focused interventions. This article poses a focused research question: Can small-scale urban acupuncture projects serve as a viable strategy for creating sustainable and socially conscious public spaces? To answer this, the analysis turns to three internationally recognized cases, selected for their strategic diversity: the Sant Antoni Superblock in Barcelona, Urban Bloom in Shanghai, and TULIP in Montréal.

The analysis is guided by a four-part framework designed to evaluate the efficacy of these urban acupuncture projects. This framework is informed by key theories of public space—including Jane Jacobs's metrics of social vitality, Jan Gehl's principles of human-centered design, and Michael Sorkin's concept of ecological intervention—and synthesizes them into the following parameters: Project Overview, which diagnoses the specific urban context and objectives; Design Approach, which analyzes the architectural and planning strategies through the lens of targeted, catalytic action; Sustainable Features, which assesses the environmental, social, and economic benefits generated; and Alignment with SDG 11.7.1, which evaluates their contribution to the global goal of universal access to safe, inclusive, and green public space. By applying this framework, the article demonstrates how targeted, sensitive interventions can allow the urban fabric to heal, adapt, and flourish, providing a vital complement to conventional top-down planning.

2. LITERATURE REVIEW

"A successful public space does not occur by accident; it is the product of intentional design informed by foundational urban theory. From a cognitive perspective, Kevin Lynch (1960) argued that spaces must function as legible nodes and landmarks within the city's mental map. Socially, Jane Jacobs (1961) demonstrated that their success is measured by their ability to generate vibrant street life and foster community through 'eyes on the street.' Perceptually, principles derived from Gestalt psychology, as applied by Gordon Cullen (1961), emphasize the importance of creating visually coherent and enclosed places. Finally, Jan Gehl (2010) synthesizes these ideas into a human-centric methodology, arguing that design must prioritize people's sensory experiences and social interactions at walking speed. Together, these theorists establish a multi-faceted ideal for urban public space against which its current state of neglect can be critically assessed. "

A successful public space is not the result of chance but emerges from intentional design grounded in foundational urban theory. From a cognitive perspective, Kevin Lynch (1960) emphasized that public spaces contribute to the city's mental map by functioning as legible nodes and landmarks. From a social standpoint, Jane Jacobs (1961) argued that the success of public space depends on its capacity to generate vibrant street life and foster community interaction through the principle of **"eyes on the street."** Perceptual approaches, particularly those informed by Gestalt psychology and articulated by Gordon Cullen (1961), highlight the importance of visually coherent and spatially enclosed environments. Building upon these ideas, Jan Gehl (2010) developed a human-centered methodology that prioritizes sensory experience and social interaction at the scale of the pedestrian. Together, these perspectives establish a multifaceted theoretical framework through which the contemporary neglect of public space can be critically examined.

2.1. A Lynchian Lens: Classifying Public Space for Urban Legibility

The quality of a public space is determined not only by its social vitality and aesthetic design, but also by its fundamental role in the city's cognitive structure. Kevin Lynch's seminal work, The Image of the City (1960), provides the critical framework for understanding this role. Lynch revealed that people navigate and connect with their urban environment through a mental map composed of five key elements: paths, the channels of movement; edges, the linear boundaries; districts, the medium-to-large areas with a common character; nodes, the strategic focal points; and Landmarks, the external reference points. This theory transforms a simple typology into a diagnostic tool for urban structure, inquiring about the cognitive role a space plays.

To establish a clear foundation for analyzing public space, it is essential to begin with its functional classification. The Charter of Public Space (The Biennial

of Public Space & UN-Habitat, 2013) categorizes public space into four primary types: Streets, Public Open Spaces, Public Facilities, and Public Commercial Spaces.

When overlaid onto the Biennial of Public Space & UN-Habitat (2013) classification, the functional definitions of public spaces reveal their potential to constitute the city's image. According to the Charter, streets are defined as "thoroughfares located within towns, cities, and neighborhoods," including "avenues and boulevards, squares and plazas, pavements, passageways, galleries, bicycle routes, sidewalks, traffic islands, tramways, and roundabouts" (United Nations Human Settlements Programme [UN-Habitat], 2019, p. 9). Primarily, these elements constitute the city's paths, an essential network for movement. However, a major boulevard can also function as a powerful Edge, dividing districts; at the same time, a prominent roundabout or an integrated plaza can transform a street from a mere conduit into a distinct Node, a point of convergence and pause.

Figure 1. Washington Square Park (New York City, USA) as an example of a street-based public space.

Source: Gaul, 2019.

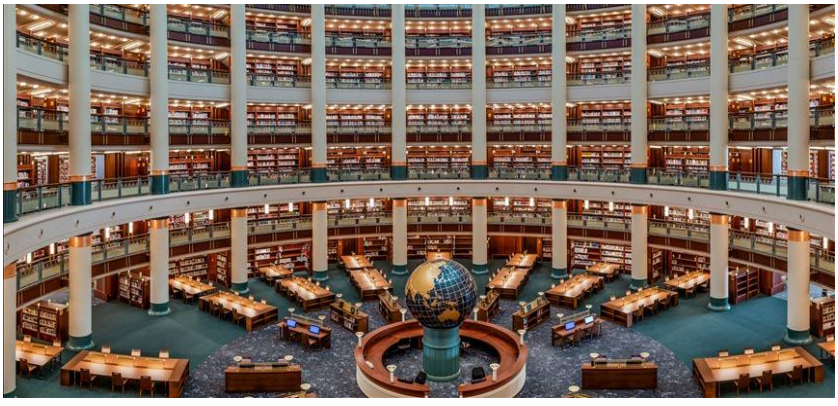
UN-Habitat defines public open spaces as the "undeveloped or unbuilt property that is open to the public," offering recreational opportunities and improving environmental quality, with examples being "parks, gardens, playgrounds, public beaches, riverbanks, and waterfronts" (UN-Habitat, 2019, p. 10). These spaces are the quintessential Nodes of the urban fabric—destinations for social and recreational life. A large, iconic park may even be perceived as a District, a "world of its own," while a linear riverbank or coastline inherently functions as a defining Edge for the city.

Figure 2. The Nest Park (Chongqing, China) as an example of a public open space.

Source: 100architects, 2021.

Public facilities include "high-maintenance amenities such as public libraries, civic/community centres, municipal markets, and public sports facilities that are owned and maintained by the public" (UN-Habitat, 2019, p. 11). Their distinct architecture and civic purpose often establish them as Landmarks—unique and memorable reference points. However, a facility with an active public forecourt or square, such as a community center with a bustling plaza, can also function as a vibrant Node, where the building itself is the Landmark and the space it creates is the Node.

Figure 3. The National Library of Turkey (Ankara, Turkey) as an example of a public facility.



Source: Anadolu Agency, 2020

Finally, public commercial spaces are "places where the socioeconomic aspect of the city is consistently expressed, such as markets and accessible commercial operations in fixed premises, public venues, and other services" (UN-Habitat, 2019, p. 11). These are typically intense, specialized Nodes, characterized by a high concentration of people and economic exchange. A historic or

architecturally unique market, such as a grand municipal market hall, can simultaneously operate as a major Landmark for its district.

Figure 4. Grand Bazaar (Istanbul, Turkey) as an example of a public facility

Source: Iroamly, 2025

This fluid application of Lynch's framework reveals that the power of a public space lies in its ability to perform multiple cognitive roles, contributing to a legible and coherent urban structure. The neglect of a space, therefore, represents a failure of its potential—a voided Node, a corrupted Path, or a dimmed Landmark—weakening the city's mental map and its capacity for sustainable, human-centered function.

2.2. The Social Metric: Jane Jacobs and the Life of Public Space

While Lynch provided a framework for understanding the city's cognitive structure, Jane Jacobs, in her seminal work The Death and Life of Great American Cities (1961), established the essential social metrics for what makes this structure thrive. Where Lynch was concerned with legibility, Jacobs was involved with vitality. She argued that the success of a public space is not found in its formal design alone, but in its capacity to generate a complex, self-regulating social life (Jacobs, 1961, p. 29).

Jacobs's theory is built upon several core principles that have become foundational to urban design. First is the concept of "eyes on the street," a form of natural, continuous surveillance that emerges when spaces are populated throughout the day and night by people going about their business (Jacobs, 1961, p. 35). This is not a function of formal policing but of a built environment that encourages diverse use. Second, she championed mixed primary uses, where a combination of residences, businesses, and cultural venues ensures a steady flow of people at different times, preventing the emptiness that leads to danger and neglect (Jacobs, 1961, p. 152). Finally, she emphasized the importance of short blocks and a dense concentration of people, which create multiple routes and increase pedestrian traffic, fostering chance encounters and a vibrant street scene (Jacobs, 1961, p. 178).

For Jacobs, the most successful public spaces—particularly streets and sidewalks—are those that facilitate this "ballet of the street," a complex, daily dance of informal interactions that builds a web of public trust and social capital (Jacobs, 1961, p. 50). A deserted park, an empty street after business hours, or a monolithic housing project that turns its back on the sidewalk are, by Jacobs's metric, social failures. They lack the essential ingredients for urban life.

Her work provides a crucial lens for diagnosing the neglect outlined in the introduction. The "lack of understanding or capacity to use public space as a complete, multi-functional urban system" (UNSD, 2025, para. 1) is, in essence, a failure to apply Jacob's principles. When public spaces are designed as isolated objects rather than integrated components of a lively urban fabric, they fail to generate the "eyes on the street" and social interaction that are the true indicators of their health and sustainability.

2.3. The Behavioral Method: Jan Gehl and Life Between Buildings

Building upon Jane Jacobs's social observations, Danish architect Jan Gehl developed a systematic, behavioral methodology for analyzing and designing public space. While Jacobs provided the why, the social imperative for vibrant, eyes-on-the-street environments, Gehl, in works like Life Between Buildings and Cities for People, provided the empirical how. His core argument is that urban design must prioritize the human scale and sensory experience, focusing on the details perceptible at a pedestrian's pace (Gehl, 2010, pp. 6-7).

Gehl's methodology, detailed in Cities for People, is structured around a fundamental taxonomy of human activities in public space, which exist in a hierarchy of necessity. Necessary Activities: Obligatory tasks like walking to a bus stop. These happen regardless of environmental quality. Optional Activities: Desirable activities such as strolling, sitting, or people-watching. These occur only when external conditions are favorable. And Social Activities: Interactions that arise because people are in the same space. For Gehl, the level of optional activity is therefore a key indicator of a public space's quality, as it reflects an environment desirable enough to encourage voluntary use (Gehl, 2010, p. 23).

His work, therefore, focuses on designing the physical conditions that encourage such activities. His analysis establishes that the fundamental purpose of public space is to create a prerequisite for all activities, thereby enabling the wide range of social and recreational life that defines a vibrant city (Gehl, 1971/2011, p. 9).

Gehl's behavioral method provides a crucial diagnostic lens. It allows for the systematic assessment of why a public space is failing. A neglected space is one that, by Gehl's metrics, fails to support optional and social activities because its design does not facilitate the full range of human behavior. His work directly addresses the "inability to effectively use public space" identified by the UN

(UNSD, 2025), by offering a clear, human-centered framework for diagnosing problems and crafting solutions that attract people and sustain public life.

2.4. The Synthesized Benefits of Public Space

The theoretical frameworks of Lynch, Jacobs, and Gehl provide the lenses through which the multifaceted benefits of public space, often catalogued in policy documents, can be fully understood and valued. These benefits are not isolated outcomes but interconnected results of a well-designed and well-used public realm.

Structural and Cognitive Benefits: Creating a Legible City

Kevin Lynch's work teaches us that public spaces are fundamental to a city's mental map. When they function successfully as Paths, Nodes, and Landmarks, they provide orientation and structure, transforming an amorphous urban expanse into a coherent, navigable, and memorable environment (Lynch, 1960). This legibility reduces stress for residents and visitors alike, making the city more accessible and demystifying its complexity. The neglect of a key Node or Path is, therefore, a direct erosion of the city's cognitive clarity.

Social and Cultural Benefits: Fostering Community and Capital

The benefits of social cohesion and cultural vitality, highlighted by UN-Habitat (2019), are precisely the outcomes predicted by Jane Jacobs's and Jan Gehl's theories. A public space that generates "eyes on the street" (Jacobs, 1961, p. 35) is, by definition, a safe and socially vibrant one. This safety, in turn, encourages the optional and social activities that Gehl identified as the hallmark of quality—strolling, sitting, and talking (Gehl, 2010, pp. 20-23). This dynamic process builds what Jacobs called "social capital," fostering a sense of belonging, facilitating cultural exchange, and creating the trust necessary for a resilient community. The benefit is not merely the presence of people, but the network of trust and interaction they create.

Economic and Vitality Benefits: Enabling Urban Prosperity

The economic benefits of public space -increased property values, stimulated investment, and support for local commerce (UN-Habitat, 2019) -are the direct economic expressions of Jacobs's and Gehl's principles. Jacobs's mixed primary uses ensure a steady flow of potential customers (Jacobs, 1961, pp. 152-153), while Gehl's optional activities represent people choosing to spend their time and money in a given area (Gehl, 2010, p. 23). A vibrant plaza or a busy, tree-lined street is not just a social good; it is an economic engine that demonstrates the financial return on investing in human-centered design.

Environmental and Health Benefits: Supporting Well-being and Resilience

Public spaces, particularly green ones, provide critical ecosystem services: cooling the air, managing stormwater, and reducing pollution (UN-Habitat, 2019). From a human perspective, they are essential infrastructure for public health, offering opportunities for physical activity and mental restoration. Gehl's focus on facilitating "walking" and "staying" (Gehl, 2011, p. 9) aligns perfectly with this, framing public space as the stage for an active, healthy lifestyle.

In conclusion, the value of public space is profound because it is multidimensional, operating simultaneously to structure the city, build its community, power its economy, and sustain its environment and inhabitants. This synthesis reveals that their neglect is not a single failure but a cascading one, impacting every facet of urban sustainability.

2.5. Public Space as Infrastructure for Urban Sustainability

The synthesized benefits of public space reveal that they are not merely urban amenities, but fundamental infrastructure for sustainable development. The concept of sustainability, defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development [WCED], 1987), rests on three interdependent pillars: social, economic, and environmental. As the previous section demonstrates, public spaces actively contribute to all three.

***Social Equity*:** The social capital, inclusivity, and community cohesion fostered by public spaces (Jacobs, 1961; Gehl, 2010) are the bedrock of a socially sustainable city—one that is just, resilient, and capable of meeting the needs of all its citizens.

Economic Vitality: The role of public space in stimulating investment, supporting local commerce, and enhancing property values (UN-Habitat, 2019) underpins long-term economic sustainability by creating resilient and attractive economic environments.

Environmental Resilience: The ecosystem services provided by green public spaces—from cooling and air purification to stormwater management (UN-Habitat, 2019)—are direct contributions to environmental sustainability and climate adaptation.

Therefore, the widespread neglect of public space constitutes a direct failure to build a sustainable urban future. It undermines social equity by depriving communities of vital communal ground, stifles long-term economic vitality, and weakens the city's environmental defenses. This systemic failure creates an urgent imperative to re-evaluate how we maintain, value, and create public spaces, moving them from the periphery to the center of urban planning. This

imperative is formally recognized and operationalized by the United Nations' Sustainable Development Goal 11.

2.5.1. The Global Mandate: SDG 11 and Indicator 11.7.1

The critical role of public space in achieving urban sustainability is formally enshrined in the United Nations' 2030 Agenda for Sustainable Development. Specifically, Sustainable Development Goal 11 (SDG 11) aims to "make cities and human settlements inclusive, safe, resilient, and sustainable" (United Nations Department of Economic and Social Affairs [UN DESA], n.d.). This global recognition reframes public space from a local amenity to a non-negotiable component of international development.

The importance of public space is crystallized in Indicator 11.7.1, which serves as the primary metric for tracking progress. This indicator measures the "average share of the built-up area of cities that is open space for public use for all" (UNSD, 2025). Its stated objective is to ensure, by 2030, "universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities" (United Nations Human Settlements Programme [UN-Habitat], 2023).

This indicator provides a crucial quantitative and qualitative framework for the theories discussed previously. It operationalizes Jacobs's and Gehl's ideals of safety and inclusivity into a measurable global target. It validates Lynch's cognitive theory by valuing the distribution and share of public space in the urban fabric. Most importantly, it directly addresses the systemic neglect documented in this review, creating an accountability mechanism for the "lack of political will" and "inadequate frameworks" that perpetuate it (UNSD, 2025). Consequently, the pursuit of SDG 11.7.1 is not merely a statistical exercise; it is the global manifestation of the effort to secure the social, economic, and environmental benefits that sustainable public spaces provide.

2.6. Urban Acupuncture: A Strategic Response to Systemic Failure

Faced with the scale of urban neglect and the ambitious targets of SDG 11.7.1, the predominant response has often been to rely on large-scale master plans and top-down policy reforms. While theoretically comprehensive, these macro-level approaches frequently struggle with the very systemic barriers—bureaucratic inertia, high costs, and a lack of hyper-local sensitivity—that cause neglect in the first place. They often fail to produce the immediate, tangible improvements in public space quality that communities need and that the SDG agenda demands.

It is within this gap between conventional planning and on-the-ground needs that the strategy of urban acupuncture emerges as a critical alternative. This approach does not seek to replace strategic policy but to complement it with a more agile, human-centered, and catalytic methodology.

2.6.1. From Medicine to Urban Planning

The National Center for Biotechnology Information defines acupuncture as a traditional Chinese medical practice and philosophical system that involves inserting fine needles or applying pressure to specific body points to promote healing and overall well-being. According to the Chinese practice, by stimulating precise points, acupuncture restores balance and harmony within the system, demonstrating how even a small, targeted action can create a holistic healing effect (Van Hal, Dydyk, & Green, 2023, para. 2). Urban acupuncture applies the same approach to the city as acupuncture does to restore harmony in the human body by stimulating specific sites. It views the urban environment as a living thing whose life and energy may be restored by making minor, well-thought-out changes. Three prominent thinkers—Manuel de Solà-Morales, Jaime Lerner, and Marco Casagrande—pioneered the idea, each providing a unique yet complementary perspective on how focused activities might lead to more extensive urban reform.

2.6.2. Urban Acupuncture Pioneers

Manuel de Solà-Morales introduced the metaphor of urban acupuncture by comparing the city to a living organism whose epidermis, or urban skin, can be strategically stimulated to restore vitality. He explained that "to act with punctures, pressures, and injections is to distribute energy through the skin," emphasizing that identifying and activating these sensitive points within the city enables internal transformation and revitalization (Sola-Morales, Frampton, & Ibelings, 2008). Jaime Lerner subsequently applied this theory to practical urbanism. He viewed urban acupuncture as a tool for immediate improvement, capable of bypassing long bureaucratic processes and overcoming limited resources. He argued that the tactic has the advantage of being a fast-tracked planning approach, implemented swiftly and often with modest means. With fewer bureaucratic requirements, these localized gestures can trigger a chain reaction of improvement in the surrounding urban environment—from stronger social cohesion to enhanced public safety. Lerner believed that small and well-placed interventions could generate widespread social and spatial benefits, famously asserting that "the lack of resources is no longer an excuse not to act" (Lerner, 2014). Lastly, Marco Casagrande expanded the concept into an ecological and participatory design methodology. He emphasized small-scale, flexible interventions that draw upon local knowledge and the city's organic rhythms. For Casagrande, Urban Acupuncture reduces social and environmental stress, reconnects urban life with nature, and promotes sustainable regeneration through minimal but catalytic actions (Casagrande, 2020, pp. 131–153).

Together, these interpretations define urban acupuncture as a strategic, fast-tracked, economically viable, human-centered, and ecologically sustainable approach to urban transformation — suggesting that even small, precise

interventions can release energy, heal urban spaces, and restore balance within the city as a living system.

2.6.3. The Academic Case for Urban Acupuncture

Academic research has further developed the concept of urban acupuncture, moving it from a metaphorical idea to a subject of empirical study. This body of work has progressed through several phases: clarifying definitions, testing applications, expanding theory, providing evidence, and refining methods.

First, researchers have sought to define the concept. Kabas and Hussein describe it as "delicate interventions... aiming to connect the systems of nature and urban social consciousness," formalizing its dual ecological and social intent (Salman & Hussein, 2021, p. 5).

Scholars have also examined its practical potential. Hemingway and De Castro Mazarro argue that it holds promise as a model for sustainable urban transformation, particularly because of its capacity for public participation. This shifts the discussion toward practical application (Hemingway & De Castro Mazarro, 2022, pp. 307-308).

Theoretical expansion has followed. Casagrande later advanced the idea into "Urban Bioacupuncture," defined as "the ecological restoration of existing cities through focusing on cracks, holes, and organic knowledge." This represents a deepening of the theory toward stronger ecological integration (Casagrande, 2012, p. 4).

Empirical studies have begun to measure outcomes. Casprini et al. used a social innovation framework to assess specific projects, concluding that such research can enhance theoretical knowledge and offer guidance for public administrations. This links theory to measurable impact and practical governance (Casprini et al., 2026, pp. 10-11).

Finally, methodological critiques have emerged. Petrova et al. identify limitations in earlier, expert-led approaches (termed "Urban Acupuncture 1.0") and propose an updated "urban acupuncture 2.0" that incorporates social media data to create a more objective basis for planning. (Petrova, Nenko, & Sukharev 2016, p. 249).

In summary, academic work has provided urban acupuncture with a clearer definition, critical evaluation, theoretical depth, empirical support, and methodological refinement. This consolidated research forms the foundation for the present study, which applies a comparative case study approach to examine how the principles identified in the literature are implemented in practice and to assess their contribution to sustainable public space.

3. METHODOLOGY

This study employs a qualitative, comparative case study approach to assess the potential of urban acupuncture for creating sustainable public spaces. The research design treats each project as a distinct unit of analysis to explore how the principles of urban acupuncture are applied in diverse contexts and to evaluate their outcomes against a consistent set of criteria derived from urban theory and sustainability goals.

3.1. Research Design and Case Study Selection

The multiple-case study design was selected because it allows for an in-depth investigation of urban acupuncture projects in their real-life urban settings. A project's success is deeply intertwined with its context, and this method allows for that complex relationship to be examined holistically. Three projects were strategically selected to provide distinct yet complementary perspectives: Sant Antoni Superblock (Barcelona, Spain); Urban Bloom (Shanghai, China); TULIP (Your Place at the Table) (Montréal, Canada). This selection provides strategic diversity, encompassing a long-term urban restructuring, a temporary installation, and a responsive placemaking intervention. Despite their differences in scale and duration, all three projects exemplify a shared focus on precise, catalytic action—the core of urban acupuncture.

3.2. Data Collection and Sources

Data for this study were sourced from ArchDaily, a leading international platform for architectural documentation. This source was chosen for its consistency, providing direct access to primary project data for all three cases, including: Official project descriptions and design statements from the architects; High-resolution photographic documentation of the completed projects;

Technical data (e.g., area, materials, timeline). The use of ArchDaily ensures that the analysis is grounded in information directly provided by the design teams, offering an authoritative basis for examining design intent and realized form.

3.3. Analytical Framework and Procedure

The core analysis was conducted using a bespoke four-part analytical framework, which synthesizes key concepts from the literature review. The procedure was as follows:

Data Organization: The raw data from ArchDaily for each case were systematically organized according to the four categories of the framework:

- *Project Overview:* Establishing context and objectives.

- *Design Approach:* Analyzing architectural and planning strategies.

- *Sustainable Features:* Identifying environmental, social, and economic benefits.

- *Alignment with SDG 11.7.1:* Evaluating contribution to safe, inclusive, and green public space.

Theoretical Interpretation: This categorized data was then interpreted through the theoretical lenses established in the literature review. This involved asking critical questions such as: How does the design facilitate Gehl's "optional activities" and Jacobs's "eyes on the street"? In what way does the project function as a Lynchian node or landmark? How do the sustainable features contribute to the pillars of sustainability?

Synthesis and Argumentation: The final step involved synthesizing the findings from the framework and theoretical interpretation to build the article's central argument: that urban acupuncture, as demonstrated by these cases, is a viable and powerful strategy for sustainable urban regeneration.

4. CASE STUDIES ANALYSIS

4.1. Super Block Of Sant Antoni

Architects: Leku Studio (Jokin Santiago, Marta Sola)

Location: Sant Antoni, Eixample District, Barcelona, Spain

Year: 2019

Area: 21,150 m²

Figure 5. Different views of the Sant Antoni Superblock (Barcelona) case study.

Source: Del Rio Bani, 2019

4.1.1. Project Overview

The project is situated within Barcelona's Eixample district, a dense grid characterized by consolidated public space dominated by vehicular traffic. According to the architects, this urban fabric now requires "reprogramming and

recycling" to address the climate emergency, pollution, and a deficit of green and social spaces. The Superblock of Sant Antoni is a pilot within the city's broader Superblocks Program, an ambitious initiative to redefine the urban order. Its primary objective is to implement a "people-centred planning" model that reclaims street space from cars to create "proximity squares" and "green-healthy streets," thereby testing a new framework for a more humane, comfortable, and healthy city (ArchDaily, 2019).

4.1.2. Design Approach

The design is defined by a methodology of flexible, modular, and adaptive urbanization, treating the intervention as a reversible and evolutionary process. The architects developed a systemic toolkit to enable this:

A Modular Graphic & Planning Mesh: A standardized grid was overlaid on the street surfaces, serving as both a guide for spatial redistribution and the basis for a new graphic language of patterns and signage. This "extendable mesh" allows the new public landscape to be rolled out progressively. (ArchDaily, 2019)

An Adaptive Urban Furniture Toolkit: A series of modular, combinable elements—benches, planters, game tables—was designed to aggregate along this mesh. Constructed from eco-materials, these elements can be easily reconfigured to integrate greenery, structure different spaces (seating, play, planting), and respond to community feedback (ArchDaily, 2019).

Progressive Deployment: The strategy explicitly incorporates testing and temporary actions. This approach allows for a "soft extension" of the superblock, where the urban transformation evolves through observation and social innovation rather than being imposed as a fixed, final plan (ArchDaily, 2019).

Figure 6. Site plan and photographic views of the Sant Antoni Superblock (Barcelona) case study.

Source: Plan by Leku Studio (2019); photographs by Del Rio Bani (2019)

4.1.3. Sustainable Features

Environmental Sustainability: The core environmental action is the replacement of an "urban highway" with a "green-healthy street." This drastically reduces local emissions and noise pollution. The integrated planters and new vegetation increase biodiversity, provide shade, and improve stormwater management and air quality (ArchDaily, 2019).

Social Sustainability: The design directly facilitates a shift in social use. As described by the architects, "car noise has been replaced by children playing, cheerful conversations between neighbours or elderly people's chess games." This illustrates the successful generation of Gehl's optional and social activities and Jacobs's "eyes on the street." The flexible, participatory deployment method fosters community ownership and allows the space to adapt to local social patterns (ArchDaily, 2019).

Economic Sustainability: By dramatically enhancing the livability and aesthetic quality of the neighborhood, the project strengthens the local urban economy. The creation of attractive, human-scaled plazas can increase foot traffic, support local businesses, and contribute to long-term property value stability, aligning with the economic benefits of vibrant public space (ArchDaily, 2019).

4.1.4. Alignment with SDG 11 and Indicator 11.7.1

The Superblock of Sant Antoni is a direct, scalable model for achieving SDG Indicator 11.7.1. It quantitatively increases the share of public open space by converting asphalt streets into public plazas. Qualitatively, it delivers safe, traffic-calmed spaces; inclusive spaces designed for all ages and activities (play, conversation, games); and green spaces through integrated vegetation. The project demonstrates that sustainable urban transformation, as called for by the SDGs, can be achieved through a strategic, incremental, and community-responsive acupuncture approach that "reprograms" existing infrastructure.

4.1.5. Theoretical Interpretation

Through Kevin Lynch's Lens: The intervention fundamentally alters the area's cognitive map. A former traffic intersection, a nondescript path, is transformed into a definitive node—a "liveable plaza" and a destination. The consistent graphic language and unique furniture can establish new landmarks. The superblock itself becomes a distinct district within the larger Eixample grid, with a recognizable character of calm and greenery.

Through Jane Jacobs's Lens: The reprogramming of the street generates Jacobs's "eyes on the street." The mix of activities throughout the day—children playing, seniors socializing, residents passing through—creates natural, informal

surveillance. The “proximity squares” become stages for the “ballet of the street,” fostering the casual interactions that build public trust and social capital.

Through Jan Gehl's Lens: The design directly facilitates Gehl’s hierarchy of activities. By removing through-traffic and introducing comfortable, varied furniture, it transforms streets from corridors for necessary movement alone into destinations that encourage optional activities (sitting, playing chess, sunbathing) and social activities (conversations between neighbours). The quality of the environment becomes the catalyst for voluntary use.

4.1.6. Synthesis and Argumentation

By implementing a modular, reversible intervention that allowed for the gradual, community-responsive reclamation of 21,150 m² of asphalt, this project demonstrates the practical effectiveness of urban acupuncture. The Superblock enabled the hardened urban fabric to recover from traffic dominance, adjust to new social patterns, and thrive as a green, multipurpose neighbourhood commons thanks to its versatile furniture and green features. Its success in increasing biodiversity and pedestrian activity validates urban acupuncture as a strategy for attaining SDG-aligned urban space regeneration through targeted action.

4.2. Urban Bloom

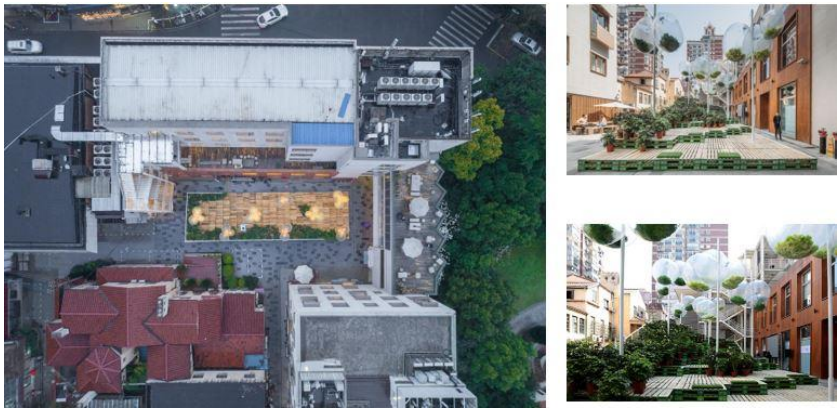
Architects: AIM Architecture + URBAN MATTERS

Location: Anfu Road, Shanghai, China

Year: 2018

Area: 330 m²

Figure 7. Different views of the Urban Bloom (Shanghai) case study.



Source: CreatAR Images, 2018

4.2.1. Project Overview

Urban Bloom is an experimental intervention situated on a former parking lot along Anfu Road, a vibrant, mixed-use Shanghai street blending residences, offices, shops, and schools within a unique mix of architectural scales. The architects identified a critical absence in this dense urban fabric: "what it didn't have is a park." The project's core objective was to test whether a temporary, low-impact installation could create a new kind of public space where "urban space and activities take precedent over a design's intention or infrastructure's needs." It aimed to cultivate "pleasure and happiness" by transforming a sterile, vehicular surface into a garden-like social node, prioritizing enjoyment and freedom as its primary program (ArchDaily, 2018).

4.2.2. Design Approach

The design is characterized by its artificial yet organic assembly and its circular material logic. It consists of two primary, low-impact systems:

A Recycled Pallet Landscape: The ground plane is formed from reconfigured, recyclable wooden shipping pallets, arranged into gently undulating platforms. This creates a flexible topography for sitting, gathering, and various activities without permanent foundations (ArchDaily, 2018).

A Floating Canopy of Foliage: Above, lightweight, balloon-like ETFE cushions are suspended, supporting climbing plants and "colorful foliage." These artificial canopies mimic a tree canopy, casting dynamic shadows and shapes, and providing a sense of enclosure and natural reference within an entirely constructed environment (ArchDaily, 2018).

The strategy deliberately embraces impermanence and interpretive use, inviting visitors to define the space's purpose through their own behavior, allowing the project to be a "physical manifestation" of a fluid, responsive urbanity (ArchDaily, 2018).

Figure 8. Additional views of the Urban Bloom (Shanghai) case study.

Source: CreatAR Images, 2018

4.2.3. Sustainable Features

Environmental Sustainability: The project is explicitly "low-impact" and "entirely sustainable" in its materiality. By repurposing wooden pallets and using recyclable ETFE, it minimizes waste and embodied carbon, proving it is "possible to make something new from nothing new at all." The integrated vegetation improves micro-climate and air quality, introducing biodiversity into a paved context (ArchDaily, 2018).

Social Sustainability: By creating a free, accessible, and aesthetically stimulating destination, Urban Bloom generates a new social anchor—a Lynchian node—in a neighborhood lacking communal green space. It facilitates Gehl's optional activities (strolling, sitting, people-watching) in a previously inhospitable location. Its open-ended design encourages diverse, user-defined scenarios, from casual gatherings to outdoor theatre, fostering social interaction and joy (ArchDaily, 2018).

Economic Sustainability: The project demonstrates a highly cost-effective model for public space creation, aligning with Lerner's principle of acting despite limited resources. Its popularity likely increased foot traffic and dwell time on Anfu Road, potentially providing an economic spillover benefit to adjacent businesses by making the street a more attractive destination (ArchDaily, 2018).

4.2.4. Alignment with SDG 11 and Indicator 11.7.1

Urban Bloom contributes to SDG 11.7.1 by qualitatively enhancing the city's stock of accessible public space. It transformed a private, auto-centric lot into a safe (vehicle-free), inclusive (freely accessible), and green (vegetation-integrated) public garden. While temporary and small in area (330 m^2), it directly increases the "share of the built-up area... for public use" for the duration of its installation and serves as a pilot for how underutilized parcels can be **reprogrammed to meet communal needs, embodying the spirit of the indicator.**

4.2.5. Theoretical Interpretation

Through Kevin Lynch's Lens: The installation functions as a vivid landmark within the mental map of Anfu Road. Its unique artificial canopy and colorful foliage create a memorable image. Simultaneously, it acts as a specialized node—a point of convergence for leisure and social activity, distinct from the surrounding commercial and residential nodes.

Through Jane Jacobs's Lens: By inserting a "park" into a street already rich with "eyes on the street" from mixed uses, Urban Bloom intensifies the area's social vitality. It adds a layer of complexity and destination, potentially increasing the duration and diversity of street life, contributing to the "ballet" of Anfu Road.

Through Jan Gehl's Lens: The project is a clear catalyst for optional activities. The undulating pallet landscape and shaded areas create a favorable environment that entices people to choose to stay, sit, and socialize, turning a necessary path into a voluntary destination.

4.2.6. Synthesis and Argumentation

By transforming a parking lot into a temporary garden using repurposed materials and an open-ended design, Urban Bloom demonstrates urban acupuncture's capacity to activate latent potential within urban voids. This precise, low-cost "puncture" served as a catalytic proof-of-concept, showing that a sense of place and communal joy can be generated without large-scale redevelopment. Its success in creating a beloved social node from discarded materials validates acupuncture as a strategy for rapid, adaptive, and sustainable place-making. It proves that strategic, sensitive interventions can effectively deliver on the qualitative goals of inclusive public space (SDG 11.7.1), offering a flexible model for instilling social and ecological value into the overlooked seams of the city.

4.3. Tulip - Your Place At The Table

Architects: ADHOC Architects
Location: Montréal, Canada
Year: 2020
Area: 3,260 m²

Figure 9. Different views of the Tulip (Canada) case study.

Source: Thibodeau, 2020

4.3.1. Project Overview

Conceived during the COVID-19 pandemic, TULIP was a rapid-response intervention in Montréal's downtown cultural district. The mandate from the Partenariat du Quartier des Spectacles was clear: to design an artistic installation

that would “attract and stimulate traffic” while enforcing social distancing, thereby helping citizens “reappropriate” the city after weeks of confinement. The specific site was Hydro-Québec Park, an award-winning ecological park designed by Claude Cormier. The project’s objective was to add a vital social component to this existing green space, transforming it into a safe, vibrant “urban terrasse” that supported local commerce and rekindled public life (ArchDaily, 2020).

4.3.2. Design Approach

The design centered on a single, powerful architectural gesture: a 100-meter-long, serpentine “urban table” precisely inserted into the existing park landscape.

Insertion, Not Overwriting: The yellow table was carefully implanted between existing trees and park furniture, respecting the ecological foundation of Claude Cormier’s design. This approach worked with the site, adding a new social layer without erasing its environmental qualities (ArchDaily, 2020).

Social Distancing as Design Driver: The table’s continuous, winding form and the strategic placement of “eclectic collections of recycled objects” (as place settings) along its length intuitively fostered safe distances between different groups, formalizing pandemic protocols into a shared, festive experience (ArchDaily, 2020).

Atmospheric Enhancement: Vibrant yellow graphics, custom signage, and enchanting lighting were introduced to brighten the shady park, creating a welcoming, luminous atmosphere day and night. This “festive, joyous” palette created a marked contrast with the monochromatic park, attracting attention and defining a new zone of activity (ArchDaily, 2020).

Figure 10. Additional views of the Tulip (Canada) case study.

Source: Thibodeau, 2020

4.3.3. Sustainable Features

Environmental Sustainability: The project had a minimal environmental footprint. As a lightweight, removable installation inserted into an existing green space, it preserved the park’s mature trees and ecological systems. The use of

recycled objects for place settings further emphasized a circular material approach (ArchDaily, 2020).

Social Sustainability: TULIP directly addressed an acute social crisis—isolation—by facilitating safe gathering. It enabled Gehl's optional and social activities (sitting, eating, conversing) under constrained conditions, proving public space could adapt to serve community health. The design fostered a sense of joyful rediscovery of the city (ArchDaily, 2020).

Economic Sustainability: The project was explicitly conceived to work in "synergy" with local businesses. By providing 80 seats and encouraging the support of 22 nearby restaurants, it acted as direct economic stimulus, driving foot traffic to reopening establishments and supporting the district's recovery (ArchDaily, 2020).

4.3.4. Alignment with SDG 11 and Indicator 11.7.1

TULIP advanced the aims of SDG 11.7.1 by intensifying the quality, safety, and inclusivity of an existing public open space. It made the park more accessible and inclusive by providing a new, attractive reason to visit. It ensured the space was safe by ingeniously encoding public health guidelines into its design. While not creating new green space, it dramatically enhanced the "public use for all" of a 3,260 m² ecological asset, demonstrating how strategic intervention can maximize the utility and social value of existing urban resources.

4.3.5. Theoretical Interpretation

Through Jan Gehl's Lens: The installation masterfully encouraged optional activities in a context where they were severely suppressed. By providing a beautiful, socially distanced reason to "stay," it transformed the park from a pass-through space into a destination for lingering, eating, and socializing, even during a pandemic.

Through Jane Jacobs's Lens: TULIP generated a new, concentrated point of "eyes on the street" (or, in this case, "eyes on the park"). Its luminous, attention-grabbing design attracted a steady flow of people, creating natural surveillance and revitalizing the street life of the surrounding district through increased activity.

Through Kevin Lynch's Lens: The bright yellow, 100-meter table functioned as an unmistakable landmark, creating a unique and memorable image within the downtown mental map. Simultaneously, it transformed the entire Hydro-Québec Park from a passive green area into an active node—a strategic focal point for social and economic convergence in the post-lockdown city.

4.3.6. Synthesis and Argumentation

By inserting a vibrant, socially distanced “urban table” into an existing ecological park, TULIP demonstrates urban acupuncture’s power to rapidly recalibrate public space in response to acute urban crises. This precise, timely intervention healed the social disconnect caused by the pandemic, adapted the park’s use through intuitive design, and allowed downtown vitality to flourish safely. Its success was measured in practical outcomes: supporting 22 local restaurants, safely accommodating hundreds of daily visitors, and revitalizing public trust in shared space. The project validates acupuncture as a nimble, empathetic, and economically synergistic strategy for sustainable regeneration, proving that targeted design actions can effectively execute broader social and economic recovery goals, making existing urban assets more resilient and socially valuable.

5. CONCLUSION

This study set out to investigate whether small-scale, targeted urban acupuncture projects can serve as a viable strategy for creating sustainable and socially conscious public spaces. By analyzing three diverse international cases, the Sant Antoni Superblock, Urban Bloom, and TULIP, through a theoretical framework informed by Lynch, Jacobs, and Gehl, and evaluated against the global mandate of SDG 11.7.1, a clear and affirmative answer emerges.

The findings demonstrate that urban acupuncture is not merely a metaphorical concept but a practical and potent approach to urban regeneration. Unlike conventional top-down planning, which often struggles with bureaucracy and a lack of localized sensitivity, urban acupuncture operates through precise, catalytic interventions that directly address specific urban ailments. These projects show that by "puncturing" the urban fabric at strategic points, whether by reclaiming streets, activating vacant lots, or enhancing existing parks, it is possible to trigger ripple effects that heal, adapt, and revitalize the broader urban system.

Each case study, despite differences in scale, context, and duration, consistently validated the core principles of sustainable public space:

Environmental sustainability was advanced through green infrastructure, recycled materials, biodiversity enhancement, and reduced vehicular dominance. Social sustainability was achieved by fostering community interaction, ensuring inclusivity, generating "eyes on the street," and facilitating optional and social activities as defined by Gehl. Economic sustainability was supported by stimulating local commerce, increasing foot traffic, and enhancing property values through improved livability.

Moreover, all three projects directly contributed to the objectives of SDG Indicator 11.7.1 by increasing safe, inclusive, and green public spaces. They

proved that sustainable outcomes do not always require massive investments or sweeping policy reforms; they can be achieved through people-centered, sensitive, and iterative interventions that engage communities and respect local contexts.

In conclusion, urban acupuncture offers a complementary and agile alternative to large-scale urban projects. It provides a pathway to implement the SDGs at the hyper-local level, turning neglected spaces into vibrant social nodes and ecological assets. For policymakers, urban designers, and communities, this approach underscores the transformative power of starting small, of using strategic, empathetic interventions to mend the urban fabric, one precise "puncture" at a time. The future of sustainable cities may well depend on our ability to recognize and activate these potential healing points within our existing urban landscapes.

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