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CASE STUDY RESEARCH PAPER

Unraveling the Narrative of Chan Chan: Analyzing the Role of Climate in Shaping its Spatial Structure and Architecture

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ABSTRACT

Throughout history, human settlements have adapted to their environments, with climate playing a crucial role in shaping urban and architectural forms. Understanding these historical interactions is vital for contemporary conservation efforts amid growing climate challenges. The preservation of historical architecture is increasingly threatened by climate change. Despite extensive studies on Chan Chan, limited research has explored how climate influenced its spatial structure and architectural evolution. This study investigates the role of climate in shaping the spatial organization and architectural development of Chan Chan, a UNESCO World Heritage site. A qualitative content analysis approach, grounded in an interpretivist research philosophy and an inductive reasoning framework, was adopted. The study employed a case study strategy, utilizing the documentary method to collect data. A three-step analytical process was followed: identifying spatial structures, categorizing climatic factors, and correlating these factors with architectural elements. The results highlight that Chan Chan's architectural evolution was intrinsically linked to its climatic conditions. The settlement's spatial organization reflects a sophisticated response to environmental factors, ensuring long-term resilience.The research underscores the significance of climate as a primary determinant of urban form, challenging existing narratives that overlook environmental influences in architectural history. Chan Chan exemplifies climate-adaptive design, offering insights applicable to modern conservation practices. Interdisciplinary collaboration among architects, archaeologists, and climatologists is essential to further explore these relationships, aiding the preservation of heritage sites against climate-related threats.

Running Title: Unraveling the Narrative of Chan Chan

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INTRODUCTION

The relationship between nature and urban planning has been central to human settlements since ancient times. (Pita & Serkhosh, 1997). While many studies focus on the descriptive aspects of historical urban development, this research seeks to bridge the gap between past insights and modern architectural needs. By introducing a systematic framework, it explores how climatic systems shaped the architectural and spatial strategies of Chan Chan, emphasizing the relevance of these adaptations for contemporary sustainability challenges. This approach not only enhances our understanding of historical practices but also provides practical solutions for addressing climate-resilient urban planning today. Chan Chan, a historic site in Peru located 550 km north of Lima, exemplifies this integration. As the political, administrative, and cultural center of the Chimu Empire, Chan Chan represents the largest pre-Columbian adobe settlement. Its mild climate, moderated by the cold Humboldt Current along the Peruvian coast, supported a prosperous society, although warmer water currents occasionally caused heavy rains and floods, known as the Niño phenomenon. Aware of this risk, Chan Chan's inhabitants constructed buildings on elevated platforms and protected the city with a rock wall to prevent flood damage (Piminchumo & Galvez , 2003) . Agriculture, the backbone of Chan Chan's economy, was facilitated by an advanced irrigation network that channeled mountain rivers to arid fields, contributing to the town's wealth and stability (Colosi, 2013, p. 188)

Designated a UNESCO World Heritage site in 1986, Chan Chan now faces significant degradation from both human activities, such as grave robbing, and natural factors, including coastal proximity, marine salts, winds, and the expanding city of Trujillo (Colosi & Malinverni, 2022). The architecture of Chan Chan demonstrates a thoughtful response to environmental challenges. Builders selected resilient materials and techniques to withstand climate fluctuations, extreme temperatures, heavy rainfall, and floods. By integrating climate, geographical factors, and material availability, Chan Chan's architects achieved a balance between built and natural environments. Examining Chan Chan's architecture and spatial structure reveals how the region's climatic systems—air, water, soil, and vegetation shaped urban development. This research not only examines how Chan Chan's architecture and spatial structure were shaped by the region's climatic systems air, water, soil, and vegetation,but also introduces a novel analytical vegetation, shaped framework that systematically links these systems with specific architectural adaptations. This innovative approach reveals insights that extend -beyond descriptive analysis, offering practical lessons for modern climate-resilient urban design. The study's innovation lies in its systematic and integrative approach, which not only examines irrigation, weather, construction techniques, materials, and vegetation but also establishes explicit correlations between climatic factors and architectural strategies. Unlike previous studies, which often focus on isolated elements, this research adopts a holistic perspective to uncover previously unexplored interactions between environmental challenges and urban planning solutions. By employing a structured qualitative content analysis grounded in multidisciplinary perspectives, the study provides a novel framework for understanding Chan Chan's climate-adaptive architecture and its relevance for addressing contemporary sustainability challenges.

MATERIALS AND METHODS

Methodology

The primary aim of this research is to explore the role of climatic systems in shaping the spatial structure and architecture of the city of Chan Chan. The main research question focuses on understanding how climatic systems have historically influenced the formation of Chan Chan's spatial and architectural structures. The secondary questions seek to identify the influential characteristics of the region's climatic systems and to examine how geomorphological solutions and construction techniques have been utilized within these systems to develop Chan Chan's spatial and architectural framework.

The methodology of this study is innovative in its integration of qualitative content analysis with an interpretivist paradigm, aiming to uncover underlying relationships between climate systems and urban planning strategies. Unlike previous research, which often remains descriptive, this study systematically correlates climatic factors such as air, water, soil, and vegetation with architectural adaptations. Furthermore, its interdisciplinary approach, incorporating climatology, archaeology, and architectural studies, enables a holistic understanding of Chan Chan's climate-adaptive design. To achieve its objectives, this research employed a qualitative content analysis using the adaptive method, inductive approach, and historical strategy, which progressed within the framework of the interpretative paradigm and a case study approach. This involves a comparative method and content analysis used to examine texts for a deeper understanding of the subject. Data collection was conducted through a documentary approach, gathering information from various sources (maps, images, climatic studies, and historical and archaeological texts). The research progressed through the following three main steps: (a) Identifying and analyzing the spatial structure of Chan Chan City, and (b) Determination of climatic categories (c) Attributing climate systems to the spatial structure of the city. In this regard, the practical sequences or steps employed for interpreting and organizing the data include exploration, reduction or condensation, and determination of variables using climatic systems. Following the discovery, analysis, description, and interpretation of these climatic systems, an analysis of the architectural and urban structure of Chan Chan was conducted. This involved comparing or correlating climatic systems with the spatial structure of the city.

Literature review:

The influence of the climate of Chan Chan on the development of its architecture and spatial structure is a crucial aspect of comprehending the historical and environmental context of this ancient urban center. Moseley(Moseley, 1975) delves into the unique character of Chan Chan as an Andean alternative to preindustrial cities in Europe and Mesopotamia, highlighting the impact of Andean cultural institutions on the city's architectural and spatial structure. Furthermore, Mauricio et al (Mauricio, Grieseler, Heller, & Viveen , 2021). sheds light on the evolution of adobe architecture as a major Andean tradition, providing insights into the technical evolution

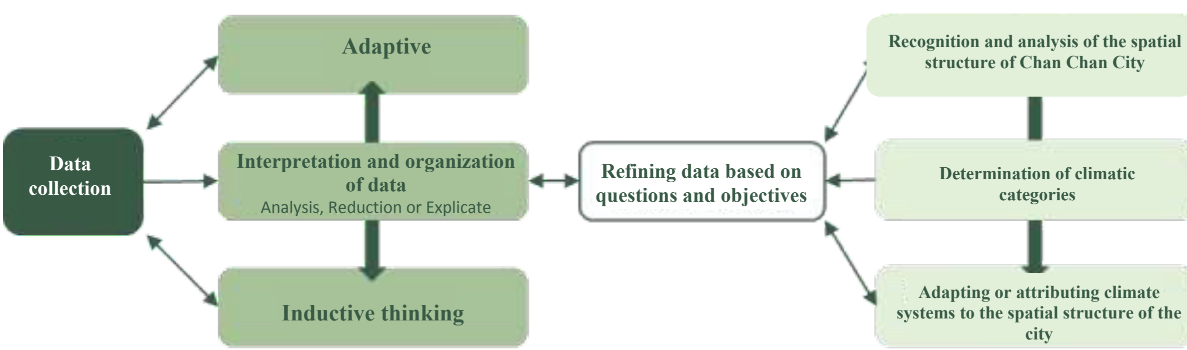


Chart. 1: The qualitative content analysis cycle employed in this research culminated in the final findings.

and experimentation that likely contributed to to Chan Chan's unique architectural and spatial characteristics. Keatinge and Day (Keatinge & Day, 1973) offer an in-depth analysis of the socio-economic organization of the Moche Valley during the Chimu occupation of Chan Chan. They highlight the administration of land, water, and labor resources, as well as the production and distribution of goods, as primary socio-economic factors that undoubtedly influenced the architectural and spatial layout of the city. Additionally, Colosi et al. (Colosi & Malinverni, 2022). present the use of Historic Building Information Modeling (HBIM) in an archaeological setting at Huaca Arco Iris in Chan Chan. This approach predicts possible natural or anthropogenic damage to buildings made of raw mud, underscoring the importance of understanding the environmental impact on historical mud architecture. In addition to these studies, Ortiz (Ortiz, 2023) explores the role of climate variability in shaping the adaptive strategies of Chan Chan's inhabitants, revealing how environmental conditions influenced architectural choices. Furthermore, Garcia and Velasquez (Garcia & Velasquez, 2023) utilize advanced spatial analysis techniques to examine the relationship between topography, microclimates, and urban layout at Chan Chan, providing nuanced insights into how local climate conditions influenced urban design. These works collectively contribute to a comprehensive understanding of how the climate of the city of Chan Chan influenced the formation of its architecture and spatial structure, shedding light on its uniqueness within the broader context of ancient urban centers.

DISCUSSION AND FINDINGS

The archaeological site

This section focuses on understanding and analyzing the spatial structure of the city of Chan Chan.

Chan Chan spans approximately 6 km2 in its most densely populated region, but the entire urbanized expanse, including urban and suburban pathways, cultivated fields, walls, and channels, extends across more than 20 km2 (Andrews, 1974). This results in a highly intricate and articulated urban structure that reflects an advanced level of social and economic organization. The central zone features nine monumental enclosures referred to as palaces or ciudadelas, along with five huacas or stepped pyramids. Within the ciudadelas, expansive ceremonial squares, adorned courtyards with niches housing small U-shaped rooms likely serving ceremonial purposes (audiencias), numerous warehouses, and, in a secluded internal area, the sovereign's tomb known as Plataforma de Entierro, designed in the shape of a stepped pyramid, can be found.

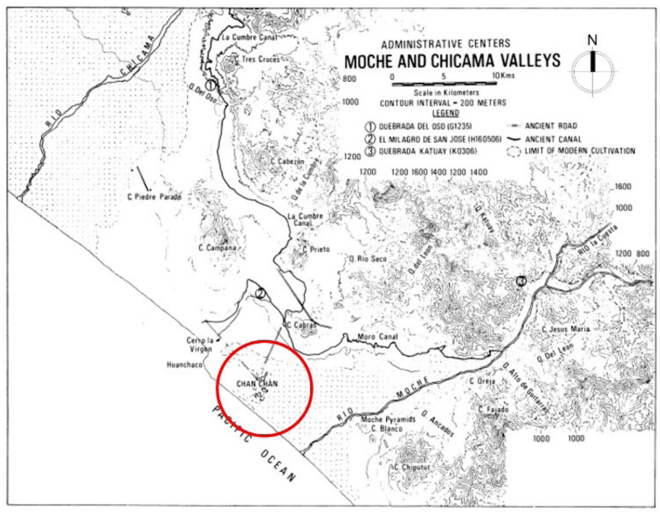


Fig. 1: Map of the Moche-Chicama Region showing the location of Chan Chan and the rural administrative centers, Source: Adapted from (Andrews, 1974, p. 242)

The perimeter walls of the ciudadelas often exceed 10 meters in height and extend up to 700 meters in length in certain instances. All the enclosures consistently align in a north-south direction, featuring an entrance door typically positioned at the center of the northern side. From the year 1100 A.D. (Chimu Medio) onwards, the enclosures adopted a distinctive tripartite plan that remains relatively unchanged across all palatial complexes until the construction of Palacio Rivero, the latest palace within the ciudadelas of Chan Chan (Kolata, 1978).

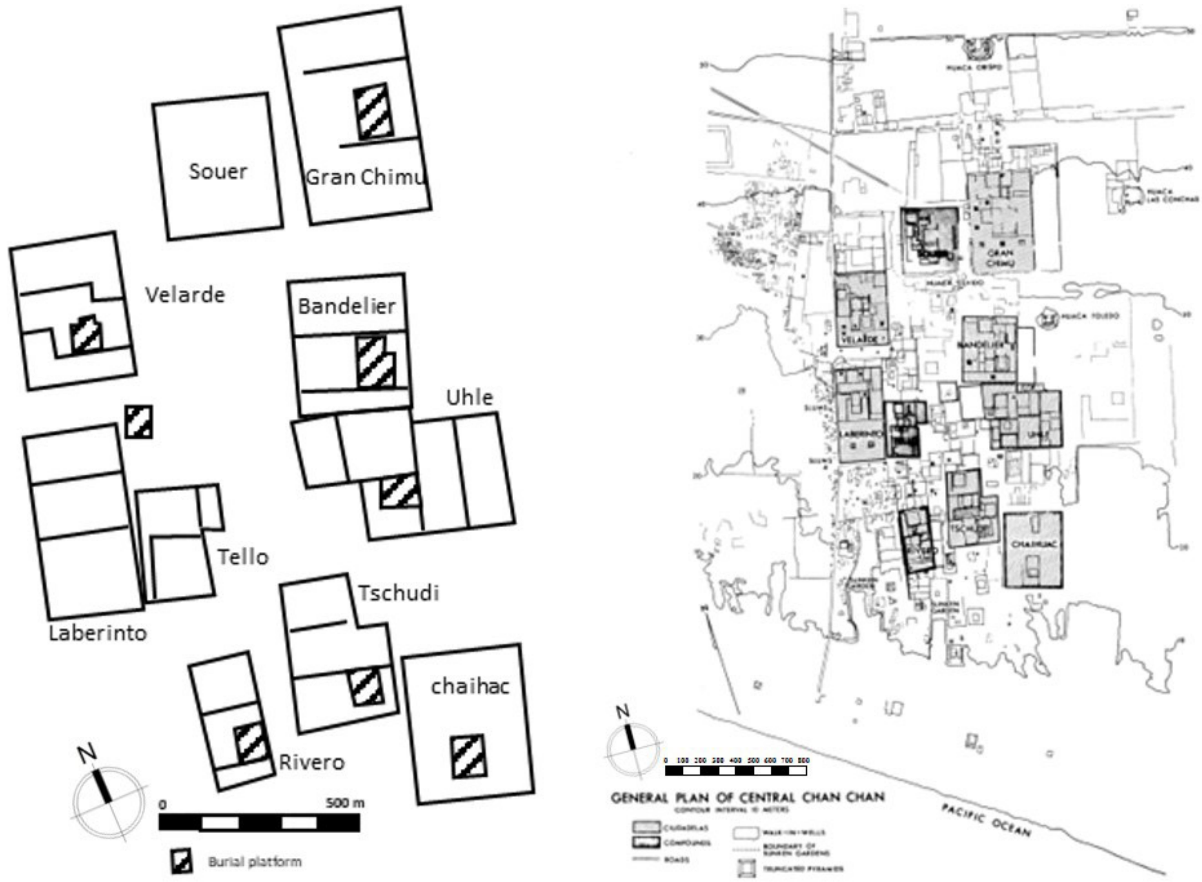


Fig. 2: Location of the ciudadelas in Chan Chan Nine monumental enclosures (palaces or ciudadelas), Source: after Topic and (Moseley, 1975)

Fig. 3: Chan Chan city entrance, Source: (Colosi & Malinverni, 2022, p. 2068)

While the civic center of Chan Chan comprises a diverse array of structures and buildings, the primary architectural focus of the site is on 10 rectilinear compounds (Day K. , 1973). The well-planned interiors of these high-walled structures feature large entry courts, narrow passageways, walk-in wells (Day K. , 1974, p. 183), banks of contiguous rooms that may have served as store rooms, U-shaped structures called audiencias (Andrews, 1974, p. 243) that may have functioned as "administrative offices," and usually but not always, a massive burial platform (Pozorski, 1971) (Conrad G. , 1974) (Conrad & Moseley, 1998). These vast compounds, ranging in size from 200 to 650 meters, are believed to have served as the palaces of the Chimu kings and as headquarters for state control over a well-organized redistributive economy. In addition to the compounds, there are sections of "intermediate architecture" situated outside the enclosures (West, 1970, p. 71) (Alexandra & Klymyshyn, 1974). The intermediate architecture consists of meticulously designed rooms, courts, and corridors, although it is slightly less intricate compared to the architectural structures within the compounds. This area is presumed to have served as the residence for the nobility, administrators, or lower-level bureaucrats. Another architectural type found in Chan Chan is the SIAR, which stands for "Small Irregular Agglutinated Rooms" (Topic, 1970). The SIAR, also variously referred to as "slum" or "barriada" architecture, is concentrated to the south and west of the civic center and was likely the residence of the majority of Chan Chan's population (Keatinge, 1975, p. 217)

The contrast between the expansive public spaces and the social structure, encompassing the architecture of the elite, middle class, and local residents, and the dense fabric of the SIAR offers the visual and spatial diversity desired in such urban planning.

The precise reason for the U-shaped structure of Cuidadela is not entirely clear, but some analyses suggest that the U shape may have been necessary to accommodate the storage of objects and food items. Additionally, these buildings can be seen as symbols of power, social standing, and political importance in ancient societies. The structures are categorized into several types, with examples found in various Cuidadelas and areas within the city of Chan Chan (P. Andrews, 2016). Surveys and excavations conducted in 1971 indicate that these structures are situated within a range of intermediate and monumental architectural contexts Invalid source specified. Based on surveys and excavations, seven types of U-shaped structures were identified: standard audiencias, audiencia variants, trocadero, trocadero variants, arcones, auxilios, and rural audiencia variants. These structures, constructed using adobe brick and silt mortar, typically exhibit a square or rectangular shape with three walls, leaving one end open. The characteristics of each type are described as follows. Invalid source specified. Additionally, the dimensions, wall thickness, horizontal depth, and vertical depth of U-shaped structures vary depending on the specific architectural context (Andrews, 1974).

Chan Chan city and main structure:

In this section, the determination of climatic categories and their correlation with the spatial structure of Chan-chan city were studied.

This climatological information is fundamental for comprehending the mechanics of what impacts adobes and for providing necessary solutions. The factors influencing the changes in the city of Chan Chan can be categorized into two groups: intrinsic factors (related to geographical conditions, soil nature, and inherent deficiencies in construction) and extrinsic factors (related to climate, physical and chemical phenomena, etc.). Chan Chan architecture is shaped in connection with the four elements of water, soil, plants, and air. These factors constitute the primary structure and the fundamental framework of cities.

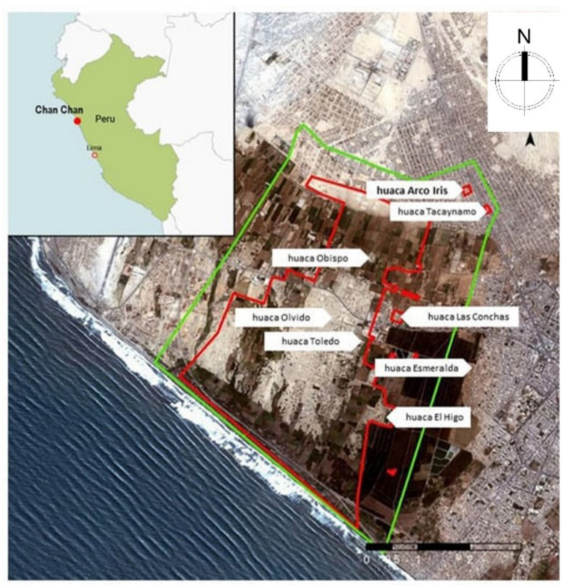


Fig. 5: The Moche-chikama region, which represents Chan-Chan's location along the Pacific Ocean, Source: (Colosi & Malinverni, 2022, p. 2064)

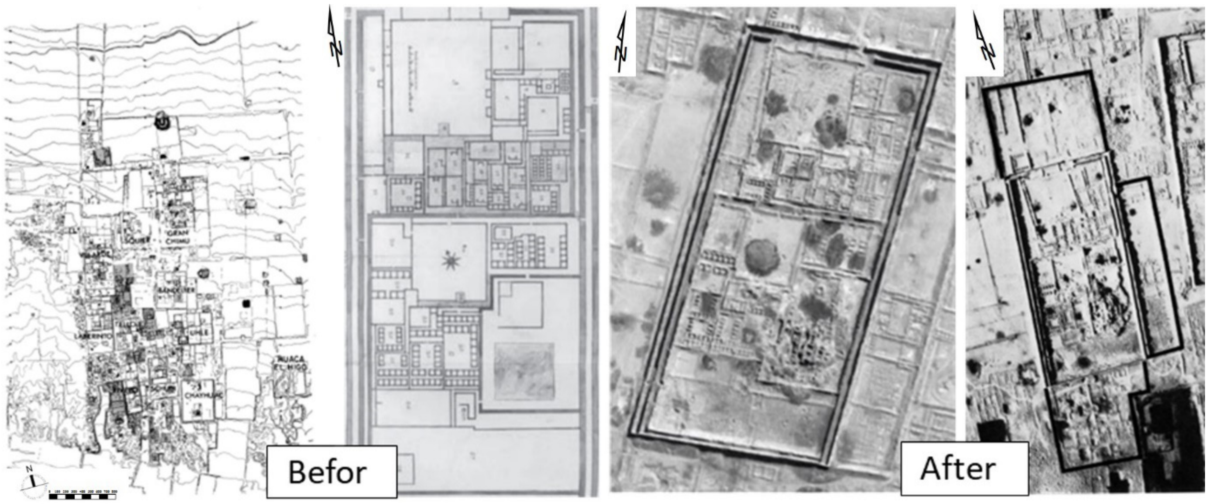
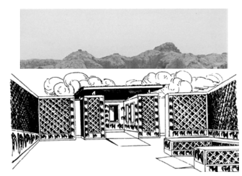
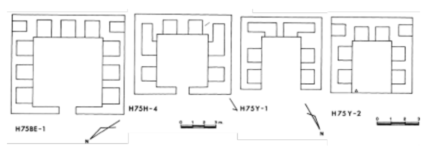
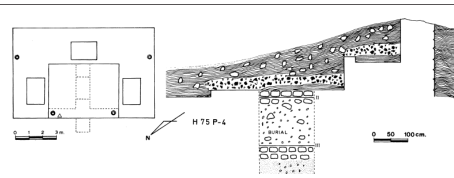
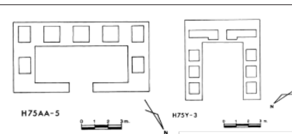
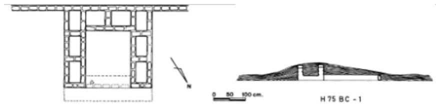
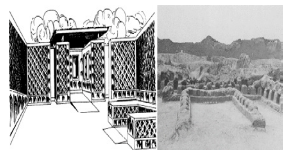
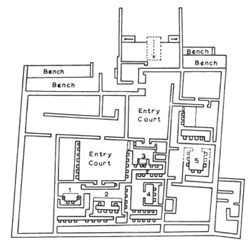


Fig. 4: Structure of the city of Chan Chan before and after the Incan invasion and the flood in the aerial photograph of ciudadela Rivero , Source: Created by the authors, 2023.

Table 1: U-shaped structures in Chan Chan, Source: Adapted from (Andrews, 1974, pp. 251-253)

Row	Structures	Description	Images
1	Standard	Standard audiencias are predominant in frequency and are characterized by six interior niches, with two niches positioned in each wall. The nomenclature originates from the concept of a person seated within the structure, essentially conducting an "audience."	 An audiencia in the north sector of cuidadela Tschudi. Drawing by Carlos Felipe.
2	Niches	The audiencia variant essentially mirrors the standard audiencia structure but incorporates additional features or modifications such as extra niches, L-shaped niches, restricted entries, and other elements.	 Plans of audiencia variants in Tello (H75BE-1) and Plans of audiencia variants in Uhle.
3	Trocadero	The trocadero shares the identical layout as 1-2, but distinguishes itself by having three or four troughs instead of niches along its interior walls. These troughs are situated with one in each side wall and one or two in the rear wall. The nomenclature for this structure is derived from the Spanish term for a location with troughs, or "trocas."	 Plan and profile of an arcbn in a unit of Lower Intermediate architecture.
4	Trocadero variants resemble Trocaderos	These structures feature several additions and/or modifications, including C-shaped layouts, extra troughs, L-shaped troughs, and so on. The arcon, Spanish for "binnery," is a smaller structure characterized by low walls lined with bins. The number of bins in the arcon ranges from six to nine, and they are notably deeper than troughs.	 Plans of trocadero variants in the south (H75AA-5) and north (75Y-3) sectors of Uhle.

Row	Structures	Description	Images
5	Arcon	The arcon (Spanish for "binnery") is a smaller structure with low walls lined with bins. These bins vary in number from six to nine and are much deeper than troughs.	 Plan and profile of an arcbn in a unit of lower intermediate architecture,
6	auxiliary structure	The auxilio is a petite structure characterized by low walls, devoid of niches, troughs, or bins. Instead, its walls are adorned with moldings, high-relief friezes, and decorative brick arrangements.	 An auxilio in the north sector of Cuidadela Tschudi.
7	The rural audiencia variants	The rural audiencia variants bear a resemblance to audiencia variants, yet exhibit several distinctions. These structures typically adopt either a U-shaped or C-shaped layout. While all rural audiencia variants incorporate niches, the shapes and quantities of these niches may vary. Construction methods and materials diverge from those employed in Chan Chan; for instance, the structures at El Milagro de San José and Quebrada del Oso are constructed using cobblestones and silt mortar, while 24 V-124 features tapia walls capped with adobe bricks.	 Plan of the main structure at El Milagro de San Josi, Moche Valley.

Air element

The city of Chan Chan originates from the Moche language word "Jang-Jang," which means "sun of the sun." Another theory suggests that the name is derived from the term "Xian" or "Xian." In this interpretation, the sound "object" is translated as the moon and "it" as the house, implying "the House of the Moon" and indicating the moon as the primary deity. (pita & Sarkhosh, 1997, p. 41)

The climate in Chan Chan deviates from its geographical location due to the influence of the cold waters from the Humboldt Current, which brings about modifications to the climate and geography of the northern coast of Peru. Consequently, summers are warm with minimal or no rainfall, characterized by dry conditions. Winters, on the other hand, are temperate, misty, and marked by a unique type of rainfall. The arrival of warm waters from the "El Niño" current significantly alters the climate, leading to elevated temperatures that persist for several months and intense rainfall. This often results in severe floods, as observed in 2017 and in previous years such as 1701, 1720, 1728, 1858, 1891, 1925, 1972, and 1983 (Via di , September 1983, p. 83) . Natural disasters are recognized as a fundamental challenge to achieving the sustainable development of human societies (Sayadnia, Motevalli, Janbaz Ghobadi, & Azimi Amoli, 2022).

Normally, temperatures reach their peak between January and March, with a mean maximum of 27°C. During the night, temperatures typically drop to around 15-20 degrees Celsius. Relative humidity is at its lowest during this period, with a mean maximum of 81%. The prevailing winds are from the south and southwest, with a mean maximum speed of 1.1 meters per second. Rainfall is infrequent, usually occurring around Holy Week. While official rainfall data is unavailable, references from Paul Coremans suggest 38 mm per year for Lima and somewhat higher for the north coast. Zoltan Zsabo indicates an average of between 0.025 and 50 mm per year for the north coast of Peru. In 1983, the total hours of rain amounted to 36; on April 12, rainfall lasted 55 minutes with an average of 7 mm (GetYourGuide, 2014-2023).

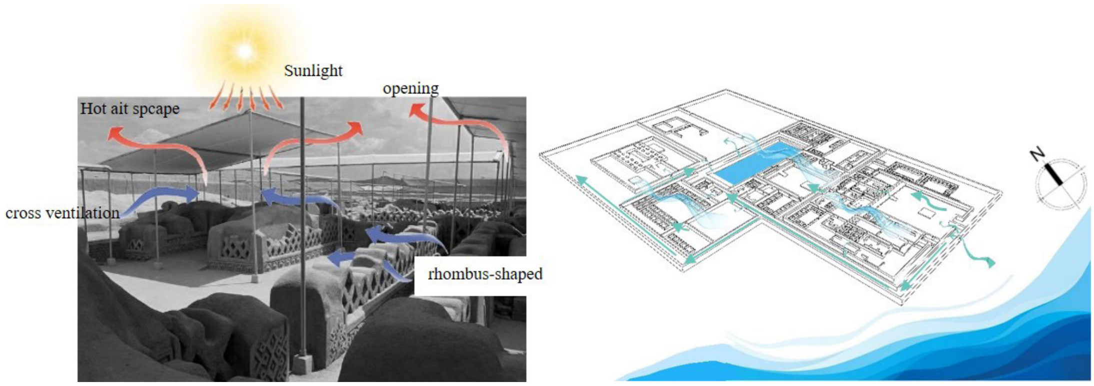


Fig. 6: Guiding optimal wind flow through the main entrance, main passages, and rhombus-shaped walls to the interior spaces, while facilitating the expulsion of hot air through roof openings. Source: Created by the authors based on geographic analysis, 2023

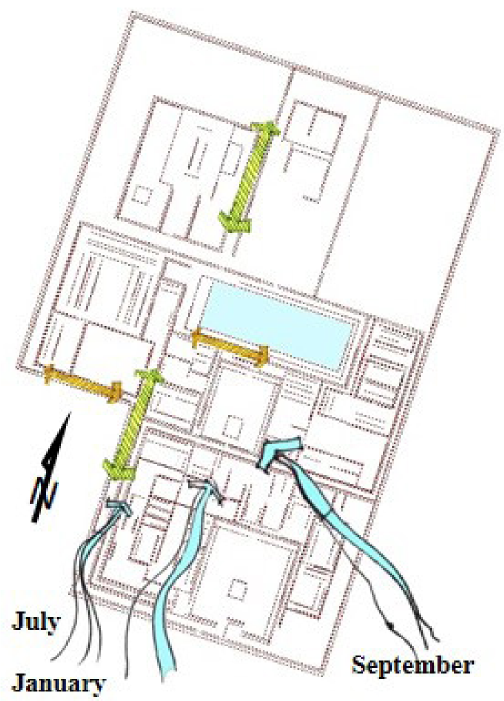


Fig. 7: The formation of alleys in the direction of the wind. Source: Created by the authors based on geographic analysis, 2023

During the period between July and September, temperatures in Chan Chan reach their lowest point, with a mean minimum of 14 °C. Relative humidity peaks during this time, averaging 86% monthly. The prevailing wind direction is predominantly from the south and southeast, with an average speed of 12 meters per second. Rainfall is nearly non-existent, and the region experiences a fine mist known as "garua" (MASSARI, 1977). At the same time, the existing contours on the surface of the decorations represent each dynamic unit for changing the behavior of the shadow. However, both the direction of light and the background level play a role in determining the movement type and perception of shadows (Dee & Santos, 2011) (Hashemi, Baghaei, & Afhami, 2022).

Water element

Chan Chan was home to a civilization that was predominantly animist, with cults specifically dedicated to creatures and deities associated with the sea. Given its coastal location, the Kingdom of Chimor thrived by the ocean. Much of its prosperity stemmed from the Pacific, and in return, it adorned the walls of its city-state with depictions of fish, pelicans, and other elements related to fishing. Even today, Chan Chan remains renowned for these wall decorations (Ponant, 2021).

A full wall in the central palace is dedicated to a giant mural over 170 feet long that emphasizes the importance of water in Chan Chan. Each decoration actually represents a wave moving towards the shore. The bas-relief shows fish moving from south to north, following the path of the Peru Current. However, a closer look reveals that the mural also depicts another moment of this significant change, with fish swimming in the opposite direction, from north to south, indicating a violent shift in the climate due to ocean currents (the flow of torrential rains and the El Niño phenomenon). (P. Andrews, 2016)

Fig. 8: The bas-relief depicts the movement of fish, Source: (Bandelier & F.Bandalier, (1840 – 1914))

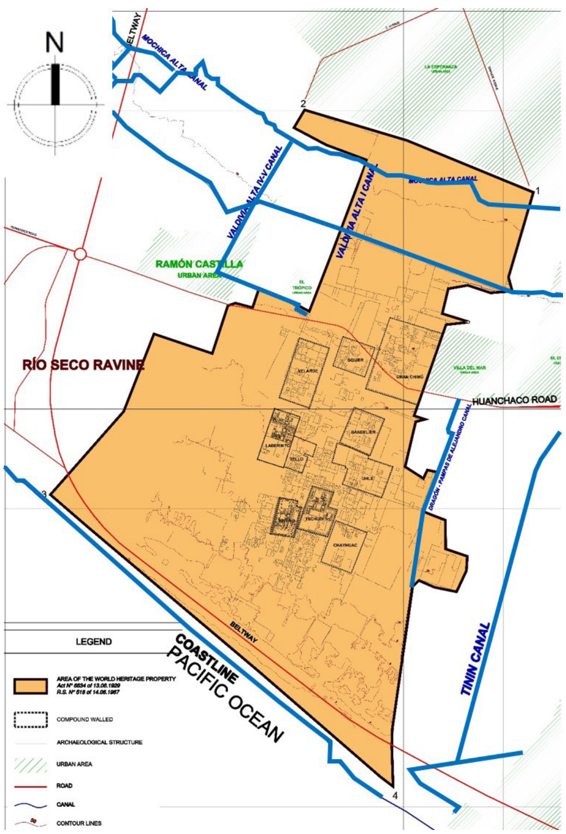


Fig. 9: The three main irrigation channels of the city of Chan Chan are N1, N2, and N3. Source: Created by the authors based on geographic analysis, 2023

The Moche Valley, also known as Santa Catalina in Chan Chan, emerged as the crucial center of the Empire. The water distribution system in Chan Chan adheres strictly to three principles.

Chan Chan's infrastructure comprises three primary components: the main city structure, the provision of potable and sanitary water, and the irrigation of gardens. The ingenious use of irrigation systems allowed them to harness ocean water for both agriculture and trade. The cultivation of a diverse range of crops, such as beans, cotton, corn, and codotnabel, was made possible through their intelligent irrigation system, which involved rectangular excavations to tap into groundwater and establish a comprehensive irrigation network. Despite the region's low annual rainfall, averaging less than 2.5 cm, the implementation of canals and pits enabled the development of robust water and agricultural infrastructure, giving rise to the creation of aesthetically pleasing gardens (user, 1997). Around the 1100s, the northern blue channels were destroyed due to flooding that shifted the focus of the economy out of agriculture. They've also done business and fishing (Moore, 1996). The Moche River, the area's freshwater source, was provided by aquifer water from mountainous rains and flowed with seasonal changes. From January to May, the average flow was about 34 cubic meters per second, but in the following months it decreased to 4 cubic meters per second (Moore, 1996). The aquifer tablecloths played a crucial role in supplying water to the city through high-slope irrigation in Pampa Esperanza. Maintaining artificial water levels also facilitated internal urban expansion. The majority of the passes in Chan Chan are aligned along an east-west axis. Consequently, cuidadelas are oriented either towards the south or north, a strategic positioning that enhances shading. Additional factors, including construction density, spatial distribution of structures, diverse forms and volumes, varying dimensions of the passes, and differences in wall heights, collectively contribute to the creation of shade. These considerations are observed along the North, South, West, and East axes at an angle of 18 degrees.

Soil element in the formation of the city:

This collection, where each symbol is meticulously positioned according to scale and spatial hierarchy, constitutes part of a sophisticated system. Establishing continuity among all the elements ensures the integrity and coherence of the components, serving as a testament to the rich identity of the landscape (Marzi, Haghani1, & Rezaei, 2021) .The soil order incorporates topography and soil slope. Indeed, the initial layout of the city of Chan Chan is situated in a location where earth-related factors can be analyzed as follows: Chan Chan is positioned on a low ridge overlooking the Pacific Ocean near the mouth of the Moche River and on the western slopes of the Andes mountain range.The soil order incorporates topography and soil slope. Indeed, the initial layout of the city of Chan Chan is situated in a location where earth-related factors can be analyzed as follows: Chan Chan is positioned on a low ridge overlooking the Pacific Ocean near the mouth of the Moche River and on the western slopes of the Andes mountain range (P. Andrews, 2016). The soil in the area is moist and salty and has little clay, which is why chlorides and other salts are found in most bricks made from materials in the area. These salts are activated by moisture and suspended salts introduced by the wind from the sea, making the negative performance of the climate the most dynamic factor in the degradation cycle (Via di , S. Michele, 1983, p. 38).

The evidence indicates that the oversight of soil order in the city's architectureal structure has led to the serious deterioration of structures through the climatic phenomenon of "weathering." Nocturnal moisture softens the surface of the bricks, activating salts. Insolation, or exposure to sunlight, induces contraction as the surface rapidly dries, resulting in saline efflorescence. Wind carries suspended salts, particularly sodium chlorides, and ocean sand, becoming a highly erosive element that damages the fragile upper crusts of the walls. Subsequently, rain exacerbates the situation by washing away surfaces due to the clay's fragility. This process increases the weight of projecting decorations, leading to their collapse. Additionally, rain forms pools that seep into foundations, resulting in the collapse of walls and the loosening of reliefs. (Anpaolesi, 1973).

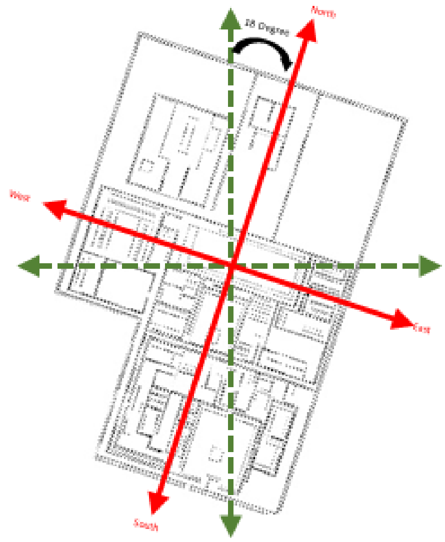


Fig. 10: Orientation of the city along the Pacific Ocean with an approximate southwest angle of 18 degrees (optimal utilization of wind and radiation) , Source: Created by the authors based on geographic analysis, 2023

Intense precipitation poses a significant threat to the foundations of earthen architecture structures. This heightened precipitation leads to increased humidity in the lower sections of the buildings, causing elevated salt contamination within the structures. Additionally, the excess moisture fosters the growth of vegetation, such as reeds and water lilies, in the lower-lying huachaques. During El Niño events, the intensified precipitation further exacerbates the situation by raising the groundwater level, amplifying the challenges faced by the architectural heritage of Chan Chan. Addressing these issues requires effective strategies for drainage, salt mitigation, and vegetation management to ensure the preservation of the site for future generations.(Q.K. , Arnell, & Anisimov, 2001).

Fig. 11: The Ruins of Chan Chan, Trujillo, Peru: A View of the Archaeological Site After the Heavy Rains of March 1982.Drainage is very important to solve this problem. Source: (Colosi & Malinverni, 2022)

Fig. 12: Roof cover to protect rainwater. Photo by R. Orazi.

Building materials used in Chimu architecture:

As one of the essential materials in Chan Chan architecture, bricks have been judiciously utilized here (both technically and visually). The Chimu architecture is characterized by the use of adobe and cotton as primary building materials, with stone used for foundations and gravel mixed with clayey mud for upper foundations. (Brown & Robbins, 1978) Adobe is a building material crafted from a blend of clayey soil and straw, left to dry in the sun. In Chan Chan, various adobe techniques are employed, including molded adobe bricks, plastered adobe, and mud adobe. The use of adobe enables the creation of intricate patterns and designs on building walls. Typically, an adobe mix comprises approximately 70% to 80% clayey soil, 15% to 25% sand, and a small quantity of straw or other organic materials. Clayey soil provides cohesion and adhesion, while sand enhances the mixture's strength and stability. The inclusion of straw or organic materials helps mitigate cracking and shrinkage during the drying process. (Brown & Robbins, 1978).

Fig. 13: How to make and mold adobes and dry them in the sun, Source: (L.Smailes, 2020, p. 36)

The adobes, varying in size and shape, are placed seismically with gaps to allow elasticity during earthquakes (Tecnología andina, 1978). Perimetric walls are trapezoidal and can reach a height of 12 meters, while inside walls have geometric designs. Decay in walls is caused by insect damage and the weight of mud-absorbing water (Coremanas, 1964). Plasterings and decorations crafted from clay exhibit plasticity and malleability. The criteria for intervention involve halting decay, consolidating structures, and justifying additions to ensure structural stability. Given the nature of adobe treatment, the consideration of reversibility is crucial in the preservation process. (Coremanas, 1964).

The brick walls of Chan Chan are constructed using tapia and adobe. Tapia walls, reaching heights of 9 to 10 meters, are typically made from mortar or adobe. Their structure is composed of diagonal blocks with various sections formed through ground-beating and direct molding techniques. The soil is crushed using wooden molds and cobblers in the ground-beating method, while direct molding involves bringing the soil to a plastic state and manual compression. Trapezoidal and triangular sections are employed to create structure and accelerate the drying process. Building in sections not only enhances productivity but also facilitates form resetting. (Easton, 1996, p. 105).

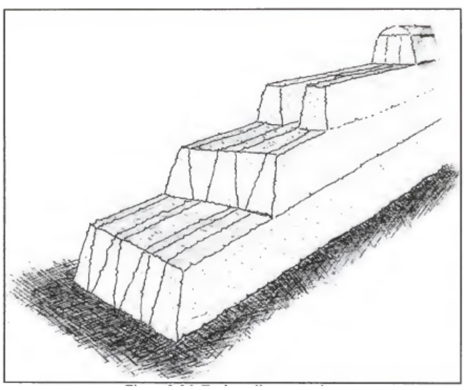


Fig. 15: Tapia wall construction, Source: (Via di , S. Michele, 1983)

In the city of Chan Chan, massive adobe walls are constructed, exceeding 3 meters in height and up to 4 meters in width within enclosures, such as the central dividing wall and those surrounding the main enclosure. The techniques employed for building these massive walls are akin to those used for Tapia, with modifications made to the exterior adobe walls.

The construction of these walls is initiated in stages, starting at the corners and progressing in a stair-like fashion. When reaching heights beyond 3 meters, the cane columns are adjusted vertically to ensure proper alignment. Workers visually align the wall by observing the lines of the columns. Two methods are employed to maintain the vertical slope (or taper) of the wall during construction.

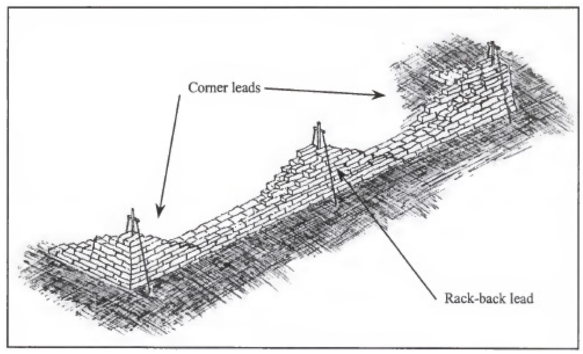


Fig. 16: The corner and back of the adobe wall, Source: (Via di , S. Michele, 1983)

In the first method, a “T” is attached to the top of the cane columns (a type of pole used in construction) with a string directed vertically downward from the “T” to establish the cone (gradual reduction in width). In the second

Fig. 14: Decorations of animal motifs on mortar, Chan Chan, Trujillo, Peru. Source: (Peru) UNESCO.

method, vertical cane beams serve as guides, attached to or leaning on the corners and working areas of the wall to determine the cone shape of the wall. (Norton, 1997, p. 36)

Plant element

The city of Chan Chan is situated in an almost hot and arid region, with its widest parts experiencing some of the most inhospitable climatic and ecological conditions. The limited amount of rainfall is not conducive to plant growth, and when it does occur, it typically happens during periods when the air and soil temperatures are unsuitable for optimal growth. The soil in the area is often characterized by salinity and alkalinity, with large areas nearly devoid of organic matter. The natural areas and vegetation in this region contend with dry and desert conditions, and the plant life is predominantly composed of species that are resilient to drought. Used primarily as roofing, supports over wall niches, and decorations, both cana brava and cana de guayaquil were readily available to Chimu builders. These native grasses provide excellent structural elements such as columns, beams, and scaffolding due to their high strength-to-weight ratio(McClure, 1953, pp. 13-15).

This storeroom example requires cana for the fabrication of the roof panels. The larger cana de guayaquil serves as roof beams, with cana brava as the covering.

RESULTS AND CONCLUSION

In contemporary global architecture today, a significant issue is the disconnect between traditional architectural practices and modern needs. This divergence has led to a loss of cultural identity and a lack of sustainability in many new constructions. While modern architecture emphasizes innovation and functionality, it often overlooks the historical and environmental context that native architectural styles embody. Bridging this gap is crucial for creating designs that are not only aesthetically pleasing and efficient but also culturally relevant and environmentally responsible. There is a growing recognition of the importance of integrating traditional methods and knowledge from the past as symbols of sustainable solutions, And by integrating traditional architectural principles with modern technologies, architects can create spaces the past while meeting the demands of the present and futur. The cultural landscape of Chan Chan serves as a significant representation of the interaction between humans and nature, preserving a rich resource of ancient canalisations, ciudadelas, and huacas as tangible evidence of the area's evolution.

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Fig. 17: cana brava, Source: (L.Smailes, 2020, p. 46)

Fig. 18: cana de Guayaquil

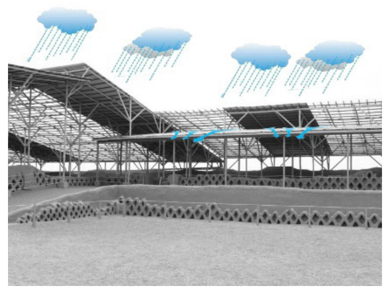
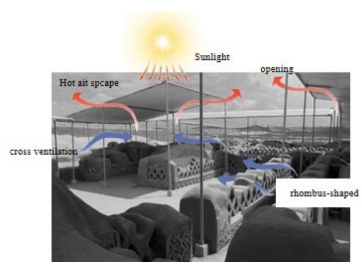
evolution. The U-shaped buildings and the construction of structures without roofs and complete walls, influenced by the local climate, are examples of adaptations to environmental conditions such as rainfall and temperature factors. These adaptations have a significant impact on the growth and development of plants and the way of life in natural communities. Additionally, the vulnerability and adaptation of ecosystems to the growing pressure of climate change are evident in Chan Chan.

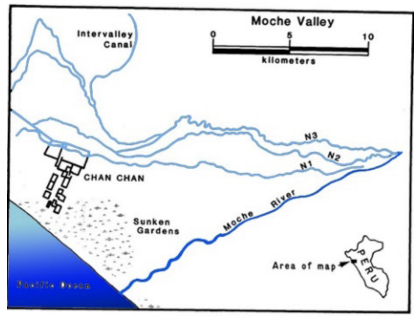
The residents of Chan Chan have implemented measures to overcome climate-related challenges and have strived to create a city that harmonizes with the natural environment. This approach highlights the importance of integrating traditional knowledge and sustainable practices into contemporary architectural design, fostering a more resilient and harmonious relationship between humans and nature.

In addition to synthesizing existing knowledge, this study contributes original insights

Table 2: An integrated analysis of the impact of climate systems on the spatial structure of Chan Chan city , derived from the integration of historical data analysis

Row	Target	Description	Example witness
1	Reduced reflection of the sun's heat	The Chan Chan people were acutely aware of the first principle, which is the reflection of the sun's heat from the dry and hot desert soil. It appears that they had a deep understanding of the impact of green spaces and water on the dry heat and cold of the desert, resulting in a significant moderation of temperature. This principle stems from the recognition that desert soil absorbs and retains heat from the sun during the day, only to release it at night. This phenomenon contributes to the creation of extreme temperature variations in the desert environment.	
2	The correct orientation of the set in the direction of the wind	The second principle that the people considered in the construction of their city is the proper orientation of the settlement with respect to favorable winds. The suggestion implies that the city should be strategically positioned to face the south or southeast direction, capitalizing on the cool and pleasant winds. This alignment not only shields the city from unfavorable winds but also allows for the harnessing of favorable winds to facilitate ventilation and cooling within the urban environment. he north-south alignment of ciudadelas minimizes solar exposure while enhancing wind circulation, reflecting sophisticated climatic adaptations.	
3	prevent the penetration of extreme heat and cold	The third principle aimed to prevent the infiltration of extreme heat and cold during summer and winter, as well as to block unfavorable winds, by incorporating specific architectural arrangements into the local fabric. The structural integrity of local buildings, combined with a compact texture and narrow, irregular passages featuring tall walls on both sides, contributes to the creation of maximum shade and minimal exposure to solar radiation. These designed spaces and elements collectively provide coolness and ventilation in urban areas, ensuring a comfortable living environment.	

Row	Target	Description	Example witness
4	Protecting passersby from heat	The fourth principle involved safeguarding pedestrians within the complex by implementing indirect, winding pathways. These pathways serve the dual purpose of impeding the intrusion of unwanted winds and creating shaded areas for pedestrians, ensuring a more comfortable and sheltered passage.	
5	Cooling the air.	The fifth principle that the people of Chan Chan observed was the dryness of the air and the potential for cooling it through the indigenous method of water evaporation. This awareness is evident in the incorporation of water reservoirs within their complexes. As dry and warm air passes over these surfaces, heat is absorbed during the evaporation of water droplets, leading to the air becoming moist and cool, contributing to a more comfortable environment.	
6	Prevention of flood entry into the city	The sixth principle addresses the climatic challenges of heavy rainfall and floods in the city of Chan Chan. To mitigate water intrusion and safeguard the buildings, the implementation of gable roofs, positioned at a distance from the walls, is proposed as an effective solution. This approach enhances structural resistance, lowers maintenance costs, and bolsters the overall security of the buildings against the impact of adverse weather conditions.	
7	Natural ventilation and humidity reduction	The seventh principle emphasizes the creation of a gap between the gable roof and the walls, which allows for better ventilation. This natural ventilation helps reduce indoor humidity, prevents the formation of fungi, molds, and mildew, and inhibits the growth of water lilies.	
8	Use of special heating capacity of materials	The eighth principle concerning wall thickness in the city dictates that the walls are approximately one to two meters thick. The high thermal capacity of the bricks facilitates heat retention within the walls, mitigating the impact of small temperature changes. During the night, the walls release heat through conduction and radiation, maintaining a lower temperature during the day and ensuring sufficient comfort for the residents. In this manner, the soil acts as a thermal insulator, leveraging its high heat capacity to provide insulation between the interior and exterior of the structures. The use of locally available adobe and its strategic composition illustrate resource efficiency and thermal regulation.	

Row	Target	Description	Example witness
9	Brick materials and trapezoidal walls	In the city of Chan Chan, the walls are constructed using both Tapia and Adobe techniques. The ninth architectural principle in Chan Chan involves the incorporation of trapezoidal and triangular sections in the walls, serving two primary purposes. Firstly, these sections facilitate the rapid absorption of water, a critical aspect as these sections need to dry before providing structural resistance. Secondly, these shapes act as molds for the interior parts of the walls. The selection of appropriate materials and wall thickness is also crucial to achieving optimal insulation for the interior climate, presenting specific solutions tailored to the unique environmental conditions of the region.	
10	Maintaining water supply through the construction of irrigation channels	The tenth principle emphasizes the construction of irrigation channels, a crucial element for securing water supply in Chan Chan. These channels, identified as N1, N2, and N3, are meticulously designed to ensure a consistent flow and prevent leakage of irrigation water, contributing to the replenishment of underground wells or city water sources. The construction of these channels is carefully coordinated with architectural advancements within the city, reflecting an integrated approach to both water management and urban development in Chan Chan.	
11	Using a lot of mudbrick in decorations	The stuccos and decorations on the mudbrick walls are very plastic. The high clay content in the stuccos and decorations contributes to their flexibility, allowing for the creation of intricate designs and reliefs. After applying plaster on the mudbrick walls, the decorations are shaped by carving or engraving on the plaster material, enabling the creation of three-dimensional designs and patterns on the walls.	

by systematically linking climatic factors to architectural and spatial strategies in Chan Chan. This integrative approach sheds light on underexplored dimensions, such as the role of wind orientation and soil salinity in shaping urban layouts and material selection. The study highlights how historical climate adaptations can inform modern sustainable practices, emphasizing the relevance of interdisciplinary research in climatology, architecture, archaeology, and environmental sciences. The profound influence of climate conditions and natural ecosystems on the architecture of Chan Chan underscores the importance of conducting further research. There is a need to gain a deeper understanding of how climate impacts the U-shaped construction and design of buildings. This necessitates an interdisciplinary approach that integrates various disciplines such as ancient history, architecture, climatology, plant biology, and hydrology. By conducting additional research across these disciplines, valuable insights can be gained into optimizing building performance in contemporary settings. Historical examples of how the builders of Chan Chan adapted to their environment can provide lessons for modern architecture, particularly in terms of sustainability. These lessons can guide the development of building techniques that minimize environmental impact, use resources efficiently, and enhance resilience to climate change. Furthermore, this interdisciplinary perspective will contribute to a more comprehensive understanding of the intricate relationship between architecture and the surrounding environment in Chan Chan. Such a holistic view is essential for preserving the site and for informing future architectural practices in similar climates. It emphasizes the importance of learning from historical adaptation strategies to address contemporary challenges, promoting a sustainable and harmonious relationship between human constructions and the natural world.

In conclusion, This study underscores the potential of historical architectural practices to inform contemporary sustainability challenges. By systematically linking climatic factors to architectural and spatial strategies, it provides a novel perspective on the interplay between climate and urban design. The interdisciplinary approach enriches our understanding of Chan Chan's adaptive strategies while offering actionable insights for modern architecture. Bridging the gap between past and present, this research advocates for leveraging historical resilience to address future environmental and urban challenges, making a compelling case for integrating traditional knowledge into contemporary practices.

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