buildings

MDPI

Article

Vernacular Architectural Knowledge in Historic Fortified Settlements of the Middle Qinhe River Basin

Yijie Wu [1,*], Gang Li [1,*] and Jiajun Yao [2]

[1] School of Design, Shanghai Jiao Tong University, No. 800 Dongchuan Road, Minhang District, Shanghai 200240, China
[2] School of Media and Communication, Shanghai Jiao Tong University, Shanghai 200240, China; curleeyao_0725@sjtu.edu.cn
* Correspondence: wuyijie0808@sjtu.edu.cn (Y.W.); lig@sjtu.edu.cn (G.L.)

Abstract

Historic fortified settlements constitute a distinctive component of the traditional settlement heritage of the Qinhe River Basin, where they historically combined defensive, residential, clan-governance, commercial, transport, and resource-use functions. Previous research has generated substantial understanding of their historical development, spatial morphology, environmental adaptation, and conservation. Less clear, however, is the intermediate process through which vernacular architectural knowledge can be identified from heterogeneous evidence, tacit social experience can be anchored to specific spatial carriers, and these findings can be translated into site-specific conservation actions. Focusing on the middle Qinhe River Basin, this study establishes a regional background inventory of 66 sites, selects 19 settlements with comparable spatial data for geographic information system (GIS) analysis, and conducts an in-depth comparison of five information-rich and typologically distinct cases: Guoyu Ancient City, Xiangyu Ancient Fortress, Huangcheng Xiangfu, Diji City, and Douzhuang Village. Documentary analysis, field investigation, spatial analysis, multi-source corroboration, hierarchical coding, spatial anchoring, and relational visualization are combined in an identification-comparison-interpretation framework for vernacular architectural knowledge. The results organize this knowledge into two interrelated layers. Explicit architectural knowledge comprises environmental siting, defensive space, building construction, and spatial organization; tacit architectural knowledge comprises clan organization, belief and ritual, craft practice, trade and transport, resources and livelihoods, collective defense, and local memory. Although the five cases share broadly similar regional settings and historical security pressures, they do not converge on a single defensive morphology. Instead, they show different knowledge relationships, including village-fort integration, vertically coordinated riverfront defense, the integration of official residence, clan organization, and defense, the coupling of resource-based construction with water-land access control, and layered defense through inner and outer enclosures. Tacit knowledge, moreover, is not treated as something that can be directly "extracted" through hierarchical coding; it is interpreted only after documentary, secondary oral-history/local-memory, field, and spatial evidence have been cross-checked and linked to identifiable spatial carriers or behavioral processes. These findings suggest that conservation should move beyond the repair of individual structures toward maintaining relationships among spatial carriers, behavioral processes, social relations, and local memory through case-specific combinations of material repair, interpretive routes, community participation, and routine monitoring.

Check for updates

Academic Editor: Antonio Formisano

Received: 6 August 2026
Revised: 10 September 2026
Accepted: 14 September 2026
Published: 16 September 2026

Copyright: © 2026 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license.

Keywords: middle Qinhe River Basin; historic fortified settlements; vernacular architectural knowledge; explicit and tacit knowledge; spatial anchoring; architectural heritage conservation

1. Introduction

1.1. Research Background

Traditional villages and historic settlements are important repositories of regional culture, architectural knowledge, and social memory [1]. Compared with ordinary traditional villages, historic fortified settlements are more strongly characterized by defensive requirements, enclosure, organized spatial order, and functional complexity [2]. Their morphology reflects both local adaptation to environmental conditions and the influence of social order, security needs, clan organization, commercial activity, and construction practice in particular historical periods.

Within the development of international heritage conservation, historic villages, towns, and settlements with aesthetic, historical, and cultural value have long been recognized as important heritage resources. Since the twentieth century, conservation practice in Europe has gradually expanded from individual monuments and buildings to historic environments, rural landscapes, and settlements as integrated wholes [3]. The 1964 Venice Charter consolidated key principles of cultural heritage conservation and brought the relationship between historic buildings and their settings into international heritage discourse. Traditional villages, historic towns, and vernacular architecture have subsequently come to be understood as heritage types that embody local culture, social memory, and accumulated building knowledge [4].

The Qinhe River Basin contains one of the major concentrations of fortified settlements and traditional village and town heritage in southeastern Shanxi [5]. The Taihang, Wangwu, and Zhongtiao mountain systems, together with the Qinhe River and its tributaries, form the region's physical framework. Since the Ming and Qing dynasties, resource exploitation, regional transport, commercial exchange, and the influence of local lineages have jointly shaped settlement development, producing clusters of fortified settlements in the middle Qinhe River Basin that combined residential, defensive, productive, ritual, and commercial functions.

The academic significance of the middle Qinhe River Basin lies not only in the number of surviving fortified sites, but also in the coexistence of multiple defensive-settlement types within a relatively continuous mountain-valley historical and cultural region. These settlements share broad regional conditions-the Qinhe hydrological system, mountain transport routes in southeastern Shanxi, Ming-Qing local society, and a resource-based economy-yet differ markedly in topographic position, enclosure, clan organization, material use, transport function, and defensive structure. This combination of a broadly comparable regional context and pronounced internal variation provides a useful setting for examining how similar environmental conditions and historical pressures were mediated through local social organization and building practice to produce different spatial outcomes. Within this clearly bounded study area, the analysis therefore develops a framework that can subsequently be tested in other reaches of the river [6].

In this study, "vernacular architectural knowledge" does not refer broadly to folklore or everyday custom. It denotes the architectural experience, spatial rules, material techniques, forms of social organization, and behavioral practices accumulated and transmitted by local communities through long-term adaptation to the environment, organization of social life, and construction of settlement space. The concept includes explicit knowledge that can

be identified directly through survey, observation, construction analysis, and spatial data, as well as tacit knowledge that requires interpretation through historical documents, local narratives, published or publicly available oral-history/local-memory materials, patterns of spatial use, and behavioral processes. Tacit knowledge enters the analytical framework only when a traceable relationship can be established with a specific spatial carrier, component, or behavioral process and when the interpretation is supported by corroboration across multiple sources. This approach allows fortified settlements to be understood not simply as static heritage objects, but as inhabited knowledge carriers in which material form, social practice, and local memory interact [7].

1.2. Literature Review and Research Gaps

Previous research on conservation and interpretation has established important principles such as holistic conservation, community participation, adaptive use, and sustainable regeneration [8–10]. The present study therefore addresses a more specific identification-to-translation gap: how heterogeneous evidence—including material remains, spatial morphology, oral memory, and social practice—can be transformed through traceable identification and spatial anchoring into propositions about vernacular architectural knowledge, and how those propositions can then be linked to concrete conservation objects, interpretive content, responsible actors, and management actions at different fortified sites. Without this intermediate chain, conservation recommendations can remain at the generic level of "enhanced collaboration" or "adaptive reuse."

Researchers have used ontologies, semantic knowledge bases, Historic Building Information Modeling (HBIM) [11], and knowledge graphs to structure architectural heritage information. Acierno et al. developed an ontology-based model for architectural heritage conservation processes [12], while Khouri et al. constructed a semantic knowledge base for traditional houses [13]. The ArCo project goes further by representing cultural heritage through formally defined entities, attributes, relations, and machine-readable semantics [14].

Research on vernacular architectural knowledge and intangible heritage has progressively expanded beyond material form to include local materials, traditional building skills, community practices, social organization, and intergenerational transmission. Reviews of sustainable vernacular architecture show that the field now addresses not only structural and environmental performance but also cultural characteristics, adaptive renewal, and evaluation criteria [10]. Recent studies of traditional building knowledge likewise emphasize that conserving physical fabric while neglecting craft skills and the people who transmit them cannot provide a complete basis for architectural heritage conservation [15]. The International Council on Monuments and Sites (ICOMOS) reinforced this position in its 2024 International Charter and Guidance on Sites with Intangible Cultural Heritage, which recognizes the close relationship between tangible heritage and intergenerational practices, knowledge, and community memory, and calls for sustained attention to community knowledge holders in documentation, interpretation, management, and transmission [16]. This perspective provides a conservation rationale for incorporating clan organization, craft experience, collective defense, and local memory into the spatial analysis of fortified settlements.

Methodologically, spatial research on traditional settlements has expanded from point-pattern statistics and morphological description toward street-network topology, spatial accessibility, and multiscale morphological indicators [17]. Studies of defensive traditional communities, for example, have combined GIS and space syntax to compare Integration, Choice, Normalized Angular Integration (NAIN), Normalized Angular Choice (NACH), Synergy, and Step Depth across macro-scale geographical patterns, meso-scale street net-

works, and micro-scale courtyards, thereby examining defensive hierarchy and access control [18]. Recent work in Buildings has similarly combined GIS and space syntax with boundary morphology, street networks, and building typology to quantify and map spatial characteristics of traditional settlements [19]. A 2026 study further integrated space syntax with resident interviews and tourism-experience data to diagnose spatial vitality and regeneration needs [20]. Together, these studies show that kernel density, distance to water, elevation, and slope alone are insufficient to explain defensive mechanisms. Regional GIS is better suited to establishing environmental context, whereas case-scale comparison requires consistent morphological dimensions and, where data permit, appropriate topological indicators [21].

Research on defensive settlements and the spatial morphology of traditional villages has produced a substantial body of work on settlement distribution, siting, walls and gates, street structure, building types, and defensive systems. A bibliometric review of Chinese defensive traditional settlements shows a gradual shift from historical description and surveys of individual buildings toward multiscale spatial analysis, heritage value, and conservation and reuse [2]. More recent studies have combined GIS, multiscale terrain parameters, and comparative defensive typologies to quantify relationships among settlements, rivers, slope, and terrain complexity [6]. These studies provide an important basis for understanding the regional spatial context of fortified settlements in the Qinhe River Basin, but they leave underexplored how spatial morphology and local social experience together constitute interpretable knowledge. The ICOMOS Guidelines on Fortifications and Military Heritage similarly emphasize that defensive heritage should be studied, interpreted, and conserved in relation to its surrounding cultural landscape, terrain, spatial relationships, strategic logic, and both tangible and intangible values [22].

Taken together, the literature provides a strong foundation for understanding the distribution, architectural morphology, local building traditions, and conservation issues of Qinhe fortified settlements, but three areas warrant further development. First, previous studies have often treated walls, gate towers, streets, courtyards, ancestral halls, historic commercial streets, and tunnels as separate objects, with less attention to cross-scale relationships among the natural environment, architectural components, behavioral processes, and social relations. Second, although visible spatial morphology has been extensively examined, procedures for identifying clan organization, craft experience, collective defense, resource-based livelihoods, and local memory from multiple sources and anchoring them to specific spaces remain insufficiently transparent and reviewable. Third, while conservation research has established principles of holistic protection, community participation, and adaptive use, relatively little work has traced a clear translation chain from identified local knowledge, through specific spatial carriers and actual or potential risks, to site-specific conservation actions. The contribution of this study is therefore deliberately limited to evidence identification, relational comparison, and conservation translation within the middle Qinhe River Basin; it does not claim to establish a universal classification system for all defensive settlements.

1.3. Research Objectives and Questions

Against these gaps, this study examines historic fortified settlements in the middle Qinhe River Basin through cases selected for both information completeness and clear typological variation. The aim is to reinterpret their spatial value and conservation significance through the lens of vernacular architectural knowledge. Rather than merely describing morphology, the analysis examines relationships among architectural space, construction experience, social organization, and local memory while making explicit the evidence and spatial carriers on which those relationships are based. Here, "representativeness" refers to

information richness in terms of typological variation, preservation, and the capacity to embody different forms of knowledge; it does not imply statistical representativeness or proportional geographical coverage of the entire river basin.

Specifically, the study addresses three questions. (1) What forms of vernacular architectural knowledge in historic fortified settlements of the middle Qinhe River Basin can be supported by evidence and anchored to space? (2) How can explicit spatial morphology and tacit social experience be identified through evidence-unit extraction, coding, spatial anchoring, and multi-source corroboration, and how do the resulting relationships differ across cases? (3) How can the knowledge relationships identified in the five in-depth cases be translated into site-specific conservation, interpretation, and design actions rather than remaining at the level of generic conservation principles?

The study makes three corresponding contributions. Conceptually, it reframes fortified settlements from collections of discrete architectural objects as relational structures linking spatial carriers, behavioral processes, social relations, and cultural meanings. Methodologically, it treats the identification of tacit knowledge as a traceable process based on multi-source corroboration, spatial anchoring, and explicit reliability controls, while comparing the five cases through a common set of dimensions. Practically, it links case-specific knowledge relationships to concrete conservation objects, potential risks, responsible actors, and interpretive routes, thereby moving from knowledge identification toward actionable conservation translation.

2. Materials and Methods

2.1. Study Area

The Qinhe River Basin is located in southeastern Shanxi Province and encompasses mountains, hills, river valleys, and basins [23]. The region is characterized by pronounced relief and river incision, and settlements commonly developed along valleys, piedmont terraces, transport nodes, and resource-producing areas [24]. This complex physical setting encouraged strong topographic adaptation in the siting of fortified settlements. Communities required access to rivers and transport routes to support production, daily life, and commerce, while historical security pressures also encouraged the use of mountain slopes, elevated ground, and naturally defensible terrain [25].

Fortified settlements in the study area show both spatial clustering and marked typological variation [26]. Zezhou, Yangcheng, and Qinshui counties contain large, relatively well-preserved fortified settlements as well as smaller sites represented only by remnant walls, gates, towers, or archaeological traces. Spatially, these settlements are closely associated with the Qinhe main channel, major tributaries, piedmont terraces, valley transport corridors, and resource-producing areas [6]. Typologically, they include fully enclosed village-fort systems, official-residence defensive complexes, material-oriented fortified settlements, clan-tower settlements, and composite mountain-water defensive forms. Five sites-Guoyu Ancient City, Xiangyu Ancient Fortress, Huangcheng Xiangfu, Diji City, and Douzhuang Village-were selected for in-depth analysis on the basis of typological differentiation, preservation, availability of multiple sources, and the richness of explicit and tacit knowledge carriers. The cases respectively foreground village-fort integration, vertically coordinated riverfront defense, the integration of official residence, clan organization, and defense, the coupling of resource-based construction with water-land control, and layered defense through inner and outer enclosures (Figure 1). The study is explicitly limited to the middle Qinhe River Basin; both the 66 regional background sites and the 19 spatial-analysis samples are used to characterize this middle-reach context.

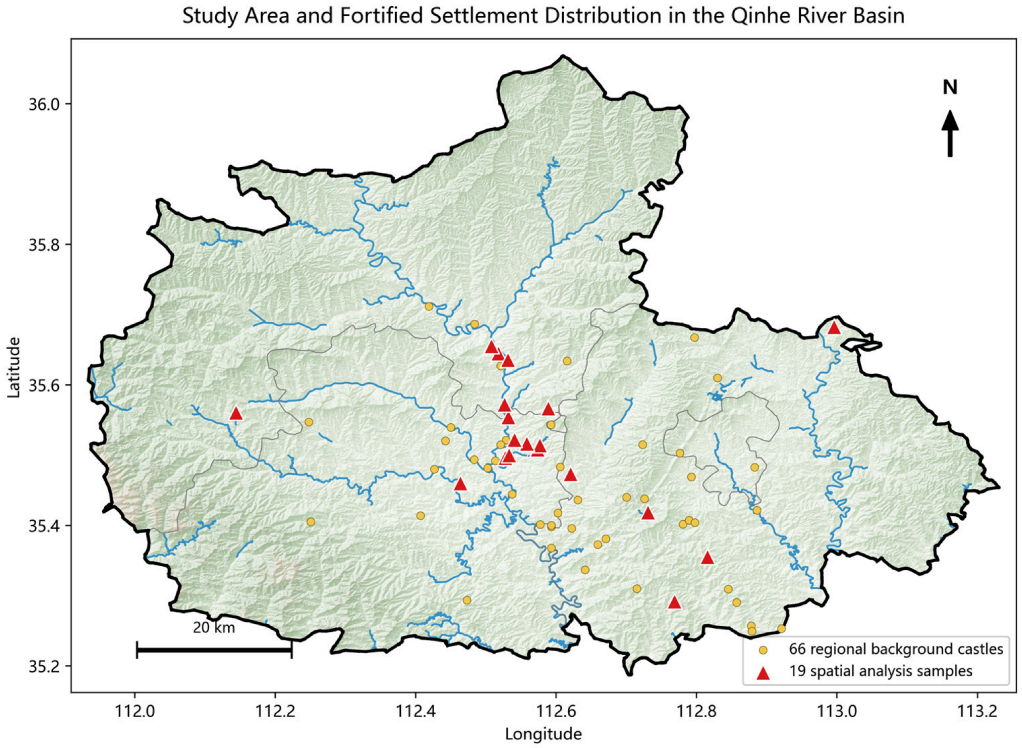


Figure 1. Study area and distribution of fortified settlements in the Qinhe River Basin.

2.2. Data Sources and Sampling Framework

A tiered research strategy was adopted to move from regional characterization to detailed case analysis. The first tier comprises the regional background sample. Local gazetteers, inventories of fortified sites, previous studies, conservation documents, and the survey results reported by Zhang Yuting in Investigation and Research on Ancient Fortresses in the Middle Reaches of the Qinhe River were used to compile an inventory of 66 fortified settlements and related remains in Zezhou, Yangcheng, and Qinshui counties, thereby defining the overall distribution, typological basis, and study boundary [27]. The complete regional inventory and spatial-analysis sample are provided in Appendix A (Tables A1 and A2). The second tier consists of 19 sites suitable for spatial analysis. Inclusion required (1) reliably identifiable geographic coordinates; (2) reasonably clear historical fort or settlement boundaries; (3) relatively complete digital elevation model (DEM), hydrological, and basic spatial data; (4) surviving morphology sufficient to identify major spatial relationships such as walls, gates, streets, and traditional courtyards; and (5) coverage, as far as possible, of different topographic settings and settlement types. These 19 sites constitute a data-availability sample rather than a probability sample of the 66 sites and are not statistically representative of the full inventory. The third tier comprises five in-depth cases-Guoyu Ancient City, Xiangyu Ancient Fortress, Huangcheng Xiangfu, Diji City, and Douzhuang Village-selected according to environmental setting, defensive structure, construction, spatial organization, social organization, and completeness of source material. Their purpose is to illuminate different knowledge relationships rather than to achieve proportional representation among counties. The selection criteria and core analytical value of the five in-depth cases are summarized in Table 1.

Table 1. Selection criteria for the five in-depth cases.

Case	Location/ Environment	Type	Principal Spatial Features	Tacit-Knowledge Dimensions	Core Analytical Value
Guoyu Ancient City	Yangcheng County; piedmont terrace–river interface	Large integrated village–fort type	Overall enclosure, three-gate system, Yu Tower, and wall-embedded caves	Village–fort community; integrated residence and defense	Village–fort integration and community-based coordinated defense
Xiangyu Ancient Fortress	Qinshui County; mountains on three sides and river cliffs to the south	Riverfront defensive type	Southern wall, four corner towers, troop-hiding caves, and over-street towers	Vertically coordinated defense; integration of residences and fortifications	Terrain, vertical defensive nodes, and coordinated defense
Huangcheng Xiangfu	Yangcheng County; mountain–water setting and relatively gentle terrain	Official-residence–clan–defense composite type	Inner and outer enclosures, Heshan Tower, troop-hiding caves, and hierarchical courtyards	Chen lineage order and ritual hierarchy of the official residence	Constructed defensive reinforcement and clan-based spatial order
Diji City	Yangcheng County; riverfront terrace enclosed by a river bend	Material-oriented construction type	Crucible wall, South Gate, North Water Gate, and barbican	Iron-production resources, material reuse, and local memory	Resource-material relationship and water-land access control
Douzhuang Village	Qinshui County; water on three sides and hills to one side	Clan–defense composite type	Inner and outer enclosures, Nine Gates and Nine Passes, tunnels, and troop-hiding caves	Clan-based residence and zoned coordinated defense	Clan organization and layered defense through inner and outer enclosures

Data collection and knowledge identification followed a multi-source evidence approach [28]. Four forms of source evidence were distinguished: (1) documentary evidence (DO), including local and village gazetteers, surveys of fortified settlements, genealogies and inscriptions, conservation plans, and relevant scholarship, used to cross-check historical background, construction processes, family relationships, and local terminology; (2) spatial evidence (SP), including site locations, river systems, DEM data, roads, and settlement boundaries, used to analyze environmental and spatial relationships; (3) field-observation evidence (FO), including photographs, survey records, and observations of streets, courtyards, and architectural components, used to verify surviving morphology, construction, and spatial nodes; and (4) secondary oral-history/local-memory evidence (OR), derived exclusively from previously published or publicly available materials, including published oral histories, local narratives, heritage interpretation materials, local chronicles, and relevant previous studies, used to supplement evidence on historical use, behavioral processes, local terminology, and community memory. Interpretive judgments made by the researchers (RI) were recorded separately from direct evidence in the coding table so that analytical inference would not be conflated with source material.

To standardize data collection, all researchers received a common briefing before fieldwork covering the research objectives and recording standards. During data organization, the analysis prioritized an evidence chain rather than any single source. Measurable spatial information was cross-checked among maps, imagery, and field observations. Tacit knowledge concerning clan organization, belief and ritual, craft experience, collective defense,

and local memory had to be associated with identifiable spatial carriers—such as ancestral halls, memorial arches, gates, defensive towers, tunnels, troop-hiding caves, and street nodes—or with describable behavioral processes. Hierarchical coding was therefore used to organize interpretations only after evidential corroboration and spatial anchoring. Secondary oral-history/local-memory materials supplemented information on historical use, local terminology, memory, and spatial practice and were checked against documentary, material, or spatial evidence. No human participants were recruited, contacted, or interviewed for this study. The evidence types, spatial-anchoring requirements, and reliability controls are summarized in Table 2.

Table 2. Multiple evidence, spatial anchoring, and rules for identifying tacit knowledge.

Evidence Type	Source Material	Primary Use	Reliability Control
DO documentary evidence	Local and village gazetteers, genealogies and inscriptions, survey/planning documents	Historical events, fort construction, family relations, and documented functions	Cross-check against spatial or other sources; avoid inferring present conditions from documents alone
SP spatial evidence	Site locations, hydrology, DEM, boundaries, and roads	Distance, elevation differences, boundaries, street networks, and node relationships	Used for measurable relationships; does not independently establish social meaning
FO field observation	Photographs, measured survey, and observations of components and streets	Surviving morphology, materials, construction, and spatial carriers	Record direct observations separately from interpretations of historical function
OR secondary oral-history/local-memory evidence	Published oral histories, publicly available local narratives, heritage interpretation materials, local chronicles, and relevant previous studies	Past use, local terminology, behavioral experience, and memory	Treat as secondary evidence; require a clear spatial anchor and, where possible, corroboration with DO/FO evidence
RI researcher interpretation	Analytical propositions based on the preceding evidence	Interpretation of relationships such as "resource–material–defense"	Label explicitly as interpretation; no major conclusion is supported by RI alone

2.3. Framework for Identifying and Representing Vernacular Architectural Knowledge

The analytical framework follows a sequence of multi-source data collection, regional and case-scale spatial analysis, evidence-unit extraction, coding and spatial anchoring, cross-case comparison, interpretation of formation pathways, and conservation translation (Figure 2). GIS is used primarily to characterize the relationships of the 66 regional background sites and 19 spatial-analysis samples to hydrology and terrain. Case-scale morphological comparison identifies differences in boundaries, street networks, gates, vertical defensive nodes, and concealed movement spaces. Hierarchical coding organizes explicit and tacit knowledge; multi-source corroboration and spatial anchoring constrain the interpretation of tacit knowledge; and cross-case comparison distinguishes shared patterns from case-specific differences. The framework is not intended to force all evidence into a single technical model. Rather, it makes traceable the sequence from the source of evidence, through coding and spatial anchoring, to the resulting interpretation and its relevance to conservation action.

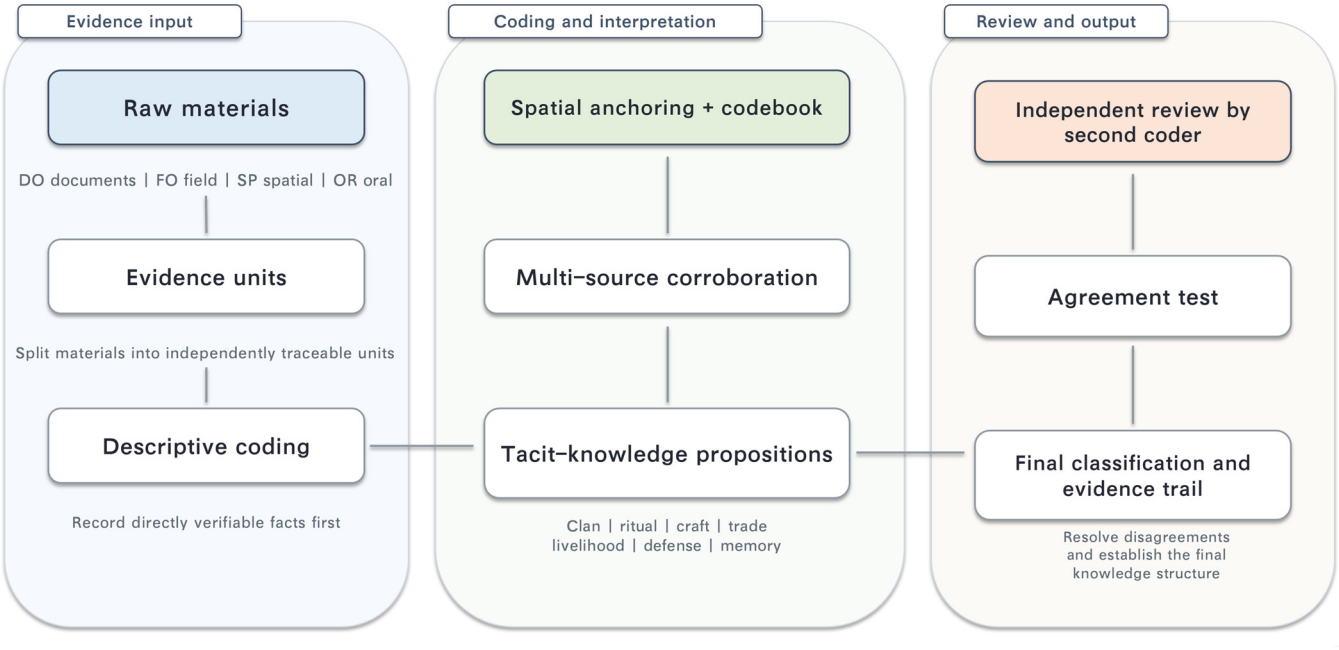


Figure 2. Coding workflow and reliability-control framework for tacit architectural knowledge.

2.3.1. Classification of Vernacular Architectural Knowledge

The classification of vernacular architectural knowledge provides the basis for subsequent hierarchical representation and comparative analysis. Two criteria—observability and mode of spatial anchoring—are used to distinguish explicit from tacit architectural knowledge. Explicit knowledge consists of material-spatial information that can be obtained directly through survey, observation, spatial data, and construction analysis. Tacit knowledge cannot be inferred from architectural appearance alone; it requires interpretation through social relations, behavioral experience, craft practice, local documents, and oral memory. Although tacit knowledge does not necessarily correspond to an independent physical object, it enters the analysis only when at least two conditions are met: it can be anchored to a specific space, component, or behavioral process; and its principal interpretation is supported, as far as possible, by evidence from more than one source rather than by formal analogy or a single legend. Knowledge of clan organization, for example, must be related to ancestral halls, courtyard hierarchies, divisions between inner and outer enclosures, gate interfaces, or documented patterns of use.

Explicit and tacit knowledge are not mutually exclusive [29]. The distinction clarifies differences in how evidence is obtained and interpreted rather than establishing a binary opposition between local and scientific knowledge [30]. A single architectural node may carry several forms of knowledge, but these must be distinguished analytically during coding. At Diji City, for example, the material composition and physical form of the crucible wall constitute construction knowledge; the reuse of discarded crucibles as building material belongs to resource and livelihood knowledge; and meanings attributed to the wall in local narratives belong to local memory. This layered approach prevents material construction, social experience, and cultural meaning from being collapsed into a single category.

2.3.2. Evidence Coding, Spatial Anchoring, and Reliability Control

Tacit knowledge was identified through a five-step sequence: evidence-unit extraction, descriptive coding, spatial anchoring, higher-order categorization, and interpretive proposition. Documentary statements, secondary oral-history/local-memory excerpts, field observations, and spatial-analysis results were first separated into traceable evidence units. First-order descriptive coding was then limited to content that could be directly

verified, such as "crucibles embedded in the wall," "division between inner and outer enclosures," "Nine Gates and Nine Passes," or "troop-hiding caves connected to streets." Each item was subsequently linked to a specific spatial carrier-such as a crucible wall, ancestral hall, gate, street, defensive tower, or courtyard-or to a behavioral sequence such as alarm, closure, movement, and refuge. Evidence was then compared across sources before being assigned to higher-order categories, including construction, resources and livelihoods, clan organization, collective defense, and local memory, and formulated as an interpretive proposition. At Diji City, for example, the physical presence of crucibles in the wall is field-observation evidence, whereas the history of local iron production derives from documentary or historical sources. Only after the two are linked through the crucible wall as a spatial carrier can material reuse, livelihood resources, and local memory be interpreted as a composite relationship. Hierarchical coding therefore improves the consistency and comparability of evidence organization; it does not convert researcher judgment into "objective fact."

To reduce researcher subjectivity in the identification of tacit knowledge, explicit coding rules were defined for each category. For clan organization, belief and ritual, craft experience, collective defense, and local memory, the analysis specified conceptual boundaries, principal evidence sources, spatial anchors, and inclusion criteria. Social or cultural meanings were not inferred from a single architectural form. Instead, historical documents, field observations, secondary oral-history/local-memory materials, and spatial relationships were cross-checked, and claims with insufficient evidence or unresolved contradictions were excluded from the principal knowledge propositions. Common coding rules, multi-source corroboration, and spatial anchoring were used to make the interpretive process as transparent and reviewable as possible.

An independent second-coder agreement test was not undertaken; accordingly, statistics such as Cohen's kappa are not reported [31]. Reliability control therefore relies on common coding rules, corroboration across multiple evidence sources, spatial anchoring, and the downgrading or exclusion of weakly supported or internally contradictory claims. This limitation is discussed further in Section 4.5.

2.3.3. Cross-Case Comparison and Interpretive Formation-Pathway Analysis

The five in-depth cases were examined using the same comparative dimensions: environmental setting, boundary and enclosure hierarchy, street-network structure, gates and access points, vertical defensive nodes, concealed movement spaces, material strategies, and spatial anchors associated with clans or communities. The aim was not to produce a composite score based on subjective weighting, but to ensure direct comparison across common dimensions and to distinguish regional patterns from case-specific features. Historical sources and evidence of tacit knowledge were then used to interpret associations among environment, security risk, clan organization, resources and technology, trade and transport, and the resulting spatial configurations.

Because the available case data do not support space-syntax or viewshed calculations at a consistent level of precision across all five cases, the study does not introduce Integration, Choice, or viewshed measures that would create a false impression of accuracy. The existing GIS analysis is therefore explicitly limited to regional environmental context, while case comparison is conducted through a common set of morphological dimensions. More detailed quantitative analysis is reserved for future research.

3. Results

3.1. Regional Spatial Context of Fortified Settlements in the Middle Qinhe River Basin

The GIS analysis first establishes where fortified settlements are distributed and how they relate regionally to hydrology and terrain; it is not used as an independent test of causal mechanisms. Across the middle Qinhe River Basin, the regional background sites form banded and clustered distributions along the Qinhe main channel, tributary valleys, piedmont terraces, and transport nodes [32]. Figure 3 shows the kernel-density pattern. All five in-depth cases reflect trade-offs among production and everyday life, transport, and security, yet their defensive spatial configurations differ substantially. Xiangyu Ancient Fortress and Diji City are strongly structured by riverfront and topographic interfaces; Guoyu Ancient City encloses an existing village in a manner responsive to local terrain; Huangcheng Xiangfu relies more heavily on constructed fortifications and hierarchical courtyard organization where natural defensive advantages are weaker; and Douzhuang Village uses a setting enclosed by water on three sides and backed by hills to organize inner and outer enclosures and gate systems. Regional GIS results are therefore treated as environmental context, whereas case-scale comparison of boundaries, street networks, and defensive nodes is used to examine differences in spatial organization.

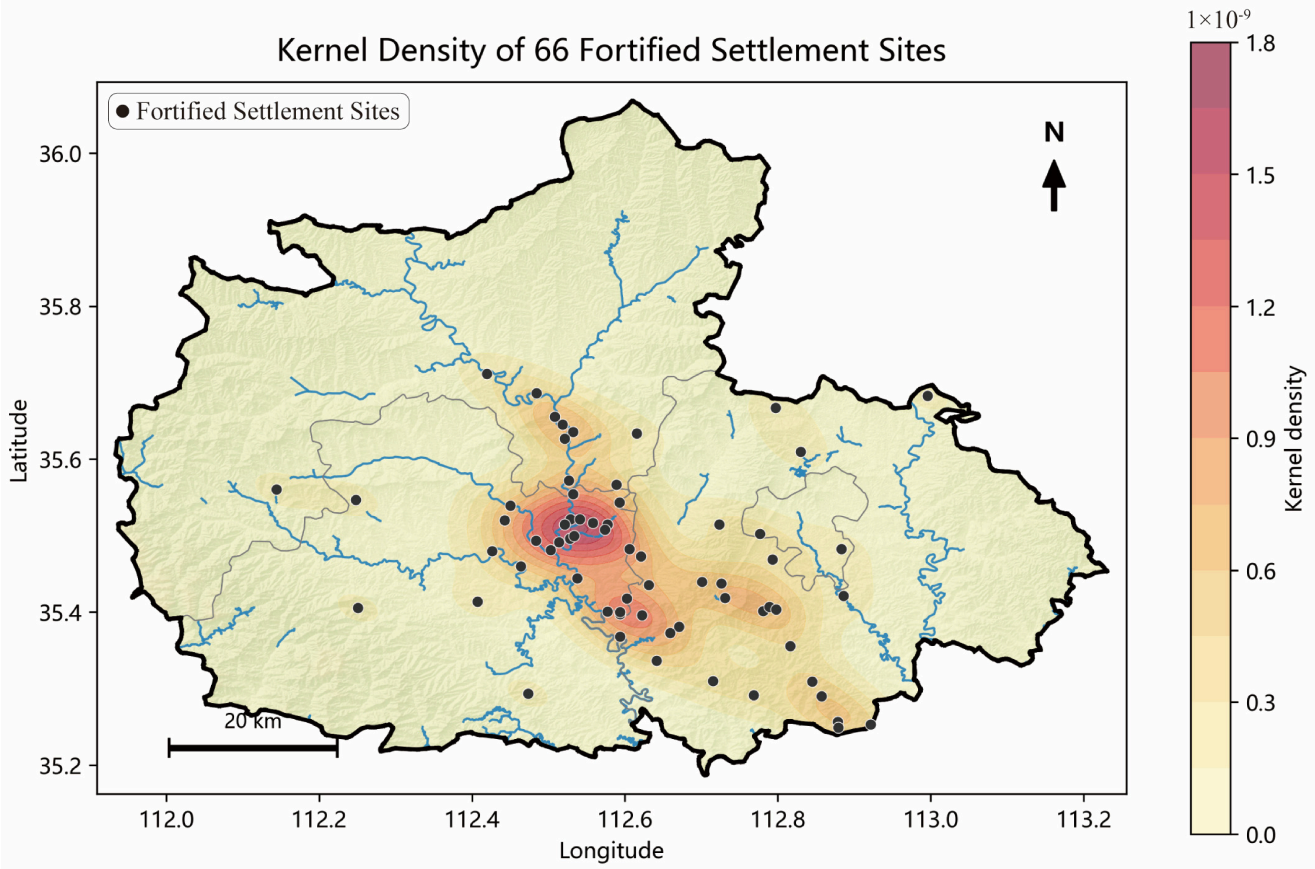


Figure 3. Kernel-density analysis of the 66 fortified-settlement sites.

3.1.1. Relationship Between Fortified Settlements and the Qinhe Hydrological System

The shortest distance from each of the 19 spatial-analysis samples to the Qinhe main channel or a major tributary was calculated and grouped into four classes: 0–200 m, 200–500 m, 500–1000 m, and >1000 m. The resulting distribution is shown in Figure 4.

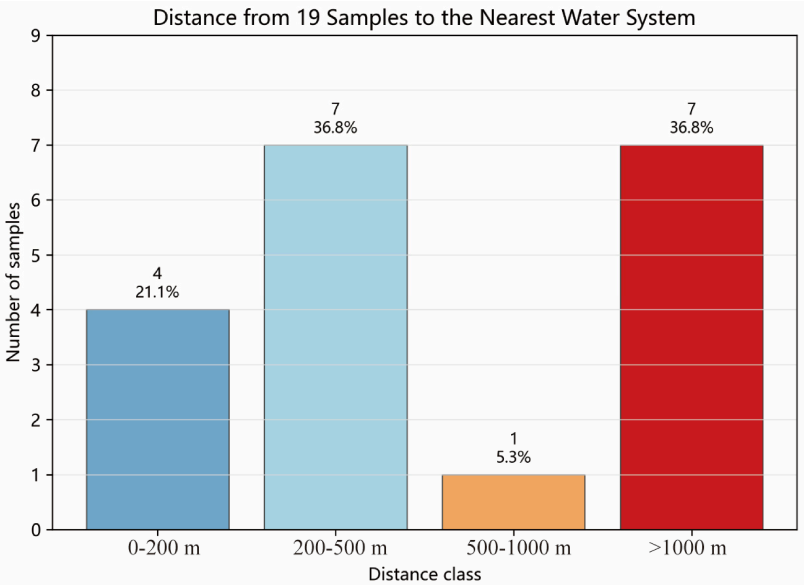


Figure 4. Distance classes from the 19 fortified settlements to the nearest major watercourse.

Eleven of the 19 samples lie within 500 m of a major watercourse and 12 within 1000 m. The close association of many sampled fortified settlements with the hydrological system indicates that water supply, water-land transport, and valley corridors were important regional considerations. Distance alone, however, does not demonstrate a defensive mechanism. Settlements near rivers often used bends, terraces, cliffs, or valley roads to organize walls, gates, water gates, and street nodes, suggesting a spatial trade-off between accessibility and boundary control.

3.1.2. Relationship Between Fortified Settlements and Terrain/Elevation

Elevation, slope, and local topographic position were extracted from a 30 m DEM, and the resulting terrain types are summarized in Figures 5 and 6.

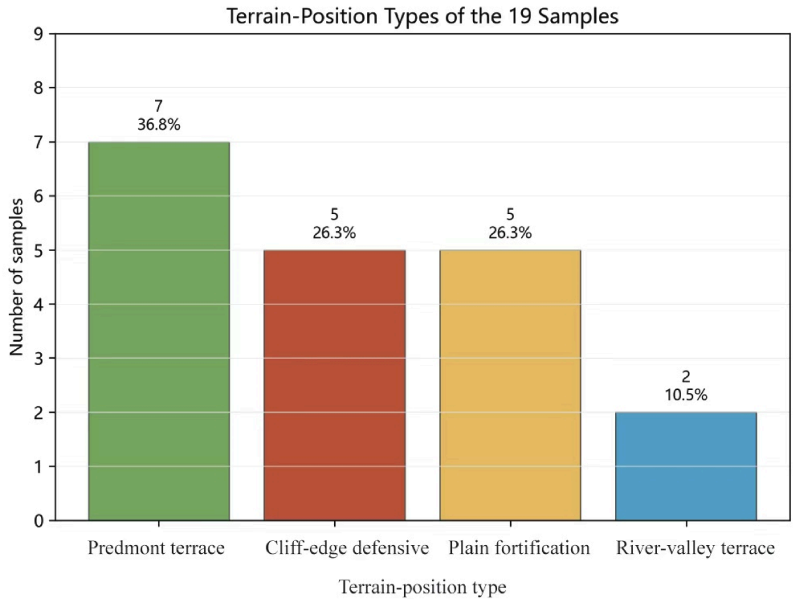


Figure 5. Terrain-position types of the 19 fortified settlements.

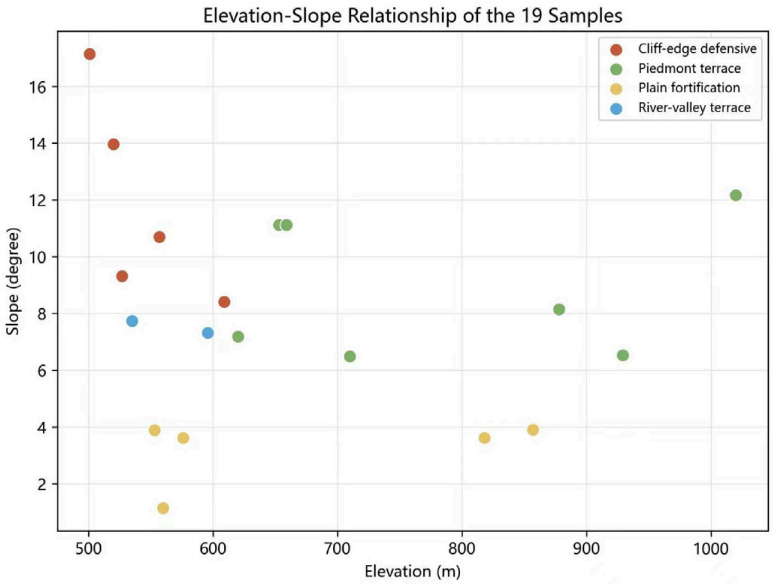


Figure 6. Elevation–slope distribution of the 19 fortified settlements.

Overall, the samples are not concentrated within a single elevation band, but occupy differentiated settings in valleys, piedmont terraces, cliff-edge locations, and plains. Valley-terrace settlements generally occupy relatively gentle terrain close to water, facilitating domestic water access, links to farmland, and movement. Cliff-edge settlements use river scarps, local relief, or steep slopes as natural barriers, reducing reliance on constructed defenses. Piedmont-terrace settlements lie between mountain slopes and valleys or plains, combining accessibility, visibility, and boundary control. Settlements fortified on open plains depend more heavily on walls, gate towers, and defensive towers to compensate for limited natural protection. The siting logic of Qinhe fortified settlements is therefore not simply one of being "beside mountains and water," but reflects a broader accommodation among water access, transport, cultivation, defense, and clan-based settlement.

3.1.3. Unified Spatial and Morphological Comparison of the Five In-Depth Cases

To move beyond point locations and single-variable environmental description, the five in-depth cases were compared within a common morphological framework after examining distance to water, DEM-derived elevation, and slope. GIS results show that all five cases lie within 500 m of the nearest major watercourse, confirming close relationships with rivers, streams, or riverfront terraces. Proximity to water alone, however, cannot explain defensive morphology. The comparison therefore also considers boundary hierarchy, street-network topology, access control, vertical defensive nodes, concealed movement spaces, material strategies, and spatial anchors of clan organization (Table 3). The analytical focus thus shifts from shared regional conditions to differences in spatial response. Figure 7 summarizes the distance-to-water, elevation, and slope characteristics of the five in-depth cases.

At Guoyu Ancient City, a piedmont terrace and the pre-existing village form the basis of an enclosure that follows local topography; walls, gates, a water gate, Yu Tower, and caves embedded in the wall together create an integrated village-fort defensive system. Huangcheng Xiangfu occupies gentler terrain and relies more on constructed defenses, including inner and outer enclosures, Heshan Tower, troop-hiding caves, and a hierarchy of official-residence courtyards. Diji City occupies a riverfront terrace, where its compact enclosure is closely related to a water gate, the crucible wall, and the river bend, combining water-land access control with distinctive material construction. Xiangyu Ancient Fortress uses river cliffs and the southern wall to create a strong external defensive interface, while

corner towers, troop-hiding caves, over-street towers, and residential watchtowers form a vertically coordinated defensive system. Douzhuang Village, surrounded by water on three sides and backed by hills, organizes clan residence and wartime defense through inner and outer enclosures and a system of gates and checkpoints.

Table 3. Unified comparison matrix of spatial, defensive, and knowledge relationships across the five in-depth cases.

Case	Environment/ Boundary	Street-Network Organization	Gates/Vertical Nodes	Concealed Movement	Material Strategy	Social Organization/ Tacit-Knowledge Anchors
Guoyu Ancient City	Piedmont terrace; overall village–fort enclosure	Three-gate system; comb-like/contour-following streets	Yu Tower, city gates, and water gate	Wall-embedded caves	Stone foundations and gray-brick walls; composite wall construction	Village–fort community; links between public buildings and courtyards
Xiangyu Ancient Fortress	Mountains on three sides; river-cliff boundary	Near-fishbone street pattern; T-junction turns	Four corner towers, over-street towers, and southern wall	Troop-hiding caves and two-level cave spaces	Brick-and-stone walls; integration of wall and residence	Residential compounds and defensive nodes form multi-level coordinated defense
Huangcheng Xiangfu	Relatively gentle terrain; nested inner and outer enclosures	Grid network with a T-shaped principal axis	Heshan Tower, corner towers, and gate passages	Troop-hiding caves and perimeter covered galleries	Brick, stone, and timber construction; hierarchical official-residence courtyards	Overlap of Chen lineage hierarchy, official-residence ritual order, and defense
Diji City	Riverfront terrace; compact near-elliptical enclosure	Dense narrow lanes and T-junction turns	South Gate battery, North Water Gate, and barbican	Internal nodes including an ammunition store	Crucible reuse; thick walls and riverfront walls	Interrelation of resource production, water-land trade, and material memory
Douzhuang Village	Water on three sides; layered inner and outer enclosures	Three longitudinal and one transverse route with a T-junction network	Nine Gates and Nine Passes, South Gate battery, and over-street towers	Tunnels and troop-hiding caves	Brick, stone, timber, rammed earth, and courtyard groups	Family courtyards, gates, and zoned coordinated defense are interrelated

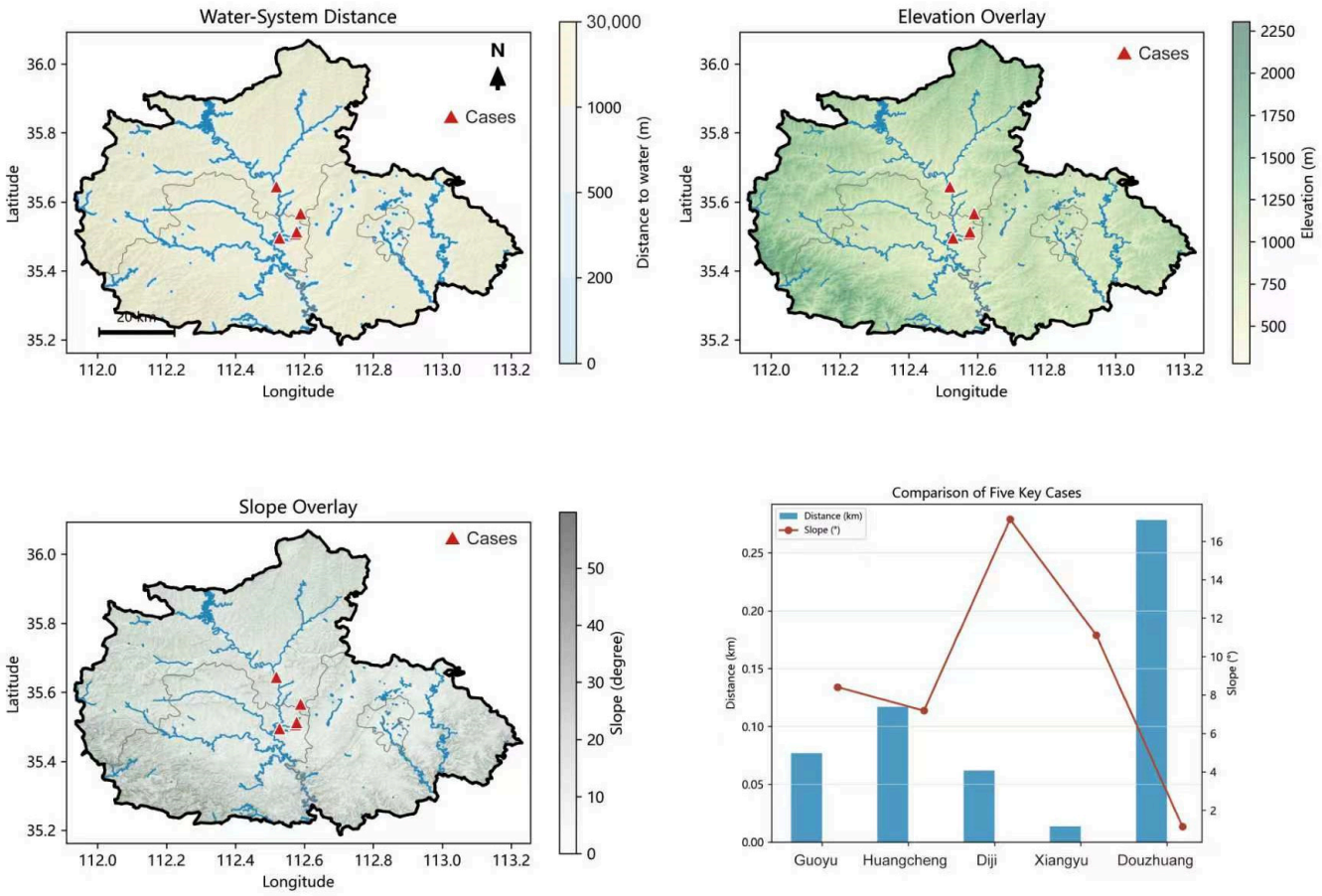


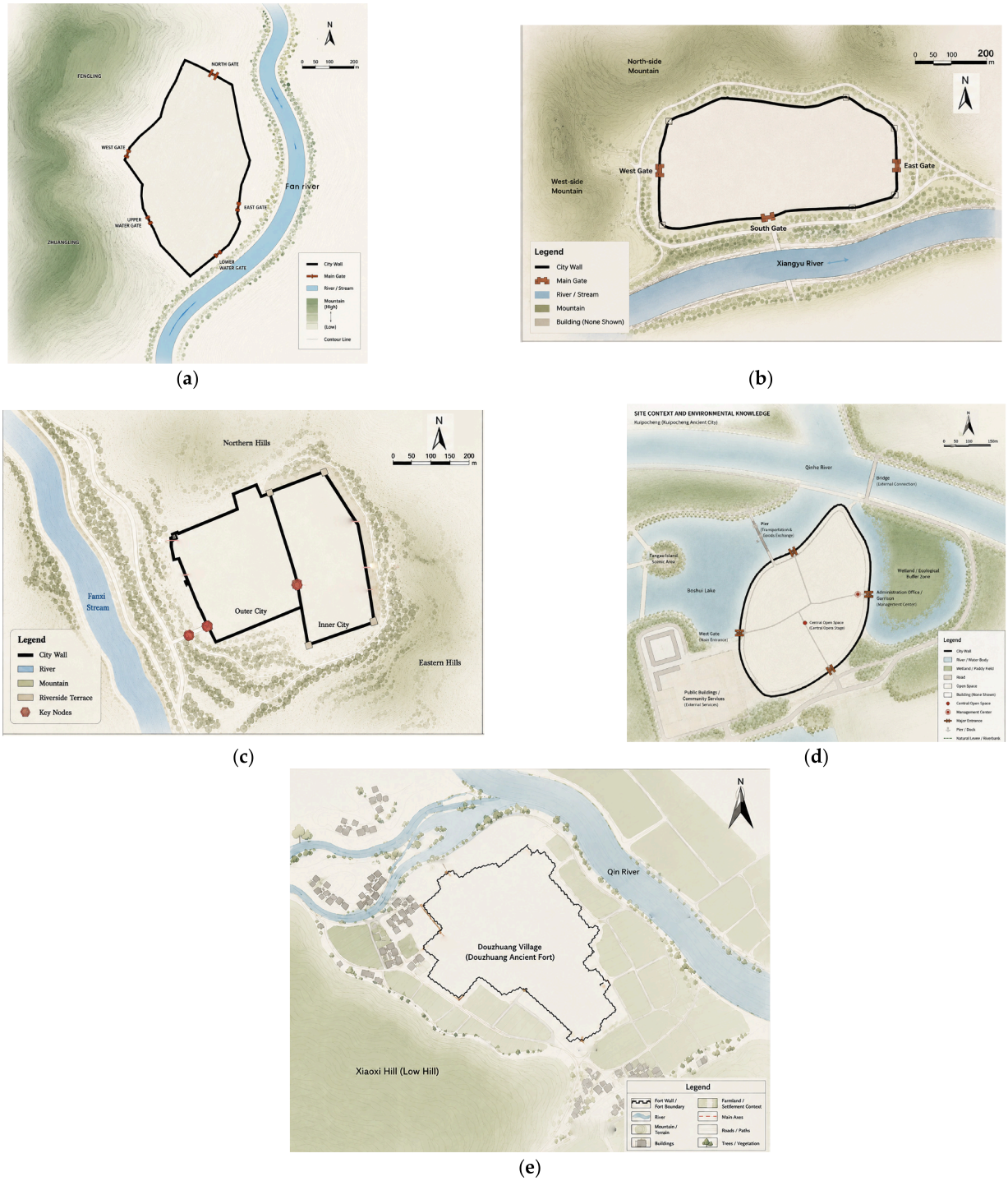
Figure 7. Spatial analysis of distance to water, elevation, and slope for the five in-depth cases.

3.2. Identification and Classification of Vernacular Architectural Knowledge

Drawing on data for traditional settlement clusters in the Qinhe River Basin, surveys of fortified sites, field observations, and comparison of the five representative cases, the analysis distinguishes explicit from tacit vernacular architectural knowledge. Compared with ordinary traditional villages, fortified settlements in the middle Qinhe River Basin display a particularly strong integration of defense and everyday habitation [33]. Explicit knowledge is expressed in topographic choice, walled boundaries, gate-tower nodes, troop-hiding caves, defensive towers, courtyard patterns, and street systems, whereas tacit knowledge is associated with clan order, ritual practice, craft experience, trade and transport, resource-based livelihoods, collective defense, and local memory.

3.2.1. Explicit Architectural Knowledge: From Environmental Adaptation to Spatial Organization

Environmental siting knowledge forms the basis of explicit architectural knowledge in fortified settlements of the middle Qinhe River Basin. It reflects integrated judgments concerning mountains, hydrology, terraces, roads, farmland, and defensive conditions. Unlike ordinary traditional villages, the siting of fortified settlements had to address not only production and everyday life but also historical security pressures, transport connections, access to resources, and the spatial requirements of clan residence. Their siting logic can therefore be understood as accumulated spatial practice balancing proximity to water, defensive terrain, accessibility, and defensibility. Walls, defensive nodes, street frameworks, and courtyard organization were subsequently developed within these site conditions (Figure 8).



(**a**) (**b**) (**c**) (**d**) (**e**)

Figure 8. Comparative siting environments of the five representative fortified settlements. (**a**) Guoyu Ancient City; Higher in the west and lower in the east; backed by hills and facing water; integrated village–fort; coordinated control by walls, city gates, and water gate. (**b**) Xiangyu Ancient Fortress; Higher in the north and lower in the south; backed by hills and facing the river; fortified riverbank; fort gate connected to the riverside road. (**c**) Huangcheng Xiangfu; Mountain–water setting; low-lying settlement; inner/outer enclosure zoning; coupling of official-residence ritual space and defensive space. (**d**) Diji City; River-enclosed terrace fort; water–land transport; compact defensive boundary and material-oriented construction. (**e**) Douzhuang Village; Near river and farmland; fortified on open ground; protected by two waterways and a low hill; continuous main axis and clan-based spatial organization.

Defensive spatial knowledge is the most distinctive component of explicit architectural knowledge in the fortified settlements of the middle Qinhe River Basin. It concerns how local communities combined natural terrain, constructed boundaries, street routes, vertical nodes, and concealed internal spaces into progressively layered defensive systems [34]. Six interrelated mechanisms can be distinguished: environmental buffering, boundary enclosure, route delay and diversion, node surveillance, concealed movement, and coordinated defense by spatial units (Table 4). Defensive space was therefore not a collection of isolated structures, but a composite system linking the natural environment, settlement boundaries, street networks, architectural nodes, and collective behavior. Comparative evidence is summarized in Table 5, with representative analytical examples shown in Figure 9. Its significance as vernacular knowledge lies in the capacity to reconfigure everyday spaces of residence, circulation, storage, and clan organization into systems of closure, movement, and coordinated defense under conditions of risk.

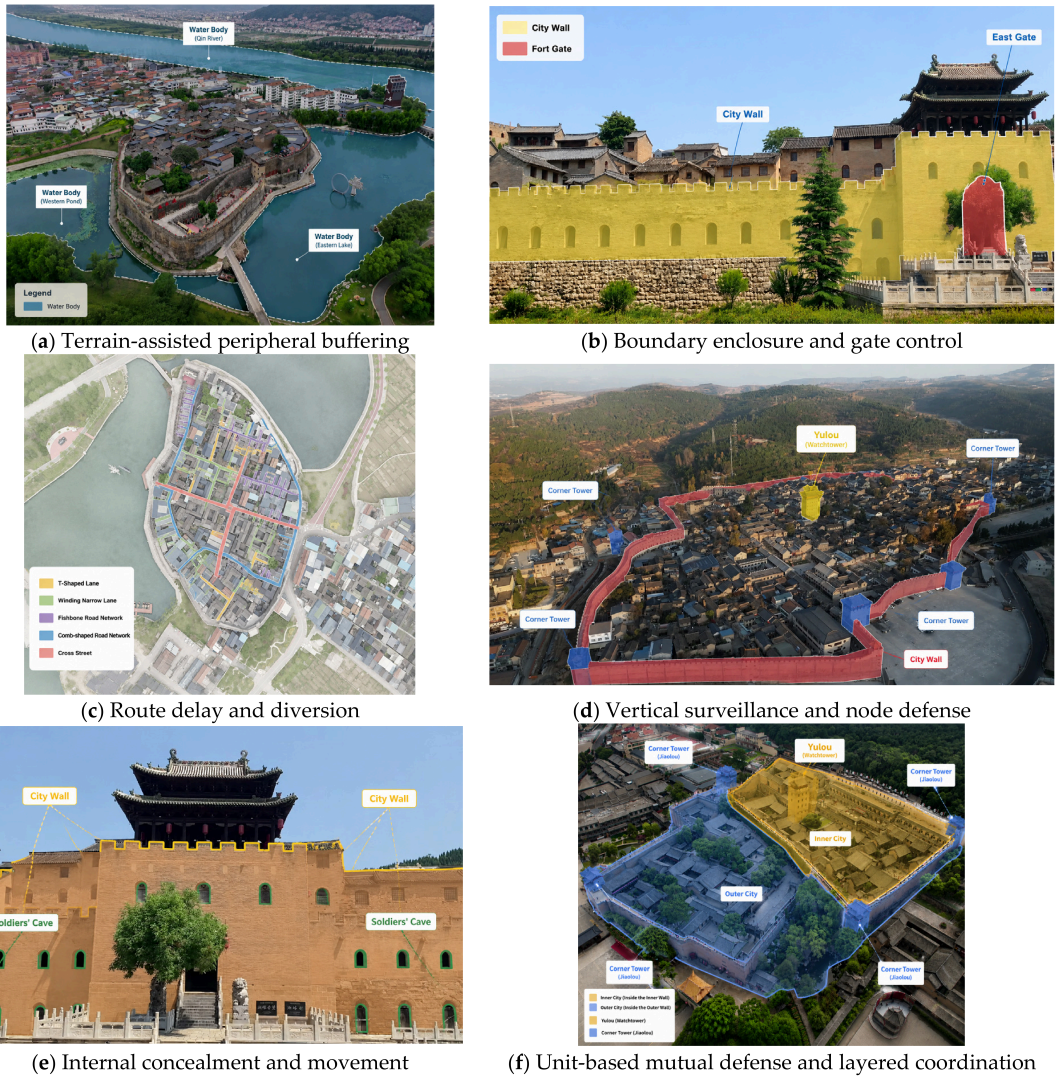
Table 4. Types of defensive spatial knowledge and their mechanisms in fortified settlements of the middle Qinhe River Basin.

Knowledge Type	Primary Spatial Carriers	Core Defensive Mechanism
Terrain-assisted peripheral buffering	Mountains, rivers, cliffs, terraces, and elevation differences	Use natural features to impede approach and combine them with constructed fortifications as the first defensive line
Boundary enclosure and gate control	Walls, fort gates, water gates, barbicans, corner towers, and batteries	Control the movement of people and goods through closed boundaries, limited entrances, and key gateways
Route delay and diversion	T-junction lanes, winding narrow alleys, fishbone and comb-like networks, and cross streets	Use non-through nodes, visual blind spots, road turns, and hierarchical networks to slow inward movement
Vertical surveillance and node defense	Yu Tower, Heshan Tower, watchtowers, corner towers, defensive towers, and over-street towers	Use elevated positions for surveillance, alarm, command, fire control, and final defense
Internal concealment and movement	Troop-hiding caves, tunnels, wall-embedded caves, underground storage, and covered patrol galleries	Organize garrisoning, storage, refuge, patrol, and concealed movement to prolong defensive endurance
Unit-based mutual defense and layered coordination	Inner and outer enclosures, courtyard clusters, clan defensive towers, street nodes, and peripheral military outposts	Use village, clan, or courtyard units to organize zoned defense, mutual support, and staged retreat

Construction knowledge is a form of explicit architectural knowledge identifiable through direct observation, measured survey, and construction analysis. It concerns how local materials were transformed into foundations, walls, gateways, cave spaces, defensive towers, and courtyard groups. Six principal types are distinguished in the middle Qinhe fortified settlements (Table 6). Together they form an explicit knowledge system based on local material selection, composite construction, multifunctional building units, and coordination among courtyard groups. The central logic is to organize architectural components in response to material conditions, the valley environment, and residential requirements so that they provide structural support, enclosure, habitation, storage, circulation, and environmental adaptation [35]. Construction knowledge in the five representative cases is compared in Table 7, with field photographs shown in Figure 10.

Table 5. Comparison of defensive spatial knowledge across representative fortified settlements.

Case	Macro-Scale Defensive Setting	Meso-Scale Spatial Organization	Micro-Scale Defensive Nodes
Guoyu Ancient City	Piedmont terrace and integrated village–fort enclosure	Three-gate system, contour-following streets, and wall–courtyard integration	Yu Tower, wall-embedded caves, barbican remains, and water gate
Xiangyu Ancient Fortress	Mountains on three sides and a riverfront boundary	Fishbone street network, coordination of inner and outer defensive points, and wall–residence integration	Four corner towers, troop-hiding caves, over-street towers, and residential watchtowers
Huangcheng Xiangfu	Mountain relief and Fanxi River setting	Nested inner and outer enclosures, grid network, and zoning of official-residence courtyards	Heshan Tower, corner towers, troop-hiding caves, and perimeter covered galleries
Diji City	Riverfront terrace surrounded by water on three sides	Compact enclosure, narrow T-junction lanes, and unitized blocks and courtyards	Crucible wall, South Gate battery, ammunition store, and North Water Gate
Douzhuang Village	Mountains and a Qinhe tributary form a peripheral barrier	Inner/outer enclosures, Nine Gates and Nine Passes, three longitudinal and one transverse route, and T-junction network	South Gate battery, lookout openings, tunnels, and over-street towers



(**a**) Terrain-assisted peripheral buffering

(**b**) Boundary enclosure and gate control

(**c**) Route delay and diversion

(**d**) Vertical surveillance and node defense

(**e**) Internal concealment and movement

(**f**) Unit-based mutual defense and layered coordination

Figure 9. Representative analytical examples of defensive spatial knowledge.

Table 6. Construction knowledge in fortified settlements of the middle Qinhe River Basin.

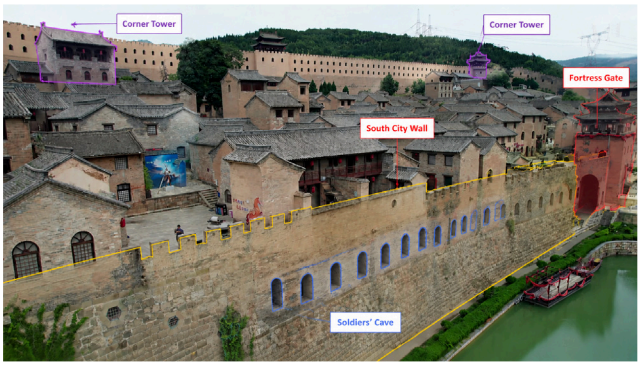
Knowledge Type	Primary Material Carriers	Core Construction Logic
Local-material selection and reuse	Stone, gray brick, mortar, timber, rammed earth, and discarded crucibles	Select materials according to local resource properties and transform production by-products into building components
Composite foundation-wall masonry	Stone bases, brick walls, thick walls, riverfront walls, and retaining/water-barrier walls	Improve stability, durability, and environmental adaptation through differentiated material selection, increased wall thickness, and composite masonry
Key-node construction	Arched gateways, fort gates, water gates, gate towers, barbicans, and lane interfaces	Use arches, deepened gateways, and component connections to organize load transfer, controlled boundaries, and spatial transitions
Wall spatialization and embedded cave spaces	Wall-embedded caves, troop-hiding caves, tunnels, and underground storage spaces	Embed cave spaces within thick walls or hillsides so that walls become usable multifunctional spaces rather than mere enclosures
Vertically integrated tower construction	Yu Tower, Heshan Tower, watchtowers, residential lookout towers, and clan defensive towers	Concentrate surveillance, storage, refuge, and residence within multilevel vertical structures
Courtyard-group and facility coordination	Inner/outer enclosures, courtyard groups, defensive towers, covered galleries, streets, and over-street towers	Link individual buildings, courtyard boundaries, and circulation systems into continuous architectural groups

Table 7. Comparison of construction knowledge across representative fortified settlements.

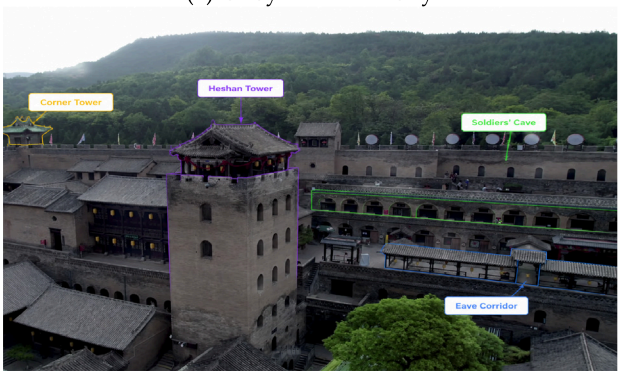
Case	Material Basis	Key Construction Methods	Representative Architectural Nodes
Guoyu Ancient City	Stone, gray brick, and mortar	Stone foundations support upper gray-brick walls, with cave spaces embedded along the inner face of the wall	Walls, wall-embedded caves, Yu Tower, and water gate
Xiangyu Ancient Fortress	Brick, stone, and mortar	Walls, water-retaining walls, troop-hiding caves, and two-level cave spaces were built as an integrated system; some residences are combined with the wall	Southern wall, troop-hiding caves, two-level cave spaces, corner towers, and over-street towers
Huangcheng Xiangfu	Gray brick, stone, timber, and gray roof tiles	Layered combination of inner and outer enclosures, official-residence courtyards, Heshan Tower, troop-hiding caves, and perimeter covered galleries	Heshan Tower, inner and outer enclosures, troop-hiding caves, corner towers, and covered galleries
Diji City	Discarded crucibles, brick, stone, and mortar	Discarded crucibles are embedded in thick walls and integrated with the South Gate, North Water Gate, barbican, and riverfront walls	Crucible wall, South Gate, North Water Gate, and barbican
Douzhuang Village	Brick, stone, timber, rammed earth, and gray roof tiles	Walls, gate towers, tunnels, troop-hiding caves, and courtyard groups are linked as an integrated system	South Gate, gate towers, tunnels, troop-hiding caves, and courtyard groups



(**a**) Guoyu Ancient City



(**b**) Xiangyu Ancient Fortress



(**c**) Huangcheng Xiangfu



(**d**) Diji City



(**e**) Douzhuang Village

Figure 10. Field photographs of building construction in the five representative fortified settlements.

Spatial-organization knowledge is explicit architectural knowledge expressed through settlement form, street networks, access nodes, courtyard groups, and movement patterns [36]. Five types are distinguished. The first concerns boundary enclosure and spatial hierarchy, created through walls, natural terrain, and the division between inner and outer enclosures [37]. The second concerns street-network topology, including axial, grid, fishbone, comb-like, and T-junction systems that organize movement and diversion. The third concerns node organization, in which fort gates, water gates, barbicans, defensive towers, corner towers, and street turns regulate access and visibility. The fourth concerns unit-based spatial organization, formed through family residences, core courtyards, and dense courtyard groups. The fifth concerns behavioral routes that allow streets, gates,

and courtyards to shift between everyday circulation and wartime defense [38]. The five representative cases exhibit distinct spatial-organization patterns (Table 8).

Table 8. Comparison of spatial-organization knowledge across representative fortified settlements.

Case	Overall Boundary	Street-Network Structure	Nodes
Guoyu Ancient City	The wall encloses the pre-existing village in an irregular form, with village and defensive boundaries interwoven	Main streets follow contour lines to form a comb-like framework; Nangou Street also serves drainage and boundary organization	The east, west, and north gates and Yu Tower form key nodes; streets connect dense courtyards and public spaces
Xiangyu Ancient Fortress	Riverfront walls and mountain boundaries jointly define the settlement, with differences between eastern and western sectors	Three transverse and multiple longitudinal routes form a near-fishbone network; T-junctions and winding lanes strengthen diversion and delay	Corner towers, over-street towers, core residences, and riverfront defenses jointly control streets and courtyard groups
Huangcheng Xiangfu	Nested inner and outer enclosures create a spatial progression from the perimeter toward the official-residence core	A grid network coexists with a T-shaped main axis that organizes the official residence and public nodes	Gate passages, corner towers, Heshan Tower, and hierarchical courtyards form a clear spatial sequence
Diji City	The enclosure follows the river bend to form a compact near-elliptical boundary with clear land–water interfaces	Dense narrow lanes and T-shaped turns form a maze-like network	The South Gate, North Water Gate, barbican, and dense courtyards jointly organize access, gathering, distribution, and internal control
Douzhuang Village	Inner/outer enclosures and multiple gateways form hierarchical boundaries, creating a “fort within a fort” pattern	Three longitudinal and one transverse main streets combine with T-junctions; alleys penetrate different courtyard groups	Nine Gates and Nine Passes, over-street towers, Jiuzhai Alley, and family courtyards form a multilayer control network

3.2.2. Tacit Architectural Knowledge: Spatial Anchoring of Social Relations and Behavioral Experience

Tacit architectural knowledge is not treated here as an abstract account of folklore or society detached from space, but as experiential knowledge embedded in particular spaces, architectural components, and behavioral processes. The analysis retains seven categories from the original study—clan organization, belief and ritual, craft practice, trade and transport, resources and livelihoods, collective defense, and local memory—but treats them as higher-order interpretations rather than objective facts. Each proposition specifies its evidence base and spatial anchor. Where oral memory conflicts with documentary or material evidence, the discrepancy is retained and the interpretive strength of the claim is reduced rather than resolved through researcher judgment. These categories therefore describe how social relations, practical know-how, and cultural memory become associated with spatial form; they do not map social or cultural factors mechanically onto individual architectural forms.

Diji City provides a traceable example of this procedure. The “crucible wall” is first recorded as a directly observable material and construction fact. Local iron production and the origin of the crucibles require documentary support. Only when the production context and the surviving wall can be corroborated in terms of time, place, and material relationship is a composite relationship among resource-based livelihood, material reuse, and local

memory proposed. The same principle applies at Huangcheng Xiangfu: divisions between inner and outer enclosures, gate hierarchy, and courtyard depth can be recorded directly, whereas their relationship to the social order of the Chen lineage requires interpretation through family history, patterns of spatial use, and documentary sources. This distinction keeps observation separate from interpretation within the results.

Knowledge of clan organization concerns not genealogy itself, but the ways in which kinship, family hierarchy, and communal governance were expressed through courtyards, ancestral halls, gate towers, defensive towers, and street boundaries [39]. At Huangcheng Xiangfu, the division between inner and outer enclosures, courtyard depth, gate hierarchy, Heshan Tower, and ritual spaces can be interpreted—when considered together with the history of the Chen lineage, patterns of courtyard use, and surviving spatial evidence—as an overlap between family order and defensive security within a single architectural system. At Douzhuang Village, relationships between the Dou and Zhang lineages and spaces such as the Dou ancestral hall, Zhang residences, Jiuzhai Alley, and the Upper Residence of the Shangshu Mansion can serve as evidence of clan-based spatial organization and family memory when documentary sources and local accounts corroborate one another. At Guoyu Ancient City, the village-fort community sustained relationships among the wall system, courtyards, and public buildings.

Belief and ritual knowledge concerns evidence-supported spatial relationships between ritual activities and ethical concepts, on the one hand, and temples, ancestral halls, memorial arches, and public nodes, on the other. Temples, ancestral halls, pavilions, arches, and street intersections provided spatial carriers through which shared beliefs, ethical norms, memories of scholarly or official achievement, and perceptions of security became legible within settlement order. Ancestor worship, blessing rituals, and temple-fair gatherings gave public space functions beyond everyday interaction and helped reinforce group identity, moral norms, and psychological stability [7]. Where supported by historical records or local narratives, belief and ritual may also be interpreted as contributing to communal reassurance and the maintenance of order; this study cautiously describes this dimension as "symbolic defense." Unlike material defenses such as walls, gates, and troop-hiding caves, symbolic defense operates through divine protection, ancestor veneration, loyalty and righteousness, symbols of achievement, and boundary rituals that strengthen collective cohesion and perceived security. When temples or pavilions occupy elevated positions, gateways, or street intersections, their symbolic and spatial roles must be interpreted through case-specific evidence rather than inferred from location alone.

Knowledge of decorative craftsmanship and architectural components is embodied in gate towers, entrance surrounds, plaques, screen walls, window latticework, and brick, wood, and stone carving. Whereas construction knowledge emphasizes material structure and spatial form, this category focuses on practical experience in material processing, component fabrication, pattern composition, and dimensional control [15]. Differences in the placement, workmanship, and motifs of decoration communicated family identity, architectural status, ritual order, and local aesthetics, translating ideas of auspiciousness, respect for learning, and filial and loyal conduct into recognizable architectural symbols. The principal types and their meanings are summarized in Table 9 and illustrated in Figure 11.

Trade and transport knowledge is expressed in the spatial organization of movement, exchange, transitions between water and land routes, and controlled access. At Diji City, the North Water Gate connected the settlement to river transport on the Qinhe, while the South Gate linked it to overland routes; internal streets, the barbican, and gate passages together formed a sequence for transshipment, entry and distribution, and access control. This is the clearest expression of trade and transport knowledge among the five cases. At Douzhuang

Village, Cross Street, Dongmenli, Jiuzhai Alley, and the Upper Residence of the Shangshu Mansion organized family movement, circulation of goods, and public interaction within the same street system, allowing streets to function simultaneously as transport corridors, ritual spaces, and carriers of memory. Trade and transport knowledge thus concerns the concentration of economic movement, social interaction, and security management within gates, water gates, streets, landing points, and courtyard boundaries. At Huangcheng Xiangfu, gate passages and courtyard sequences similarly regulate movement between outer and inner domains.

Table 9. Types and meanings of decorative craftsmanship and architectural-component knowledge.

Knowledge Type	Primary Spatial Carriers	Craft Characteristics	Cultural and Spatial Significance
Brick-carving knowledge	Entrance surrounds, gable-end details, screen walls, and wall nodes	Create decorative surfaces through variations in carving depth, compositional layering, and brick assembly	Express auspicious meanings, family aspirations, and courtyard hierarchy
Wood-carving knowledge	Beams and purlins, bracket elements, doors and windows, and latticework	Use openwork, relief, and incised carving according to timber grain and component scale	Integrate structural components, spatial decoration, and ritual expression
Stone-carving knowledge	Door-pillow stones, column bases, steps, and balustrade panels	Use the durability of stone for load-bearing, protection, and decorative treatment	Reinforce entrance boundaries while expressing residential identity and construction status
Plaque and inscription knowledge	Gate towers, halls, ancestral halls, and memorial arches	Organize spatial meaning through wording, calligraphic form, and placement	Record family achievement, ethical values, and local memory
Doors, windows, and screen-wall components	Gate passages, courtyard entrances, latticework, and screen walls	Control views and spatial hierarchy through scale, form, and degrees of ornamentation	Differentiate inner and outer space and express ritual order and family identity

Resource and livelihood knowledge refers to experience accumulated through the long-term acquisition, use, storage, and allocation of resources [40]. It concerns how water, farmland, production materials, and everyday supplies entered the operational system of fortified settlements and were organized spatially through wells, water gates, riverbanks, courtyards, cave spaces, storage areas, and defensive towers. Four aspects are particularly evident in the middle Qinhe cases: rivers, wells, and internal storage facilities secured domestic and defensive water supplies; valley flats, slopes, and courtyards supported cultivation, processing, and household production; local resources and production by-products were reused; and grain, fuel, and daily necessities were stored in cave spaces, courtyard outbuildings, and towers to increase resilience during periods of risk. At Guoyu Ancient City, caves embedded within the wall combine residence, storage, and refuge, illustrating multifunctional use of limited space. At Huangcheng Xiangfu, Heshan Tower combines defense, refuge, and material storage, reflecting the resource-mobilization capacity of the resident lineage.



(**a**) Brick carving



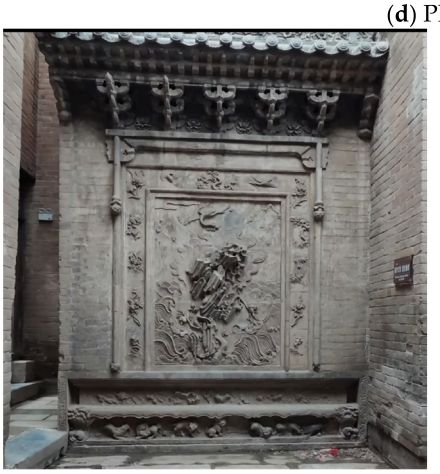
(**b**) Wood carving



(**c**) Stone carving



(**d**) Plaques and inscriptions



(**e**) Door, window, and screen-wall components

Figure 11. Decorative craftsmanship and architectural-component techniques.

Collective-defense knowledge comprises shared experience developed in response to warfare, banditry, raiding, and other acute risks. Its core is not the presence of walls, gates, or troop-hiding caves in themselves, but the ways in which community members used these spatial nodes to organize alarm, closure, sectional defense, movement, refuge, and counteraction. Defensive spaces in the middle Qinhe fortified settlements commonly exhibit the capacity to shift between everyday use and wartime defense [41]. In ordinary periods, gates, streets, courtyards, and towers supported access, interaction, residence, and storage; under threat, the same system could be converted into controlled closure,

segmented guarding, route delay, and collective refuge. The principal types of collective-defense knowledge are summarized in Table 10.

Table 10. Types of collective-defense knowledge and supporting case evidence.

Type of Collective-Defense Knowledge	Case Evidence	Defensive Behavioral Process
Village-fort community coordinated defense	Guoyu wall system, Yu Tower, and wall-embedded caves	In ordinary periods, these spaces supported residence, storage, and circulation; in wartime, the walls closed the settlement, Yu Tower provided surveillance, and wall-embedded caves supported refuge, storage, and sectional defense.
Vertically coordinated defense	Xiangyu southern wall, corner towers, troop-hiding caves, and street system	In wartime, corner towers supported surveillance and warning, troop-hiding caves concealed defenders, and streets organized movement and delayed attackers.
Clan-fort defense	Huangcheng Xiangfu inner and outer enclosures, Heshan Tower, and troop-hiding cave system	The outer enclosure provided initial defense, the inner enclosure enabled retreat, Heshan Tower supported surveillance and storage, and troop-hiding caves provided refuge, together forming a multilayer defensive process.
Water-land gateway defense	Diji City South Gate, North Water Gate, barbican, and riverfront wall	In ordinary periods, these nodes linked water and land transport; in wartime, gates, the water gate, and the barbican controlled access, slowed attacks, and concentrated defense.
Inner-outer enclosure coordinated defense	Douzhuang inner and outer enclosures, Nine Gates and Nine Passes, tunnels, and troop-hiding cave system	In wartime, gateways were closed, tunnels enabled movement, troop-hiding caves supported concealed defense, and courtyards and streets formed zones of coordinated defense.

Local-memory knowledge is a form of tacit architectural knowledge with strong narrative and identity-forming dimensions [42]. It extends beyond oral legends or historical anecdotes to encompass collective experience formed through long-term residence, defense, production, and ritual practice and preserved through spatial carriers. Compared with explicit architectural form, local memory places greater emphasis on the historical events, personal and family relationships, lineage trajectories, phases of fort construction, and community experience associated with particular places. Its defining characteristic is the anchoring of historical events, personal narratives, and collective experience to specific spatial settings, allowing fortified settlements to function as sites of cultural memory that can be narrated, recognized, and transmitted.

3.3. Hierarchical Structure and Relational Representation of Vernacular Architectural Knowledge

Building on the preceding identification and case comparison, explicit and tacit architectural knowledge are organized through hierarchical and relational representation. The purpose is to show both hierarchy and cross-connections among knowledge categories, spatial carriers, and representative cases, thereby supporting classification, cross-case comparison, and conservation translation. The framework comprises two interrelated layers and 11 categories. Explicit knowledge includes environmental siting, defensive space, construction, and spatial organization, corresponding primarily to material-spatial information identifiable through survey, field observation, and spatial analysis. Tacit knowledge includes clan organization, belief and ritual, craft practice, trade and transport, resources and

livelihoods, collective defense, and local memory, describing associations among social relations, behavioral experience, local memory, and specific spatial carriers. Figures 12 and 13 visualize the hierarchical structure and principal relationships of the two layers.



Figure 12. Hierarchical structure and spatial relationships of explicit vernacular architectural knowledge.



Figure 13. Hierarchical structure and spatial anchoring of tacit vernacular architectural knowledge.

This relational representation serves three purposes: to reveal hierarchical and intersecting relationships among knowledge categories; to make tacit social experience more explicit by linking it to spatial anchors and evidence sources; and to provide a structural basis for interpreting formation pathways and developing site-specific conservation translations.

4. Discussion

4.1. From Defensive Morphology to Socio-Spatial Knowledge: Comparison with Previous Research

Previous research on defensive traditional settlements and fortified villages has focused mainly on siting, walls and gates, defensive facilities, street structure, and settlement morphology, with a gradual shift from historical description and typological classification toward geospatial and quantitative morphological analysis [2]. A recurring finding is that rivers, mountains, terraces, elevation differences, and transport conditions influence settlement siting and defensive organization. Research on fortified settlements in the Fen River Basin, for example, shows that siting reflected both the practical requirements of production and daily life and micro-scale defensive needs, with different terrain conditions associated with different defensive patterns [6]. The analysis of 66 regional background sites and 19 spatial-analysis samples in the middle Qinhe River Basin broadly supports this view: fortified settlements are closely associated with valleys, water systems, and varied topographic positions, and proximity to water, use of elevation differences, and exploitation of natural boundaries are common regional characteristics. The five in-depth cases, however, show that broadly similar environmental settings do not necessarily generate the same defensive morphology. Xiangyu Ancient Fortress relies on river cliffs, its southern wall, and vertical defensive nodes to form a layered defensive system; Huangcheng Xiangfu, where natural defensive advantages are more limited, depends more heavily on constructed inner and outer enclosures, Heshan Tower, and a hierarchical courtyard system; Diji City combines a riverfront setting and water-land gates with distinctive crucible-wall construction; and Douzhuang Village organizes layered defense through inner and outer enclosures and multiple gates. The findings therefore agree with earlier environmental-adaptation research in recognizing the importance of terrain and hydrology, while treating the environment as a set of constraints and opportunities rather than as a single determinant of spatial form.

Research on internal settlement space has likewise moved beyond descriptive street morphology toward analyses of network topology, spatial depth, accessibility, and node centrality. Recent studies combining GIS with space syntax have used Integration, Choice, NAIN/NACH, and Step Depth to examine street organization, access control, and defensive hierarchy in traditional defensive communities [18]. Other work has used boundary morphology, road structure, and architectural spatial indicators to reduce reliance on purely experiential judgment [19]. These approaches show that defensive space is not simply an accumulation of walls, gates, and towers; it functions as a continuous system incorporating road networks, entrances, node hierarchies, and spatial depth. The cases examined here are consistent with this direction. Xiangyu's fishbone network and T-junctions, Diji City's dense narrow lanes, and Douzhuang's "three longitudinal and one transverse" framework with multiple gates all indicate that street organization contributed to access control, route delay, and spatial subdivision. The present study, however, extends the question beyond spatial configuration to ask how these material arrangements were connected to historical patterns of use and collective behavior. Morphological analysis is therefore linked to behavioral processes and local experience rather than treated as an end in itself.

The distinction becomes more pronounced when explicit and tacit architectural knowledge are considered together. Research on vernacular architecture has long recognized that heritage value lies not only in physical form but also in material use, building skills, local

practices, and intergenerational transmission [15]. Recent international heritage scholarship likewise emphasizes the close relationship between tangible places, traditional knowledge, social practice, local memory, and the people who hold that knowledge [16]. The present study shares this position but adds a methodological constraint for architectural-spatial analysis: tacit knowledge must have both a traceable spatial anchor and an identifiable evidential basis. Clan organization, belief and ritual, collective defense, and local memory are therefore not inferred from architectural form alone; they enter the analysis only after documentary sources, field observations, spatial relationships, or oral materials have been cross-checked and linked to specific spaces or behavioral processes.

The five cases further demonstrate the multiple correspondences among spatial carriers, behavioral processes, social relations, and cultural meanings. At Guoyu Ancient City, the wall not only defines the settlement boundary but, together with wall-embedded caves, Yu Tower, and village space, supported residence, storage, surveillance, and coordinated defense. At Diji City, the crucible wall embodies local material selection and wall construction while also being associated with historical iron production, resource reuse, and local memory. Heshan Tower at Huangcheng Xiangfu is both a vertical defensive structure and a space connected with family organization, material storage, and historical narrative. A single architectural node therefore need not correspond to only one knowledge category; it may instead become a point at which material technology, spatial function, social behavior, and cultural meaning intersect. Figures 12 and 13 serve this purpose: they do not in themselves prove social meanings, but organize different forms of knowledge and their spatial carriers into a relational framework for cross-case comparison.

The contribution relative to previous work is therefore not to demonstrate again that fortified settlements were defensive or environmentally adaptive, nor to introduce a new digital knowledge technology. Rather, it is to connect established environment-morphology research with scholarship on local knowledge and social practice. Fortified settlements are treated as socio-spatial knowledge carriers composed of material space, behavioral processes, social organization, and local memory, while the scope of interpretation is constrained by multi-source evidence, spatial anchoring, and cross-case comparison. This perspective shifts analysis from describing what architectural and spatial features exist to examining how those spaces carried, organized, and transmitted local experience. It also provides the conceptual basis for the following discussion of knowledge-formation pathways and conservation translation.

4.2. Interpretive Formation Pathways of Vernacular Architectural Knowledge

Vernacular architectural knowledge in the historic fortified settlements of the middle Qinhe River Basin was not the product of any single influence, whether environmental, institutional, or technological. Rather, it emerged through the repeated adjustment and consolidation of residential, productive, defensive, and construction practices within specific regional and historical contexts [43]. Across the five cases, its formation can be interpreted through interconnected pathways of environmental adaptation, risk response, organizational embedding, and technological transformation.

Terrain and hydrology provide an important environmental context for the formation of this knowledge. The middle Qinhe River Basin is characterized by interlocking mountains, hills, valleys, and basins; water systems, terraces, gorges, and local relief together shaped the physical settings of fortified settlements. Siting required a balance between production and everyday life, on the one hand, and security, on the other: communities sought access to water, farmland, and transport routes while also using elevated ground, cliffs, riverbanks, and mountain slopes to reinforce boundaries and surveillance. Across the sample, settlements tend to be close to water without occupying identical river-edge

positions, and they use terrain defensively in different ways [44]. This pattern is comparable to findings from the Fen River Basin that emphasize micro-siting adaptation and distinct defensive responses under different geographical conditions [6]. The five Qinhe cases, however, further show that proximity to water alone cannot explain differences in internal street networks, material strategies, or coordinated defense.

Persistent historical insecurity is strongly associated with both defensive facilities and the organization of behavior. Many Qinhe fortified settlements were established or enlarged during the Ming and Qing dynasties against backgrounds of social unrest, banditry, warfare, and local needs for self-protection. These pressures correspond with walls, gates, troop-hiding caves, and defensive towers, as well as street turns, courtyard enclosure, access control, and the organization of public space. Yet the cases do not share a single defensive template. Xiangyu emphasizes vertically coordinated defense among river cliffs, corner towers, and troop-hiding caves; Huangcheng Xiangfu reinforces defense through constructed inner and outer enclosures and tall vertical nodes; and Douzhuang relies on multiple gates and the subdivision of inner and outer enclosures. Security risk is therefore better understood as an important contextual condition that encouraged defensive spatial organization rather than as its sole determinant.

Clan and family organization provided an important social basis for implementing, maintaining, and transmitting local experience. Many fortified settlements in the Qinhe River Basin were not constructed solely by official military forces; their development was also related to the organizational capacity of local elites, official families, merchant families, and lineage communities. Clan organization could mobilize labor, finance, and management and could be expressed spatially through courtyard depth, gate hierarchy, ancestral-hall location, street boundaries, and relationships between inner and outer enclosures. Relationships between these spatial phenomena and social rules-such as generational hierarchy, lineage branches, and collective cooperation-are treated here as interpretive propositions that require documentary, secondary oral-history/local-memory, and spatial support; clan institutions are not inferred directly from courtyard form. This association among social organization, spatial order, and defensive cooperation is particularly evident in the better-documented cases of Huangcheng Xiangfu and Douzhuang Village.

The interaction between local resources and craft practice was central to the localization of technical knowledge. Coal, iron ore, timber, stone, brick and tile, and commercial capital provided material conditions for construction, while the properties of local materials and accumulated craft experience shaped particular building techniques. At Diji City, production by-products were incorporated into the thick crucible wall, providing a clear example of the relationship among resource context, material reuse, and defensive construction. Huangcheng Xiangfu, by contrast, illustrates the association between family economic capacity and the construction of large residences, Heshan Tower, and public buildings. Material selection, wall construction, defensive towers, and courtyard building can therefore be understood as localized outcomes of interactions between resource conditions and technical practice.

Transport and commerce are also associated with the development of multifunctional fortified space [45]. The middle Qinhe River Basin linked valley routes with local material exchange, while fort gates, streets, water gates, and courtyard forecourts accommodated the movement of people and goods and could also function as controlled access points under conditions of risk. At Diji City, the route from the South Gate to the North Water Gate combines transitions between land and water transport with defensive control. Main streets, gates, and courtyard nodes at Guoyu, Xiangyu, and Douzhuang similarly show the coexistence of everyday interaction and security management. Trade and transport should therefore not be treated as functions separate from defense; in some settlements they

intersected with entrance control, spatial concentration and dispersal, and public nodes to shape multifunctional patterns of use.

In summary, the formation of vernacular architectural knowledge in the middle Qinhe fortified settlements can be represented as an interpretive sequence linking historical-regional conditions, mediating practices, spatial outcomes, and knowledge interpretation (Figure 14). Natural settings and historical pressures provided constraints and opportunities, while local communities, clan organization, resource use, and craft practice mediated how those conditions were translated into different boundaries, street networks, spatial nodes, and material constructions. The five cases support the explanatory value of these associations but do not justify claims of stable, one-way causality. Figure 14 is therefore framed as an interpretive pathway rather than a deterministic mechanism.

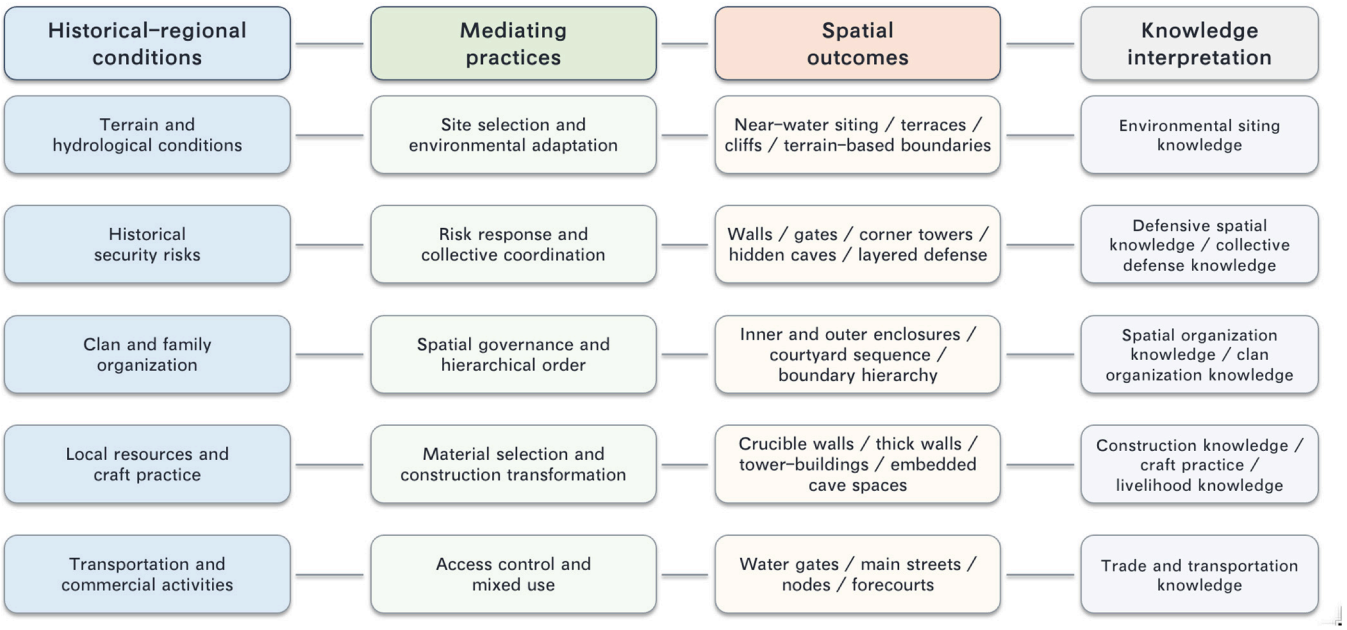


Figure 14. Interpretive formation pathways of vernacular architectural knowledge in historic fortified settlements of the middle Qinhe River Basin.

4.3. Contemporary Change and the Vulnerability of Vernacular Architectural Knowledge

The historical pathways discussed above explain how vernacular architectural knowledge developed. In contemporary conservation contexts, however, urbanization, out-migration and population aging, tourism development, standardized repair, and changes in climate and hydrological conditions may simultaneously affect physical fabric, patterns of spatial use, and knowledge transmission. Recent research on traditional settlements has brought population decline, aging, tourism experience, and continuity of public space into a common analytical frame [20], while reviews of vernacular architecture identify adaptive renewal and cultural continuity as central concerns of sustainable development [10]. Conservation of vernacular architectural knowledge must therefore consider both whether material carriers survive and whether the associated knowledge continues to be used, understood, and transmitted.

Out-migration and community aging may reduce the number of everyday bearers of local terminology, building skills, ritual practices, and local memory. Tourism development may privilege visually recognizable walls and towers, reducing complex knowledge of production, clan organization, and collective behavior to a limited set of scenic symbols. Standardized repair using substitute materials unrelated to local material logic can likewise sever relationships among materials, craft, and memory. Traditional villages are also

increasingly exposed to combined pressures associated with rapid urbanization and climate change, including hydrological degradation, declining social resilience, and deterioration of cultural heritage [46]. These environmental pressures are particularly relevant to riverfront walls, slope-edge boundaries, and drainage systems and should be incorporated into long-term monitoring.

Tourism intensity, demographic change, and climate risk were not quantitatively modeled for the five cases. They are therefore discussed here as contemporary conservation pressures and sources of knowledge vulnerability rather than as drivers empirically demonstrated by this study. Future research should combine demographic data, visitor movement, repair archives, material-deterioration records, and climate data to monitor the vulnerability of different knowledge categories over time.

4.4. Conservation Translation of Vernacular Architectural Knowledge

Vernacular architectural knowledge is an important cultural basis for the continuity of fortified settlements in the middle Qinhe River Basin. Its conservation should therefore extend beyond physical repair to the integrated maintenance of spatial form, construction experience, social relations, and local memory [4]. Walls, gates, streets, courtyards, ancestral halls, defensive towers, tunnels, and troop-hiding caves are not only elements of architectural morphology but also spatial carriers through which local knowledge is preserved and transmitted. The conservation gap addressed here is not the absence of general principles, but the difficulty of translating those principles into decisions about which knowledge relationships should be conserved, who should be responsible, how they should be interpreted, and how their condition should be monitored. The strategy therefore follows a translation chain linking knowledge assets, spatial carriers, potential risks, specific actions, responsible actors, funding and other resources, and monitoring.

First, vernacular architectural knowledge should be documented systematically. Field surveys, historical documents, genealogies and inscriptions, existing oral-history records, and visual records can be used to establish categorized records of siting, defensive systems, courtyard organization, building skills, clan ritual, trade and transport, collective defense, and local memory. Rather than describing this archive as a "knowledge-graph database," the revised framework proposes traceable knowledge records. Each record should specify the evidence source, spatial location, knowledge category, reliability status, relevant conservation object, and date of update. Such a system could support conservation planning, interpretive texts, educational programs, and pre-intervention review.

Second, conservation should be organized through collaboration among multiple actors [9]. Vernacular knowledge often resides in residents' everyday experience, family memory, and local narrative and cannot be fully identified through external expert survey and planning alone [47]. Responsibilities can be differentiated in practice. Heritage and construction authorities can oversee standards, approvals, and public funding; township and village organizations can coordinate routine management and public-space maintenance; residents, local knowledge holders, and traditional craftspeople can provide information on use, terminology, and techniques and participate in verifying interpretive content; professional conservation and design teams can undertake survey, material diagnosis, repair planning, and interpretation design; and universities and research institutions can support archival work, education, and long-term monitoring. Such differentiation translates "community participation" from a general principle into specific tasks of knowledge provision, content verification, routine maintenance, and transmission.

Third, vernacular knowledge should be integrated into conservation and regeneration practice [10]. Conservation should not simply reproduce conventionalized symbols of traditional architecture [48], but should derive spatial organization, material use, behavioral routes, and cultural narratives from local knowledge and connect them directly to conservation objects and scenarios of use. At Guoyu Ancient City, the wall, wall-embedded caves, water gate, and Yu Tower can be documented and interpreted as a continuous system of residence, storage, surveillance, and coordinated defense. At Xiangyu Ancient Fortress, an interpretive route can follow the river cliff, southern wall, corner towers, troop-hiding caves, over-street towers, and internal streets to explain vertically coordinated defense. At Huangcheng Xiangfu, interpretation should extend beyond iconic buildings to emphasize relationships among inner and outer enclosures, courtyard hierarchy, Heshan Tower, official-residence organization, clan order, and defense. At Douzhuang Village, the inner and outer enclosures, Nine Gates and Nine Passes, tunnels, and family courtyards can be used to explain community-based, spatially segmented defense.

At the same time, regeneration and tourism development should avoid reducing vernacular knowledge to superficial imagery or scenic consumption. Cultural festivals, educational activities, heritage interpretation, and rural tourism can all transmit local knowledge, but their value depends on accurate interpretation rather than on consuming fortified-settlement imagery as a visual symbol [7]. Conservation interventions should follow principles of minimum intervention, authenticity, and reversibility, and interpretive installations should avoid obscuring or altering heritage fabric. When materials are replaced, routes modified, or public facilities upgraded, existing material logic, patterns of use, and community memory should be incorporated into decision making. Depending on the project, funding may combine public heritage or traditional-village conservation funds, routine maintenance budgets, research and educational programs, village collective resources, and, where applicable, earmarked reinvestment of tourism revenue. Specific financing mechanisms, however, must reflect current local institutions and fiscal conditions and are not assumed to be uniform across the study area.

Diji City illustrates how knowledge translation can move from principle to implementation. A basic interpretive route is proposed from the South Gate to the crucible wall, a material and iron-production interpretation node, the riverfront wall, and the North Water Gate. Interpretation can be organized in four layers. The first explains local iron production and the origin of discarded crucibles. The second uses wall sections, material samples, or reversible graphics to show how crucibles were incorporated into masonry. The third explains how the thick wall, South Gate, and North Water Gate relate spatially to water-land transport and defense. The fourth uses verified local-memory and secondary oral-history materials to explain how this distinctive construction material became part of local identity. Interpretive installations should remain reversible and minimally intrusive and may incorporate appropriately sourced oral-history material.

Before physical repair, the material composition, deterioration, replacement history, and spatial location of the crucible wall should be documented. Compatible repair can then be considered without replacing irregular crucible masonry with standardized walling that would erase the material logic of the structure. The corresponding knowledge relationships, conservation risks, specific actions, responsible actors, and monitoring priorities are summarized in Table 11.

Table 11. Conservation-translation matrix for the five in-depth cases.

Case	Core Knowledge Relationship	Potential Conservation/ Interpretive Risk	Specific Action	Principal Actors	Monitoring/ Review
Guoyu Ancient City	Village–fort integration; wall–caves–water gate–Yu Tower	Object-focused repair or display may separate residential and defensive relationships	Document the elements as a continuous system; interpret relationships among residence, storage, surveillance, and coordinated defense	Competent authorities; village organizations; professional conservation teams; residents	Record wall/cave deterioration; periodically review interpretive content
Xiangyu Ancient Fortress	River cliffs and vertically coordinated defense	Treating defensive nodes as isolated attractions may obscure the behavioral chain of coordinated defense	Create an interpretive sequence from river cliff to southern wall, corner towers, troop-hiding caves, over-street towers, and streets; use reversible signage where necessary	Heritage management body; village organizations; professional teams	Condition of key nodes, visitor-route conflicts, and visitor understanding
Huangcheng Xiangfu	Official-residence–clan order and defense through inner and outer enclosures	Overemphasis on iconic buildings may obscure spatial hierarchy and social organization	Interpret inner and outer enclosures, gate hierarchy, courtyard depth, Heshan Tower, and family history together	Management body; heritage authorities; researchers; community knowledge holders	Cross-check interpretive texts against historical sources; monitor integrity of the spatial sequence
Diji City	Crucible-material memory and water-land control	Generic material replacement or purely scenic presentation may erase material–production–memory relationships	Create a material archive and compatible repair rules for the crucible wall; establish an interpretive route linking the South Gate, crucible wall, riverfront wall, and North Water Gate	Heritage authorities; materials/structural specialists; management body; community	Annually update records of crucible-wall deterioration, replacement materials, and repairs
Douzhuang Village	Inner/outer enclosures, Nine Gates and Nine Passes, and clan-based layered defense	Fragmentation of remains and loss of oral memory may weaken understanding of the integrated defensive system	Reconstruct a relational diagram of gates and checkpoints; use oral history to explain zoned defense across inner and outer enclosures, tunnels, and courtyards	Village organizations; professional teams; local knowledge holders	Condition of gate-ways/tunnels; update oral-history records

4.5. Research Limitations

Several limitations should be noted. First, the study is confined to the middle Qinhe River Basin. The 66 regional background sites, 19 spatial-analysis samples, and five in-depth cases cannot substitute for independent validation in the upper and lower reaches. The five cases were selected purposively for maximum variation; this is useful for revealing typological differences but does not support probabilistic generalization. The framework

proposed here should therefore be understood as potentially transferable rather than universally applicable and requires further testing in other reaches and at sites with different preservation conditions. Second, tacit architectural knowledge remains interpretive. Distinguishing DO/SP/FO/OR/RI evidence, corroborating multiple sources, spatially anchoring claims, and using a coding guide increase transparency, but interpretations may still vary among researchers and across secondary source traditions. Third, the regional GIS analysis is limited to kernel density, distance to the nearest watercourse, and elevation and slope derived from a 30 m DEM. These measures establish environmental context but cannot independently demonstrate street-network topology, accessibility, or visual-surveillance mechanisms. Fourth, urbanization, population outflow, tourism, and climate pressures are discussed primarily as conservation contexts rather than through longitudinal quantitative models. Fifth, community perspectives in the present study are represented indirectly through previously published or publicly available secondary oral-history/local-memory materials rather than through direct participant recruitment or co-researcher involvement; future work may strengthen community validation and participation where appropriate ethical review and consent procedures are in place. Finally, the proposed conservation-translation pathways require testing through actual repair, interpretation, and management projects to assess their cost, institutional fit, and long-term effectiveness.

5. Conclusions

This study examined historic fortified settlements in the middle Qinhe River Basin through GIS-based analysis of regional spatial context, a unified comparison of five cases, multi-source corroboration, hierarchical coding, and spatial anchoring. The findings address the three research questions. First, vernacular architectural knowledge can be distinguished analytically into two interrelated layers. Explicit knowledge comprises environmental siting, defensive space, construction, and spatial organization; tacit knowledge comprises clan organization, belief and ritual, craft practice, trade and transport, resources and livelihoods, collective defense, and local memory. This distinction is not a simple tangible-intangible dichotomy; it reflects differences in how evidence is obtained and how much interpretation is required. Second, tacit knowledge cannot be directly extracted through hierarchical coding. Credible identification depends on corroboration among documentary, spatial, field, and secondary oral-history/local-memory evidence and on anchoring interpretations to specific spatial carriers or behavioral processes; hierarchical coding serves to organize evidence-supported interpretations into comparable categories. Third, broadly similar regional environments and historical security pressures did not produce a single fortified morphology. Village-fort integration at Guoyu, vertically coordinated riverfront defense at Xiangyu, the integration of official residence, clan organization, and defense at Huangcheng Xiangfu, the linkage of resource-based construction with water-land control at Diji City, and layered defense through inner and outer enclosures at Douzhuang show that environmental conditions were translated into different spatial responses through mediating processes involving social organization, material resources, transport functions, and collective behavior.

The principal contribution of the study is a traceable pathway linking multi-source evidence, spatial anchoring, knowledge classification, cross-case comparison, and conservation translation. This shifts research on fortified settlements beyond isolated descriptions of form and components toward relational interpretation of material space, behavioral practice, social relations, and local memory. In conservation terms, the findings support a move from generic repair of individual structures and scenic presentation toward the maintenance of site-specific knowledge relationships. Material repair, interpretive routes, archival updating, and long-term monitoring should be defined for each fortified settle-

ment according to its principal knowledge carriers, potential risks, community roles, and management conditions. The evidence base nevertheless covers only the middle Qinhe River Basin, and the five cases are not statistically representative of the entire basin. Future work should include formal intercoder agreement testing for tacit knowledge and, where consistent primary data are available, case-scale quantitative analyses such as space syntax and viewshed analysis. Research should also extend to the upper and lower reaches of the Qinhe River, undertake cross-regional validation, and evaluate the transferability and practical effectiveness of the framework through community co-validation, conservation practice, and interpretation projects.

Author Contributions: Conceptualization, Y.W. and G.L.; methodology, G.L. and Y.W.; investigation, Y.W. and J.Y.; resources, G.L.; data curation, Y.W.; writing—original draft preparation, Y.W.; writing—review and editing, Y.W. and G.L.; visualization, Y.W.; funding acquisition, G.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study did not involve human participants. Ethical review and approval were not applicable for this study.

Informed Consent Statement: Not applicable, as this study did not involve human subjects.

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding authors.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. Inventory of 66 Fortified Settlements and Related Remains in Three Counties of the Middle Qinhe River Basinc.

County	Number	Fortified-Settlement Sites
Yangcheng County	23 sites	Guoyu Fortress, Huangcheng Xiangfu, Diji City, Yicheng Zhongyi Fort, Wangcun Ningyuan Fort, Liushan Fort, Xiafu Qianle Fort, Huaizhuang Fort, Hujia Village Baoning Fort, Xipo Fort, Shiyuan Niutou Fort, Xiakong Fort, Yinjia Village Fort, Liangjia Village Nanpo Fort, Zhaishang Village Fort, Tuncheng Fort, Shangkong Fort, Nan'anyang Pan Family Courtyard, Shangzhuang Village, Zhongzhuang Village, Shangfu Village, Daqiao Village, and Yangcheng Old City
Zezhou County	32 sites	Xiaozhai Shengmu Hall, Peiwa Fort, Dongguituo Fort, Wanzi City, Zhaixi Fort, Hetaowa Fort, Cuigou Fort, Yedi Fort, Shenhou Laoguan Fort, Lingtang Fort, Xiantai Fort, Nangou South Fort, Huanghe Jianshan Fort, Huanghe Jinshan Fort, Heshang Fort, Nanlingshang Fort, Qinglong Fort, Huanxiu Yong'an Fort, Zhoucun, Ershengtou Fort, Tianjing Pass, Dayang Ancient Town, Shicongtou Pan Family Site, Xihuangshi, Dongbaling Xie Family Fortress, Jiaozan City, Eastern Xiaokou Great Wall, Gaohuiliang Xingbing Fort, Lanche Village, Yehe Fort, Mengliang Fort, and Heishiling General Yue Fort
Qinshui County	11 sites	Xiangyu Ancient Fortress, Wu'an Military Fort, Guonan Site, Guozhuang Fort, Nandazhai, Huaizhuang Fort, Pingshang Fort, Douzhuang Fortress, Guobi Fortress, Liu Family Residence, and Wangjie Fortress

Table A2. Spatial-analysis sample.

No.	County	Township/ Town	Village/Sample Name	Overall Preservation	Sample Type	MOHURD Traditional-Village Batch
1	Yangcheng County	Beiliu Town	Guoyu Village (Guoyu Ancient City/Guoyu Fortress)	Walls survive; interior fabric is relatively complete	Large integrated village–fort type	First batch
2	Yangcheng County	Beiliu Town	Huangcheng Village (Huangcheng Xiangfu/Huangcheng)	Walls survive; interior fabric is relatively complete	Official-residence–clan–defense composite type	First batch
3	Yangcheng County	Runcheng Town	Runcheng Village (Diji City/Runcheng Small Fort)	Walls survive; interior fabric is relatively complete	Material-oriented fortified settlement	Fourth batch
4	Yangcheng County	Runcheng Town	Shangzhuang Village (Shangzhuang Fortress)	Residential houses and courtyards	Clan defensive-tower type	First batch
5	Yangcheng County	Runcheng Town	Shangfu Village	East Gate checkpoint; residential houses and courtyards	Transport–commercial fortified settlement	Fourth batch
6	Yangcheng County	Runcheng Town	Zhongzhuang Village (Zhongzhuang Historic Building Group)	Residential houses and courtyards	Courtyard type within the Runcheng settlement cluster	Fourth batch
7	Yangcheng County	Fengcheng Town	Nan'anyang Village (Pan Family Courtyard)	Residential houses and courtyards	Family-courtyard traditional settlement	Third batch
8	Yangcheng County	Runcheng Town	Tuncheng Village (Tuncheng Fort)	Fort gate	Fortified settlement represented by surviving gate remains	Third batch
9	Qinshui County	Zhengcun Town	Xiangyu Village (Xiangyu Ancient Fortress)	Walls survive; interior fabric is relatively complete	Riverfront defensive type	First batch
10	Qinshui County	Jiafeng Town	Douzhuang Village (Douzhuang Fortress)	Residential houses and courtyards	Clan–defense composite type	First batch
11	Qinshui County	Tuwo Township	Xiwenxing Village (Liu Family Residence)	Residential houses and courtyards	Clan-residence traditional settlement	First batch
12	Qinshui County	Jiafeng Town	Wu'an Village (Wu'an Military Fort)	Remnant walls	Military-fort remains type	Fourth batch
13	Qinshui County	Duanshi Town	Pingshang Village (Pingshang Fort)	South and north gates	Fortified settlement represented by surviving gateways	Fifth batch
14	Qinshui County	Jiafeng Town	Guobi Village (Guobi Fortress/Guobi Historic Building Group)	Residential houses and courtyards	Trade–clan–defense composite type	Third batch
15	Zezhou County	Beiyicheng Town	Xihuangshi Village	Residential houses and courtyards	Courtyard-fort traditional village	First batch
16	Zezhou County	Zhoucun Town	Zhoucun	West and south city gates	Historic-town gate-tower settlement	Second batch

Table A2. *Cont.*

No.	County	Township/ Town	Village/Sample Name	Overall Preservation	Sample Type	MOHURD Traditional-Village Batch
17	Zezhou County	Jinmiaopu Town	Tianjingguan Village	City gate tower	Historic pass-type settlement	Second batch
18	Zezhou County	Nancun Town	Yedi Village (Yedi Fort)	Fort walls survive	Mountain fortified settlement with surviving walls	Third batch
19	Zezhou County	Shanhe Town	Dongbaling Village (Dongbaling Xie Family Fortress)	Residential houses and courtyards	Mountain courtyard-fort type	Third batch

References

1. Pardo, J.M.F. Challenges and Current Research Trends for Vernacular Architecture in a Global World: A Literature Review. *Buildings* **2023**, *13*, 162. [CrossRef]
2. Lin, X.; Zhang, Y.; Wu, Y.; Yang, Y.; Yang, W. A Bibliometric Review of Chinese Traditional Defensive Settlement Heritage. *Buildings* **2024**, *14*, 3107. [CrossRef]
3. Rössler, M. World Heritage Cultural Landscapes: A UNESCO Flagship Programme 1992–2006. *Landsc. Res.* **2006**, *31*, 333–353. [CrossRef]
4. Taylor, K.; Lennon, J. Cultural Landscapes: A Bridge between Culture and Nature? *Int. J. Herit. Stud.* **2011**, *17*, 537–554. [CrossRef]
5. Lin, Z.; Li, B.; Chen, K. Spatial Distribution Patterns of Cultural Heritage in the Qinhe River Basin and Its Influencing Factors. *Huazhong Archit.* **2025**, *43*, 72–76. (In Chinese) [CrossRef]
6. Wang, X.; Fan, W.; Meng, L.; Wang, Y. Site Selection Characteristics and Defense Patterns of Fort Settlements in the Fen River Basin, China. *npj Herit. Sci.* **2025**, *13*, 590. [CrossRef]
7. Smith, L. *Uses of Heritage*; Routledge: London, UK, 2006. [CrossRef]
8. Tweed, C.; Sutherland, M. Built Cultural Heritage and Sustainable Urban Development. *Landsc. Urban Plan.* **2007**, *83*, 62–69. [CrossRef]
9. Zhu, S.-C.; Chou, R.-J. Analysing the Resilience of Fortified Settlements from the Perspective of Community Capital: The Case of Pujing Community in the Ancient Acropolis, Yongning, Quanzhou. *Land* **2025**, *14*, 143. [CrossRef]
10. Zong, J.; Wan Mohamed, W.S.; Zaky Jaafar, M.F.; Ujang, N. Sustainable Development of Vernacular Architecture: A Systematic Literature Review. *J. Asian Archit. Build. Eng.* **2025**, *24*, 3558–3574. [CrossRef]
11. Yang, X.; Grussenmeyer, P.; Koehl, M.; Macher, H.; Murtiyoso, A.; Landes, T. Review of Built Heritage Modelling: Integration of HBIM and Other Information Techniques. *J. Cult. Herit.* **2020**, *46*, 350–360. [CrossRef]
12. Acierno, M.; Cursi, S.; Simeone, D.; Fiorani, D. Architectural Heritage Knowledge Modelling: An Ontology-Based Framework for Conservation Process. *J. Cult. Herit.* **2017**, *24*, 124–133. [CrossRef]
13. Khouri, S.; Oufaida, H.; Amrani, R.; Kacher, S.; Ouahab, S.; Cherrad, M. Knowledge Base Construction for the Semantic Management of Environment-Enriched Built Heritage: The Case of Algerian Traditional Houses Architecture. *J. Cult. Herit.* **2023**, *63*, 217–229. [CrossRef]
14. Carriero, V.A.; Gangemi, A.; Mancinelli, M.L.; Nuzzolese, A.G.; Presutti, V.; Veninata, C. Pattern-Based Design Applied to Cultural Heritage Knowledge Graphs: ArCo: The Knowledge Graph of Italian Cultural Heritage. *Semant. Web* **2021**, *12*, 313–357. [CrossRef]
15. Curk, A.; Momčilović Petronijević, A.; Cvetković, I.; Stajić, D. Preservation of Vernacular Knowledge and Skills as a Form of Architectural Heritage Protection in Serbia. *J. Asian Archit. Build. Eng.* **2026**, *25*, 1173–1191. [CrossRef]
16. ICOMOS. *International Charter and Guidance on Sites with Intangible Cultural Heritage*; International Council on Monuments and Sites: Charenton-le-Pont, France, 2024.
17. Li, B.; Lu, Y.; Li, Y.; Zuo, H.; Ding, Z. Research on the Spatiotemporal Distribution Characteristics and Accessibility of Traditional Villages Based on Geographic Information Systems—A Case Study of Shandong Province, China. *Land* **2024**, *13*, 1049. [CrossRef]
18. Zhang, N.; Zhu, L.; Sun, Y.; Shi, Z.; Chen, Q.; Deng, H. Spatial Temporal Evolution Characteristics of Defensive Traditional Community in Southwest China with a Case Study of Chengzi Village in Yunnan. *npj Herit. Sci.* **2025**, *13*, 178. [CrossRef]
19. Huang, Y.; Ye, Z.; Zhang, Q.; Chen, Y.; Wu, W. Space Gene Quantification and Mapping of Traditional Settlements in Jiangnan Water Town: Evidence from Yubei Village in the Nanxi River Basin. *Buildings* **2025**, *15*, 2571. [CrossRef]

20. Ding, L.; Huang, S.; Li, Q.; Zhang, H. Using Space Syntax and Regression Analysis to Decode Spatial Vitality: A Mixed-Methods Study of Traditional Settlements. *Buildings* **2026**, *16*, 3279. [CrossRef]
21. Bi, S.; Du, J.; Tian, Z.; Zhang, Y. Investigating the Spatial Distribution Mechanisms of Traditional Villages from the Human Geography Region: A Case Study of Jiangnan, China. *Ecol. Inform.* **2024**, *81*, 102649. [CrossRef]
22. ICOMOS. *ICOMOS Guidelines on Fortifications and Military Heritage*; International Council on Monuments and Sites: Paris, France, 2021.
23. Bian, J.; Chen, W.; Zeng, J. Spatial Distribution Characteristics and Influencing Factors of Traditional Villages in China. *Int. J. Environ. Res. Public Health* **2022**, *19*, 4627. [CrossRef] [PubMed]
24. Li, B.; Wang, J.; Jin, Y. Spatial Distribution Characteristics of Traditional Villages and Influence Factors Thereof in Hilly and Gully Areas of Northern Shaanxi. *Sustainability* **2022**, *14*, 15327. [CrossRef]
25. Zhang, X.; Yang, H.; An, Y. Spatial Morphology and Geographic Adaptability of Traditional Villages in the Hehuang Region, China. *Buildings* **2025**, *15*, 244. [CrossRef]
26. Wang, X.; Shen, A.; Hou, X.; Tan, L. Research on Cluster System Distribution of Traditional Fort-Type Settlements in Shaanxi Based on K-Means Clustering Algorithm. *PLoS ONE* **2022**, *17*, e0264238. [CrossRef] [PubMed]
27. Zhang, Y. Investigation and Research on Ancient Fortresses in the Middle Reaches of the Qinhe River. Master's Thesis, Shanxi University, Taiyuan, China, 2025. (In Chinese)
28. Tengö, M.; Brondizio, E.S.; Elmqvist, T.; Malmer, P.; Spierenburg, M. Connecting Diverse Knowledge Systems for Enhanced Ecosystem Governance: The Multiple Evidence Base Approach. *Ambio* **2014**, *43*, 579–591. [CrossRef] [PubMed]
29. Nonaka, I. A Dynamic Theory of Organizational Knowledge Creation. *Organ. Sci.* **1994**, *5*, 14–37. [CrossRef]
30. Agrawal, A. Dismantling the Divide between Indigenous and Scientific Knowledge. *Dev. Change* **1995**, *26*, 413–439. [CrossRef]
31. O'Connor, C.; Joffe, H. Intercoder Reliability in Qualitative Research: Debates and Practical Guidelines. *Int. J. Qual. Methods* **2020**, *19*, 1609406919899220. [CrossRef]
32. Li, D.; Gao, X.; Lv, S.; Zhao, W.; Yuan, M.; Li, P. Spatial Distribution and Influencing Factors of Traditional Villages in Inner Mongolia Autonomous Region. *Buildings* **2023**, *13*, 2807. [CrossRef]
33. Jia, S.; Bin Mohd Isa, M.H.; Binti Abdul Aziz, Z. Spatial Characteristics of Defensive Traditional Architecture in Multiethnic Village of Guangxi: Case Studies of Mozhuang Village and Guxietun Village. *Front. Archit. Res.* **2023**, *12*, 683–699. [CrossRef]
34. Wu, L.; Zhan, Q.; Li, Y. Three-Tiered Defensive System and Ethnic Fusion: A Study of Architectural Art in Guomari Fortress, Eastern Qinghai. *Buildings* **2025**, *15*, 2218. [CrossRef]
35. Nguyen, A.T.; Truong, N.S.H.; Rockwood, D.; Le, A.D.T. Studies on Sustainable Features of Vernacular Architecture in Different Regions across the World: A Comprehensive Synthesis and Evaluation. *Front. Archit. Res.* **2019**, *8*, 535–548. [CrossRef]
36. Zhang, W.; Yang, H. Quantitative Research of Traditional Village Morphology Based on Spatial Genes: A Case Study of Shaanxi Province, China. *Sustainability* **2024**, *16*, 9003. [CrossRef]
37. Oliveira, V. *Urban Morphology: An Introduction to the Study of the Physical Form of Cities*, 2nd ed.; Springer: Cham, Switzerland, 2022. [CrossRef]
38. Hillier, B.; Hanson, J. *The Social Logic of Space*; Cambridge University Press: Cambridge, UK, 1984. [CrossRef]
39. Yan, K. Study on the Spatial Form and Ancestral Hall Architecture of Fortified Villages in Southeastern Shanxi. Master's Thesis, Xi'an University of Architecture and Technology, Xi'an, China, 2019. (In Chinese)
40. Berkes, F. *Sacred Ecology*, 4th ed.; Routledge: New York, NY, USA, 2018. [CrossRef]
41. Liang, X.; Yin, J.; Yang, B.; Song, Z. The Spatial-Temporal Evolution of Kaiping Diaolou and Villages' Defensive Functional Pattern. *Geogr. Res.* **2017**, *36*, 121–133. (In Chinese) [CrossRef]
42. Hu, J.; Gong, S.; Wei, Y.; Li, Z.; Ding, K. Research of Ancient Villages and Towns Types on Social Memory Symbols System: A Case of Shanxi Province. *Hum. Geogr.* **2018**, *33*, 107–115. (In Chinese) [CrossRef]
43. Sillitoe, P. The Development of Indigenous Knowledge: A New Applied Anthropology. *Curr. Anthropol.* **1998**, *39*, 223–252. [CrossRef] [PubMed]
44. Xie, G.; Zhou, Y.; Liu, C. Spatial Distribution Characteristics and Influencing Factors of Hakka Traditional Villages in Fujian, Guangdong, and Jiangxi, China. *Sustainability* **2022**, *14*, 12068. [CrossRef]
45. Wu, J.; Li, Z.; Zhong, Q.; Xie, L. Spatial Morphological Characteristics of Traditional Settlements: A Comparative Study along the Miaojiang Border Wall and Miaojiang Corridor in Hunan, China. *Ain Shams Eng. J.* **2024**, *15*, 103071. [CrossRef]
46. Wang, H.; Liu, P.; Shan, Y.; Zhang, J.; Xia, S. Evolutionary Characteristics, Improvement Strategies and Driving Mechanisms of the Human Settlement Environment in Chinese Traditional Villages Based on Historical Hydrological Resilience Assessment. *Buildings* **2025**, *15*, 4264. [CrossRef]

47. Raymond, C.M.; Fazey, I.; Reed, M.S.; Stringer, L.C.; Robinson, G.M.; Evely, A.C. Integrating Local and Scientific Knowledge for Environmental Management. *J. Environ. Manag.* **2010**, *91*, 1766–1777. [CrossRef] [PubMed]
48. Vellinga, M. The Noble Vernacular. *J. Archit.* **2013**, *18*, 570–590. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.