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Chongen Wang

en076@qq.com

Taiyuan University of Technology

Sijiang Liu

Taiyuan University of Technology

Chuanjin Hu

Taiyuan University of Technology

Min Liu

Shanxi No.1 Construction Group Co., Ltd.

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Shared axial organisation and contrasting gate and stage arrangements in Chengtang temples of Jincheng China

Chongen Wang[1], Sijiang Liu[1], Chuanjin Hu[1] & Min Liu[2]

[1] College of Architecture and Art, Taiyuan University of Technology, Taiyuan, China
[2] Shanxi First Construction Group Co., Ltd., Taiyuan, China

Correspondence and requests for materials should be addressed to Chongen Wang (en076@qq.com) or Sijiang Liu (1830555151@qq.com).

Abstract

Gate–stage categories distinguish temple entrances, but their relationship to wider spatial organisation remains unclear. A year of team research documented all 116 Chengtang temple sites in Shanxi. Of 112 sites in Jincheng, China, 39 compounds whose surviving buildings are predominantly of the Ming and Qing periods were eligible for analysis; 35 have resolved entrance and axial relationships. Cross-tabulation identifies 22 combined and 13 separate gate–stage arrangements, yet 34 share a stage–hall axis. Nine confirmed axial offering structures occur across both categories. Seven spatial tests detect no significant global same-category clustering. The analytical group covers 34.8% of Jincheng sites and has a higher proportion of sites in relatively good or fair condition than the remaining inventory. Entrance variation coexists with shared axial organisation and a lateral-stage exception. The inventory quantifies these relationships within the analytical group and defines their regional evidential coverage.

Keywords: Chengtang temples; spatial configuration; architectural typology; global join counts; heritage conservation; architectural survey

Introduction

Cheng Tang was the founding ruler of China's Shang dynasty (c. 1600–1046 BCE), later also known as Shang Tang, Tangwang or Tangdi. Worship of this figure connects narratives of virtuous kingship with agrarian appeals for rain. Pre-imperial texts, including the Xunzi and Lüshi chunqiu, recount his self-reproach and prayers during drought. Han and later writings elaborated the miraculous elements of these accounts, while Song and Ming literati used them to discuss royal virtue and political responsibility[1]. In local worship, Cheng Tang is both a commemorated historical ruler and a deity invoked for rainfall. Chengtang temples provide the architectural setting for this tradition.

Chengtang worship forms part of the ritual traditions of the Central Plains of ancient China. Shanxi Province preserves an important concentration of related temples. The study area, Jincheng, is located in southeastern Shanxi Province, China. Inscriptional and documentary studies trace temple building in the region to the late Tang period. In 1116, during the Northern Song dynasty, the Chengtang temple on Mount Xicheng in Yangcheng received the imperial designation Guangyuan; village temples continued to be built and repaired thereafter[2]. By the Ming and Qing periods (1368–

1912), these temples were widely involved in village rain prayers, worship and ritual performance in southeastern Shanxi[3]. This historical context provides a basis for comparing spatial variation among compounds associated with a shared religious tradition. The present study focuses on compounds whose surviving buildings are predominantly of the Ming and Qing periods, distinguishing the history of the belief from the dates of the buildings analysed.

In southeastern Shanxi, Chengtang worship is closely associated with village organisations, ritual performance and temple construction. Li and Zhu[2] show through inscriptions from Yangcheng that official and local participation supported temple building, while village associations and their leaders raised funds, organised construction and managed ritual affairs. Cai[3] discusses the influence of local associations and Tangwang worship on community life. Zhang's study of Kangying[4] shows that a Chengtang temple could accommodate multiple deities and serve educational and village administrative functions at different times. These studies establish the links between Chengtang temples and village life, providing historical context for interpreting the spatial accommodation of worship, performance and public activities.

Architectural studies further examine the spatial organisation of Chengtang temples through individual cases and regional comparison. Zhu and Yao[5] examine terraced courtyards and the offering hall at Xiajiao, noting its roles in worship and watching performances. Research on Kangying distinguishes the Tianqi and Chengtang temples and links the stages in the front and rear courts to their respective deities[4]. Li[6] compares 12 Chengtang ritual complexes in southern Shanxi and northern Henan, examining components, axes and spatial sequences. Zhu et al.[7] examine folk ritual architecture in Shanxi within the historical context of the Song and Jin dynasties. Group comparison and axial organisation are therefore established subjects. An inventory-based study can extend this knowledge by establishing the frequency, combinations and exceptions of these relationships within an explicitly delimited analytical group.

Such comparison requires explicit spatial levels of typological analysis. Moneo[8] (pp. 23–24) relates type to a shared formal structure and the relationships and historical conditions of its constituent elements. Hillier's account of spatial configuration[9] explains why individual spaces must be understood within a larger relational whole. Chengtang temples can therefore be compared through the relationships between access, performance and worship, while retaining their specific courtyard arrangements. The combination or separation of a gate and stage defines a functional relationship; the position of an offering structure concerns its configuration within a courtyard; and the combination of ritual courtyards concerns the organisation of the compound. Distinguishing these levels allows different arrangements of the same relationship to be compared.

Regional heritage studies offer methodological precedents. Arias Tapiero et al.[10] combine digital recording and GIS to inventory more than 2,000 vernacular buildings in 13 Portuguese villages, integrating materials, construction systems, use and condition. Wang[11] connects vernacular landscape fragments to regional structure, Yang et al.[12] examine ancestral temples and village space, and Kang et al.[13] compare Shanxi churches through semantic integration and graph-enhanced clustering. Recent studies further emphasise functional connections between heritage elements[14], architectural knowledge in interpretable morphological comparison[15], and traceable links between

data and historical context[16]. These directions require quantitative findings to be explained through architectural relationships rather than additional indicators alone.

This study examines 39 Chengtang temple compounds in Jincheng, Shanxi Province, China, whose surviving buildings are predominantly of the Ming and Qing periods, comparing shared functional relationships and layout variation across combined and separate gate–stage arrangements. Entrance categories and stage–hall axial organisation are recorded separately. Cross-tabulation, geographical testing and case comparison identify shared relationships, differences within categories and spatial patterns, while the complete inventory defines evidential coverage.

A year of systematic work by the team produced a complete inventory of all 116 Chengtang temple sites in Shanxi, including 112 in Jincheng. From 51 spatially legible compounds, 39 whose surviving buildings are predominantly of the Ming and Qing periods were selected; 35 have resolved entrance and axial relationships. Of these 35, 34 share an axial stage–hall relationship across combined and separate gate–stage categories. Case comparison shows that this shared relationship accommodates different offering structures and courtyard combinations, alongside an exception with lateral stage placement. Entrance categories alone therefore do not adequately describe compound layouts; they must be interpreted alongside courtyard configurations and compound organisation. The inventory establishes the frequency, combinations, exceptions and evidential coverage of earlier architectural observations within the analysable group, providing a basis for identifying regional heritage values through group comparison.

Methods

Study area and data sources

The study area is Jincheng, in southeastern Shanxi Province, China. The research dataset, hereafter termed the survey records, results from a year of compilation and analysis by the team and covers all 116 Chengtang temple sites in Shanxi Province. The records include original identifiers, coordinates, dates, dimensions, condition, architectural descriptions, schematic plans and photographs. Recorded attributes and descriptions form the analytical basis. Original collection, checking and aggregation followed the relevant technical specification[17], supporting comparable recording fields. For this study, identifiers, component names, relative positions and image dates were checked and linked to their textual and visual evidence. Ambiguous fields were flagged individually without excluding other interpretable attributes. Spatial comparison concerns identifiable functions and relationships; schematic plans were not converted into measured dimensions.

The inventory counts each distinct temple site as one unit, yielding a total of 116 sites. Jincheng contains 112 sites (96.6%); the other four remain in the provincial distribution map. The analytical unit is the surveyed compound, not each hall, pavilion or stage. In composite compounds, the gate–stage label describes the overall entrance, while the axial field records the stage–Chengtang hall relationship; internal ritual units are interpreted separately. At Kangying, these refer to the combined compound entrance and the rear Chengtang unit, respectively. The 116-site inventory defines provincial coverage, the 112 Jincheng sites provide the reference group for selection, 39

eligible compounds support configuration analysis, and 35 resolved cases support joint entrance–axis comparison (Table 1). These denominators are not interchangeable.

Table 1 | Study-group selection

Area	All	Legible	Pre-Ming	Altered entry	Conflicting	Included
Chengqu	2	2	0	0	0	2
Qinshui	18	7	1	0	0	6
Yangcheng	60	23	3	1	0	19
Zezhou	26	13	5	1	0	7
Gaoping	6	6	0	0	1	5
Total	112	51	9	2	1	39

Thirty-nine sites are included; exclusion categories are mutually exclusive.

The study examines the identifiable present-day spatial relationships of 39 Chengtang temple compounds whose surviving buildings are predominantly of the Ming and Qing periods. Period attribution follows the recorded dates and descriptions of surviving buildings; some records rely on architectural style. Foundation, rebuilding, addition and repair dates are distinguished, and dates for individual buildings are not assigned to the formation of the entire layout. Of 51 legible compounds, nine retaining Song, Jin or Yuan core fabric are excluded. Beiyigu and Xizhuang are excluded because of modern entrance reconstruction or alteration; Xiyang is set aside because gate–stage descriptions differ between records. Guoyu is included despite its Yuan foundation: its surviving main buildings are explicitly described as Ming–Qing in character, with Ming rebuilding and Qing repairs recorded. Routine maintenance or ancillary additions alone do not exclude a site, and new additions are not classified as Ming–Qing buildings. Recorded dates and styles place 31 compounds in the Qing group and eight in the mixed Ming–Qing group. These groups do not imply that all temples were founded in these periods or that entire compounds were built simultaneously.

GIS maps show the location within China, Shanxi's terrain and temple sites, distinguishing the 39 selected compounds from other heritage sites (Fig. 1). Of 116 sites, 112 use a single recorded centre and four use mean coordinates of deduplicated component centres. Centres represent recorded measurement points rather than assumed gate positions; the single-centre test evaluates the influence of representative-point selection.

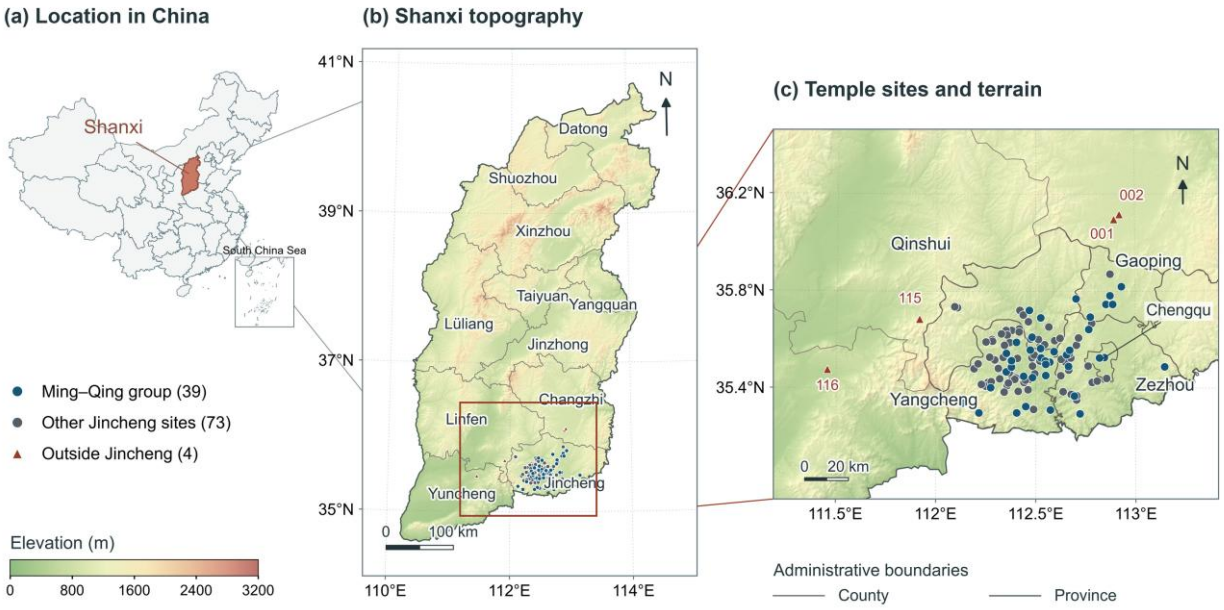


Fig. 1 | Study area and temple distribution. a Location in China; **b** Shanxi terrain; **c** enlarged site distribution. Numbers identify four sites outside Jincheng.

Functional coding and relational comparison

The workflow comprises eligibility screening, functional coding, relational comparison, geographical testing and case interpretation (Fig. 2). The compound is the unit of comparison. Gate–stage category describes its overall entrance, whereas stage–hall organisation describes the relationship between performance and principal worship buildings. Internal ritual units remain distinguishable within composite compounds. Each field is coded separately before cross-tabulation.

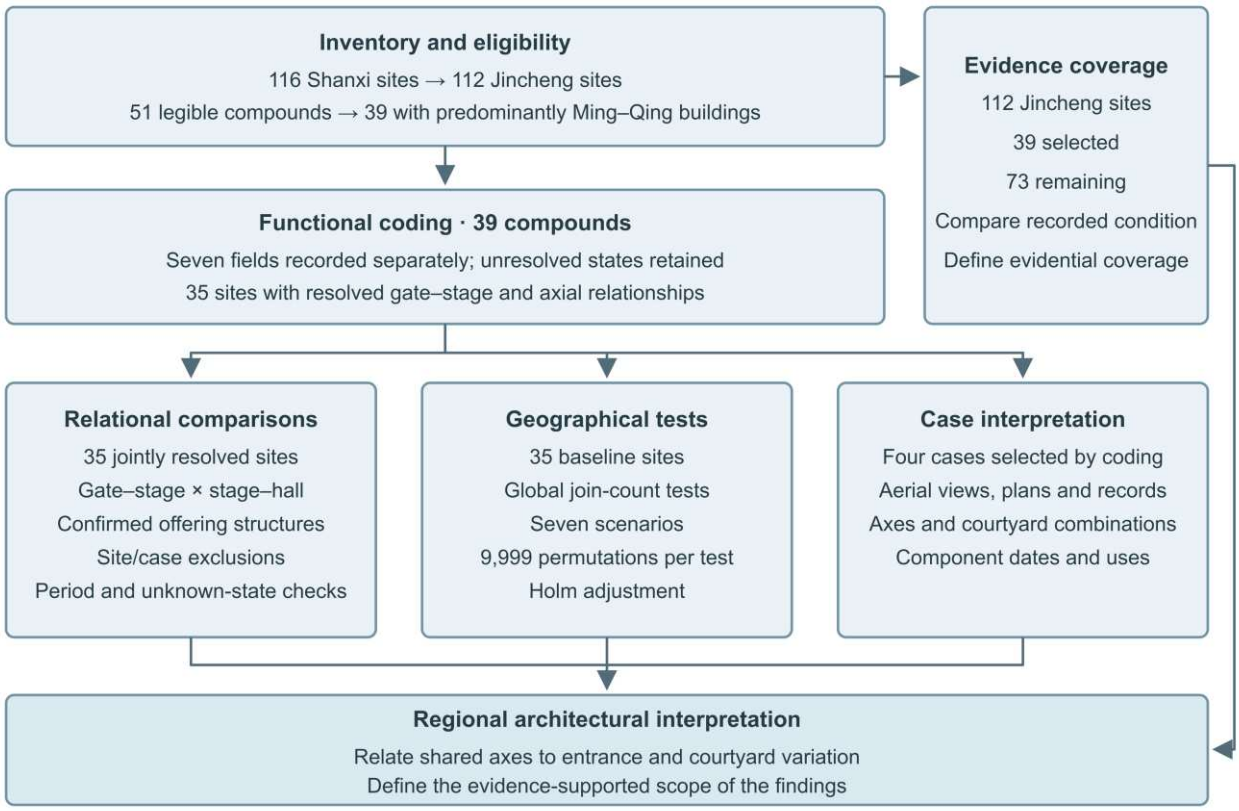


Fig. 2 | Research workflow.

Seven fields describe access, performance and worship (Table 2). Stage–hall organisation is coded A when the textual and plan evidence identifies a shared main axis, L when the stage occupies a lateral position, and U when the performance building or relationship is unresolved. This field records axial organisation, not measured collinearity or equivalence in courtyard depth, elevation or ritual use. A site-level evidence record links named components, source excerpts and plan positions to each code. Textual and plan-based evidence states remain separate; unconfirmed or unshown features are not converted into absence.

Table 2 | Functional and spatial coding rules

Field	Definition and recording status	Analytical role
Gate–stage relationship	Combined: entrance and stage occupy one building. Separate: they occupy different buildings. Unclear records remain unknown.	Distinguishes access–performance relationships; supplies the binary labels for spatial testing.
Stage count	Number of identifiable surviving performance buildings; unknown counts are not coded as zero.	Identifies single- and multiple-stage arrangements.

Field	Definition and recording status	Analytical role
Axial offering structure	A structure on the main axis with an explicit offering-related name and function. Original terms (baiting, baidian and xiandian) are retained without treating them as identical forms. Xiangting, Tianqi halls and terraces are not automatically included; unconfirmed cases remain unconfirmed.	Identifies the position of offering structures along the stage–hall axis.
Sequential courts	Longitudinally connected courts: confirmed, not visible or unknown.	Distinguishes successive ritual spaces from a single court.
Terraced courts	Courts organised at different elevations: plan-confirmed, text-only or unconfirmed.	Identifies vertical variation without inferring it from a schematic plan alone.
Subsidiary courts	Courts attached outside the principal courtyard: visible in images, not visible or unknown.	Identifies extensions to the principal ritual unit.
Stage–hall organisation	A: shared main axis; L: lateral stage; U: unresolved. Coded from named components and relative positions, not measured collinearity.	Tests whether axial organisation crosses gate–stage categories.

Fields are coded separately and may overlap; unknown, unconfirmed or unshown features are not coded as zero.

Gate–stage category is used as the initial descriptive classification. Stage–hall organisation is then cross-tabulated with it to distinguish relationships shared across entrance categories from differences within a category. Confirmed axial offering structures are then identified within each combination. These comparisons use the same sites with resolved entrance and axial relationships, so differences reflect the recorded fields rather than changes in membership. Unconfirmed offering structures remain unresolved; their presence–absence association is not estimated. The comparison assesses the architectural information omitted by the initial classification, not predictive accuracy or superiority of a classification algorithm.

Descriptive checks omit each resolved site in turn, exclude Kangying and then all four illustrated cases, and compare shared-axis proportions between the recorded Qing and mixed Ming–Qing groups. All unresolved axial relationships are assigned first to axial and then to lateral organisation; all unresolved entrance labels are assigned first to combined and then to separate arrangements. These alternative assignments provide bounds for the corresponding proportions. The ranges are not confidence intervals, and exclusions do not constitute validation using an independent sample.

Each field uses the number of sites with interpretable evidence as its denominator, with unresolved states reported separately. Evidence checking links source descriptions and plans to the coding record; independent double coding was not undertaken. Recorded condition is compared between the analytical group and the remaining Jincheng inventory to describe evidence coverage. Since selection also involves chronology and spatial legibility, this comparison does not isolate preservation as the cause of inclusion or adjust the observed layout proportions.

Geographical adjacency and global join counts

Categorical spatial dependence has been examined in archaeology[18]. The global join-count test assesses whether temples sharing a gate–stage category are more often adjacent than expected under random labelling. Anselin and Li[19] define global same- and different-category join counts. We sum the two same-category counts and report each component. Labels 0 and 1 identify categories rather

than architectural intensity. Permutation inference for the 35 sites avoids a large-sample normal approximation.

The spatial analysis includes 35 temples with known labels and coordinates: 22 combined arrangements coded 1 and 13 separate arrangements coded 0. Each site selects its k nearest neighbours by WGS84 ellipsoidal geodesic distance. An undirected edge is created if either site selects the other. The weight W_{ij} is 1 for an edge and 0 otherwise, with a zero diagonal and no row standardisation. The baseline uses k = 5, with k = 3 and 8 testing scale dependence; the union rule can give a site more than k neighbours. Edges depend on location, not labels. Nearest neighbours accommodate uneven site density and do not represent a historical transmission radius. Fifth-neighbour distances have a median of 13.83 km and range from 6.47 to 28.94 km. The source datum is not separately specified; WGS84 is a convention for distance calculation.

Let BB and WW denote joins between two sites with combined arrangements and two sites with separate arrangements, respectively, and let BW denote joins between sites in different categories. Their sum is the total number of edges, M. The same-category count T and proportion Q are:

$$T = BB + WW = \sum_{1 \le i < j \le n} W_{ij} I(y_i = y_j), \quad Q = \frac{T}{M} \quad (1)$$

Here i and j index temples, n is the scenario's site count, and y_i and y_j are gate–stage labels. I(·) equals 1 for matching labels and 0 otherwise; i < j counts each undirected edge once. T is the same-category join count, M the total edge count and Q their ratio. Equation (1) combines the standard BB and WW counts. On a fixed graph, upper-tail tests using T or Q are equivalent.

The null model fixes site locations, the adjacency graph and category totals, allowing only the labels to be exchanged. With fixed totals, the probability that two distinct sites receive the same category defines the expected value of Q. Adding the two same-category probabilities under random labelling gives:

$$E_0(Q) = \frac{n_1(n_1 - 1) + n_0(n_0 - 1)}{n(n - 1)} \quad (2)$$

$E_0(Q)$ denotes the expected same-category proportion under unrestricted random labelling; n_1 and n_0 are the combined and separate counts, and $n = n_1 + n_0$. Equation (2) follows from sampling without replacement at fixed category totals and provides a theoretical reference; inference uses permutations. County- and period-restricted permutations have their own conditional distributions. Inference is conditional on the observed sites and graph, without treating the inventory as a random sample or assuming independent edges.

Permutation inference and sensitivity analysis

Gate–stage labels are randomly permuted 9,999 times on the fixed graph. T is recalculated for each permutation, and the number of simulated counts at least as large as the observed count is recorded. The upper-tail Monte Carlo p value uses the plus-one correction[20]:

$$p = \frac{b + 1}{B + 1} \quad (3)$$

B is the number of random permutations (9,999), and b counts permutations with a same-category count greater than or equal to the observed value. Permutations are generated independently and may repeat; the plus-one correction avoids reporting a zero p value. The upper-tail test assesses clustering. A significant result indicates excess same-category joins under the specified adjacency rule; a non-significant result means that such clustering was not detected.

Seven tests comprise the k = 5 baseline, k = 3, k = 8, single-centre sites, within-county permutation, within-period permutation and Qing-group sites. The single-centre set retains 32 sites and the Qing-group set 29 sites with known labels; each receives a rebuilt k = 5 graph. County- and period-restricted permutations retain the 35 baseline nodes and graph but exchange labels only within the same county or recorded period group, preserving the corresponding category totals. The latter assesses additional same-category adjacency after controlling for recorded chronological composition.

Each test uses 9,999 permutations. The seven tests form one exploratory family, with Holm adjustment controlling the family-wise error rate at 0.05[21]. Raw p values are ranked from smallest to largest and multiplied by 7, 6, …, 1; cumulative maxima are capped at 1 and returned to the original test order. The random seed is set to 20260913 for reproducibility. The k = 3, 5 and 8 tests share unrestricted label permutations, while other scenarios use independent random streams. Figures show observed Q, permutation means and the 2.5th–97.5th percentile ranges of simulated distributions. These are random-labelling reference bands, not confidence intervals; inference uses upper-tail p values.

Chronological control combines eligibility with within-group checks. Pre-Ming core fabric and documented modern entrance alterations are excluded before distinguishing Qing and mixed Ming–Qing groups using recorded dates and styles. Period-restricted permutation and the Qing-only test assess whether the spatial finding depends on this recorded composition. These checks reduce chronological heterogeneity but do not demonstrate identical layouts across the Ming and Qing periods or date the formation of the surviving relationships.

Table 3 summarises the roles of relational comparison and spatial testing.

Table 3 | Analytical methods and purposes

Procedure	Calculation or basis	Role	Source
Eligibility	51 → 39 → 35	Defines period groups and field denominators	Records and images
Relational comparison and checks	Progressive fields; exclusions and period groups	Identifies relationships and checks case/period dependence	Table 2
Join counts	T = BB + WW; Q = T/M	Measures geographical adjacency of labels	Eq. 1; ref. 19
Random labelling	Fixed category totals	Defines the expected same-category proportion	Eq. 2
Permutation	B = 9,999; p = (b+1)/(B+1)	Compares the observed count with random labelling	Eq. 3; ref. 20
Sensitivity	Seven scenarios; Holm	Checks neighbourhood, point and period assumptions	Ref. 21

Significance is assessed using each scenario’s own permutation distribution.

Case comparison and historical evidence

Four cases are selected on the basis of their group-level combinations and available imagery, covering combined–axial, separate–axial and separate–lateral arrangements. Yong'an and Beichen are compared to examine axial components across entrance categories; Kangying illustrates composite ritual units, and Xishanling illustrates lateral stage placement. Group coding establishes their positions before aerial photographs, plans and historical records are interpreted. Category frequencies are calculated from the analytical group, not from the four cases.

Each case is examined through an aerial photograph, an original plan and a functional diagram. Photographs show building volumes and enclosure; plans locate named components and annotations of new or collapsed buildings; analytical diagrams summarise access, performance and worship relationships. Functional diagrams are schematic and not to scale. Comparison examines shared functions, relative component positions and combinations of ritual units to explain how similar codes can correspond to different architectural configurations.

Historical records supplement case interpretation. Survey records are compared with published inscription transcriptions and accounts of use for specific components, distinguishing additions and repairs from changes in use. For retrospectively recorded events, the inscription date and the reported event date are distinguished. These records inform interpretation of individual components; dates of local work are not treated as dates for the formation of entire compounds.

Group comparison and case interpretation use the same component names and relational definitions. Only fields coded across the group enter group statistics; attributes verified only in individual cases, including ritual-unit use and change, remain case-level evidence.

Results

Functional relationships and descriptive checks

The study group contains 39 compounds: 31 assigned to the Qing group and eight to the mixed Ming–Qing group on the basis of recorded dates and styles. Entrance and axial relationships are both resolved at 35 sites. The 22 combined gate–stage compounds are all axial; of the 13 separate compounds, 12 are axial and one has a lateral stage at Xishanling (Table 4). Shared stage–hall axes thus occur across both entrance categories, accounting for 34 of the 35 resolved sites (97.1%). Entrance separation includes both axial and lateral arrangements.

Of the four sites with unresolved gate–stage labels, Shangqin has a confirmed shared stage–hall axis and three have unresolved axial relationships. Across all 39 sites, 35 are axial, one is lateral and three are unresolved. Site-level relationships are shown in Fig. 3.

Table 4 | Gate–stage relationships and functional configurations

Gate–stage	Shared axis A	Lateral L	Unknown U	Offering confirmed	Offering unconfirmed	Total
Combined	22	0	0	4	18	22
Separate	12	1	0	5	8	13
Unknown	1	0	3	0	4	4

n = 39. A: shared axis; L: lateral stage; U: unresolved. Unconfirmed offering structures are not coded as absent.

Including the offering-structure field identifies nine confirmed axial offering structures across two combinations: four combined–axial cases (Wu'an, Zhongzhai, Xishentou and Beichen) and five separate–axial cases (Mazhuang, Yong'an, Baijiazhuang, Zhongzhuang and Hongshang). Offering provision remains unconfirmed at 30 of the 39 sites, including the lateral case; these are not coded as absent. Entrance categories, gate–stage and axial combinations, and confirmed offering provision are traceable in the site-level matrix (Fig. 3).

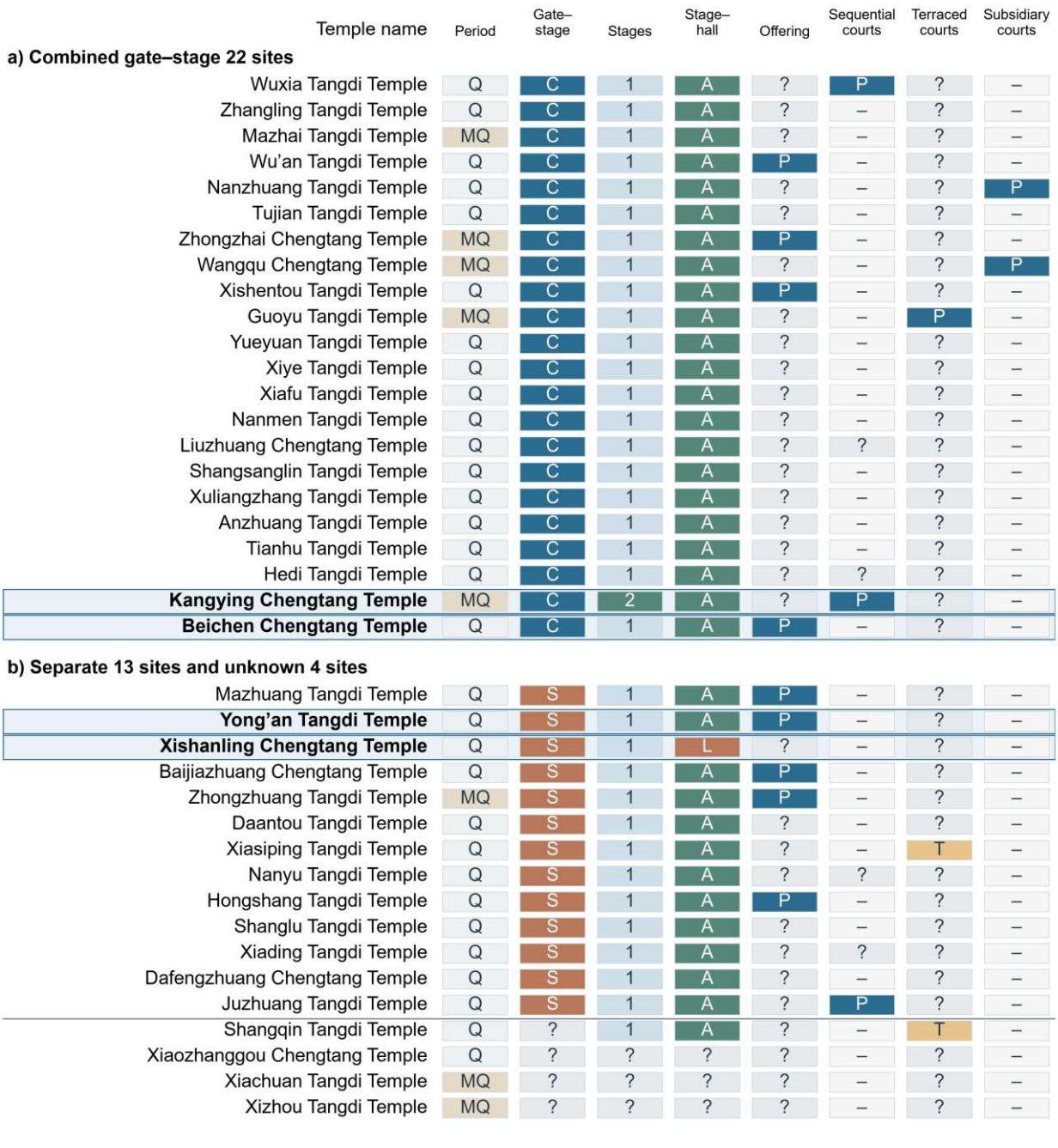
Shared-axis proportions remain 33/34–34/34 under leave-one-out checks and 33/34 after excluding Kangying. Excluding the four illustrated cases leaves 31 axial sites: 20 combined and 11 separate. The proportions are 28/29 for the Qing group and 6/6 for the mixed Ming–Qing group. Assigning the three unresolved axial relationships to either endpoint gives a full-group range of 35/39–38/39 (89.7–97.4%). These descriptive checks assess dependence on individual sites and unresolved states, not coding accuracy.

Recorded period-group composition and entrance categories are reported in Table 5. Combined arrangements account for 17 of 29 resolved Qing cases (58.6%) and five of six mixed Ming–Qing cases (83.3%). Assigning all four unresolved entrance labels to either category bounds the combined share at 56.4–66.7% across the 39 compounds.

Table 5 | Recorded period groups and gate–stage relationships

Period group	Total	Combined	Separate	Unknown	Known	Combined (%)
Qing	31	17	12	2	29	58.6
Mixed Ming–Qing	8	5	1	2	6	83.3
Total	39	22	13	4	35	62.9

Combined percentages use known labels; period groups follow recorded dates and styles of surviving buildings, not foundation dates or the formation dates of entire layouts.



Temple name	Period	Gate–stage	Stages	Stage–hall	Offering	Sequential courts	Terraced courts	Subsidiary courts
a) Combined gate–stage 22 sites								
Wuxia Tangdi Temple	Q	C	1	A	?	P	?	–
Zhangling Tangdi Temple	Q	C	1	A	?	–	?	–
Mazhai Tangdi Temple	MQ	C	1	A	?	–	?	–
Wu'an Tangdi Temple	Q	C	1	A	P	–	?	–
Nanzhuang Tangdi Temple	Q	C	1	A	?	–	?	P
Tujian Tangdi Temple	Q	C	1	A	?	–	?	–
Zhongzhai Chengtang Temple	MQ	C	1	A	P	–	?	–
Wangqu Chengtang Temple	MQ	C	1	A	?	–	?	P
Xishentou Tangdi Temple	Q	C	1	A	P	–	?	–
Guoyu Tangdi Temple	MQ	C	1	A	?	–	P	–
Yueyuan Tangdi Temple	Q	C	1	A	?	–	?	–
Xiye Tangdi Temple	Q	C	1	A	?	–	?	–
Xiafu Tangdi Temple	Q	C	1	A	?	–	?	–
Nanmen Tangdi Temple	Q	C	1	A	?	–	?	–
Liuzhuang Chengtang Temple	Q	C	1	A	?	?	?	–
Shangsanglin Tangdi Temple	Q	C	1	A	?	–	?	–
Xuliangzhang Tangdi Temple	Q	C	1	A	?	–	?	–
Anzhuang Tangdi Temple	Q	C	1	A	?	–	?	–
Tianhu Tangdi Temple	Q	C	1	A	?	–	?	–
Hedi Tangdi Temple	Q	C	1	A	?	?	?	–
Kangying Chengtang Temple	MQ	C	2	A	?	P	?	–
Beichen Chengtang Temple	Q	C	1	A	P	–	?	–
b) Separate 13 sites and unknown 4 sites								
Mazhuang Tangdi Temple	Q	S	1	A	P	–	?	–
Yong'an Tangdi Temple	Q	S	1	A	P	–	?	–
Xishanling Chengtang Temple	Q	S	1	L	?	–	?	–
Baijiazhuang Chengtang Temple	Q	S	1	A	P	–	?	–
Zhongzhuang Tangdi Temple	MQ	S	1	A	P	–	?	–
Daantou Tangdi Temple	Q	S	1	A	?	–	?	–
Xiasiping Tangdi Temple	Q	S	1	A	?	–	T	–
Nanyu Tangdi Temple	Q	S	1	A	?	?	?	–
Hongshang Tangdi Temple	Q	S	1	A	P	–	?	–
Shanglu Tangdi Temple	Q	S	1	A	?	–	?	–
Xiading Tangdi Temple	Q	S	1	A	?	?	?	–
Dafengzhuang Chengtang Temple	Q	S	1	A	?	–	?	–
Juzhuang Tangdi Temple	Q	S	1	A	?	P	?	–
Shangqin Tangdi Temple	Q	?	1	A	?	–	T	–
Xiaozhanggou Chengtang Temple	Q	?	?	?	?	–	?	–
Xiachuan Tangdi Temple	MQ	?	?	?	?	–	?	–
Xizhou Tangdi Temple	MQ	?	?	?	?	–	?	–

Q: Qing; MQ: mixed Ming–Qing; C: combined; S: separate; 1/2: stages.

A: stage and hall share an axis; L: lateral stage; P: confirmed; T: text only.

–: not shown in plan; ?: unknown/unconfirmed. Blue outlines: four cases.

Fig. 3 | Compound relationship matrix. a Combined gate–stage arrangements; **b** separate and unresolved arrangements. Q: Qing; MQ: mixed Ming–Qing; C: combined; S: separate; A: shared axis; L: lateral stage; P: confirmed; T: text only; 1/2: stage count; –: not shown in the plan; ?: unknown or unconfirmed. Blue outlines identify the four cases. Unconfirmed fields do not indicate absence.

Courtyard organisation varies beyond the axial relationship. Stage counts are identifiable at 36 sites: 35 have one stage and Kangying has two. Plans confirm sequential courts at Wuxia, Kangying and Juzhuang, terracing at Guoyu, and subsidiary courts at Nanzhuang and Wangqu. Terracing at

Xiasiping and Shangqin is explicitly described in text. Nanyu and Xiading are described as two-court compounds, but their divisions are unconfirmed in the reviewed plans; the matrix retains these evidence states. The case comparison below illustrates how axial relationships correspond to particular courtyard configurations.

Configuration analysis covers 39 of Jincheng's 112 sites (34.8%); the joint entrance–axis comparison covers 35 (31.3%). Recorded condition differs between selected and remaining sites. Sites in relatively good or fair condition account for 28/39 selected sites (71.8%) and 36/73 remaining sites (49.3%), a difference of 22.5 percentage points.

Geographical tests of gate–stage categories

The 35-site baseline at k = 5 contains 117 undirected edges: 43 combined–combined, 16 separate–separate and 58 mixed-category joins (Fig. 4b). The 59 same-category joins account for 50.4%, below the theoretical expectation of 51.9% at fixed category totals. The upper-tail p value from 9,999 permutations is 0.6568 (Table 6), so significant global same-category clustering is not detected.

Table 6 | Spatial clustering tests

Scenario	n	k	T/M	Q (%)	Permutation mean (%)	Raw p	Holm p
k = 3	35	3	32/68	47.1	51.9	0.8499	1.0000
Baseline k = 5	35	5	59/117	50.4	51.9	0.6568	1.0000
k = 8	35	8	94/188	50.0	51.9	0.7608	1.0000
Single centre	32	5	56/111	50.5	51.5	0.6162	1.0000
Within county	35	5	59/117	50.4	50.8	0.5787	1.0000
Within period	35	5	59/117	50.4	52.0	0.6623	1.0000
Qing only	29	5	48/96	50.0	49.8	0.4906	1.0000

n: sites; k: neighbours; T/M: same-category/all joins; Q: same-category percentage. Based on 9,999 permutations; Holm adjustment covers seven tests.

Changing the neighbourhood to k = 3 or k = 8 yields 32/68 and 94/188 same-category joins, respectively (Fig. 4a,c; Table 6). Neither test detects significant clustering. Site selection and labels are unchanged across these scale checks.

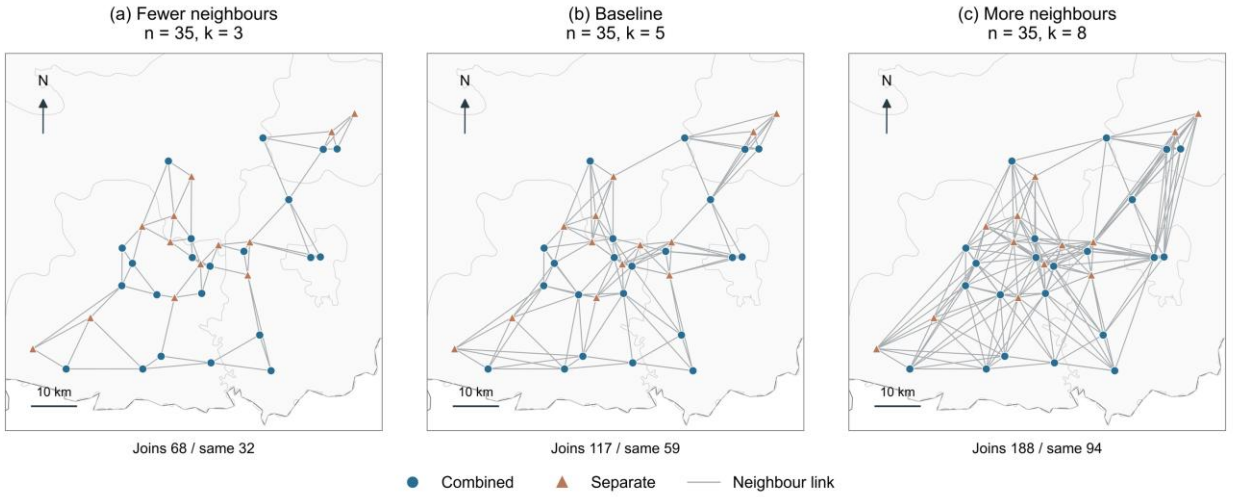


Fig. 4 | Gate–stage networks at different neighbourhood sizes. a k = 3; **b** k = 5; **c** k = 8. All networks contain 35 sites. Blue circles denote combined arrangements, orange triangles separate arrangements and grey lines adjacency. k is the number of nearest neighbours selected by each site. Within-county and within-period permutations use the graph in **b**.

Excluding Kangying, Beichen and Juzhuang, whose coordinates average component centres, leaves 32 single-centre sites. The Qing-only group contains 29 sites. Their rebuilt k = 5 networks give same-category proportions of 50.5% and 50.0%, respectively, with non-significant upper-tail p values (Table 6; Fig. 5).

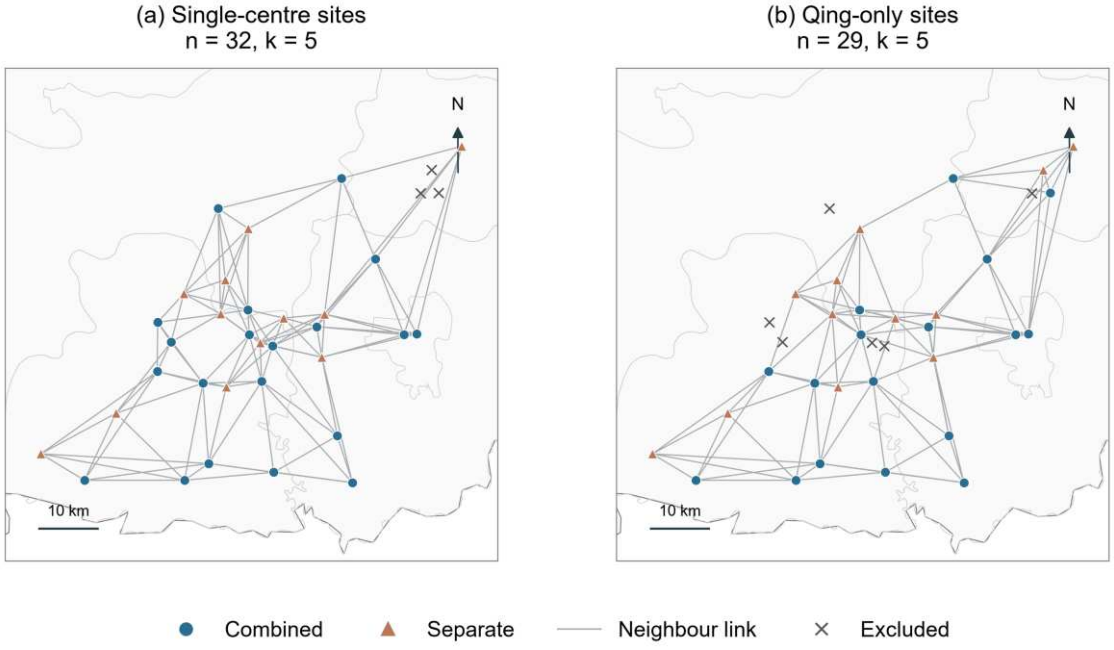


Fig. 5 | Gate–stage networks for restricted study groups. a Single-centre sites (n = 32); **b** Qing-only sites (n = 29). n denotes the number of sites; k = 5 nearest neighbours are selected per site. Blue circles denote combined arrangements, orange triangles separate arrangements and grey lines adjacency. Crosses mark excluded sites.

Observed same-category proportions, permutation means and reference intervals for all seven specifications are shown in Fig. 6.

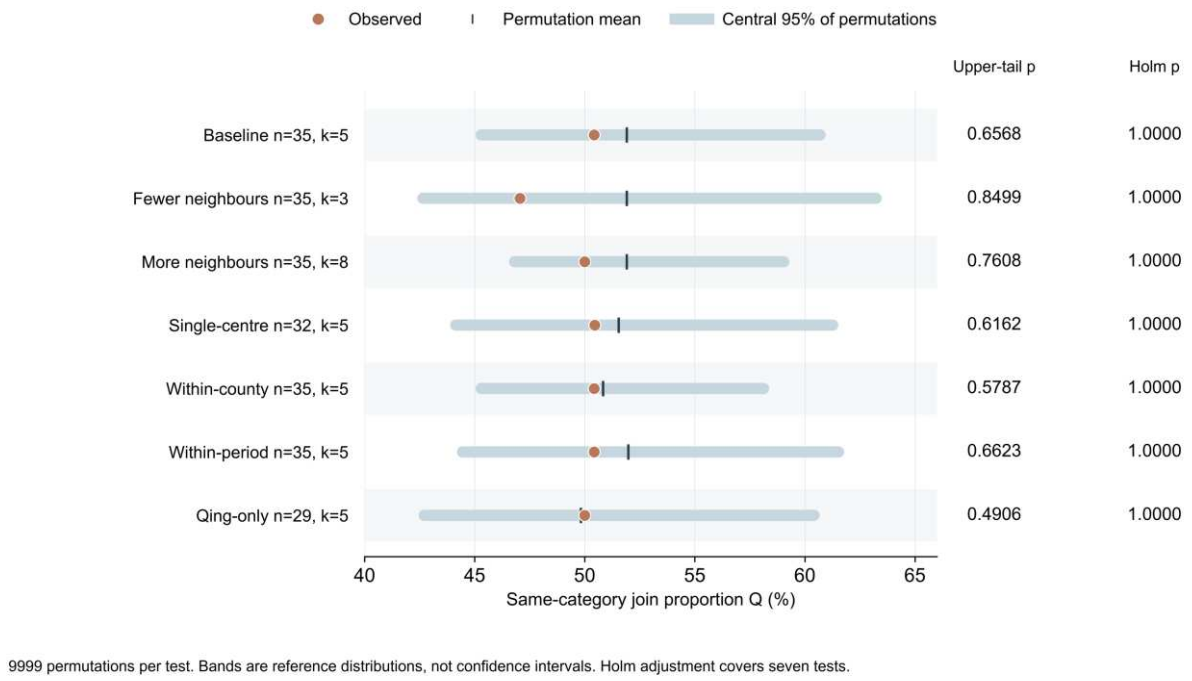


Fig. 6 | Same-category proportions and permutation distributions. Dots denote observed proportions, vertical marks permutation means and bands the central 95% of 9,999 permutations. These bands are reference ranges, not confidence intervals.

Within-county and within-period permutations also detect no significant clustering (Table 6; Fig. 6). All seven Holm-adjusted p values are 1.0000. These specifications assess the same distribution under alternative assumptions; they are not independent replications.

Layout variation within shared functional relationships

Yong'an represents separate–axial organisation, Beichen and Kangying combined–axial organisation, and Xishanling the separate–lateral configuration. The four cases cover all three confirmed gate–stage and axial combinations; component and courtyard arrangements are presented in Table 7 and Figs. 7–10.

Table 7 | Comparison of case configurations

Case and configuration	Shared relationship	Distinctive arrangement
Yong'an: separate gate and stage	Stage–offering hall–main hall axis, also present at Beichen.	The southeastern gate is separate from the axial stage.
Beichen: combined gate–stage	Stage–offering hall–main hall axis, also present at Yong'an.	Entrance and stage occupy one building.
Kangying: composite courtyards	Ritual and performance buildings face across courts.	Front and rear stage–hall units serve separate ritual courtyards.
Xishanling: lateral stage	Access, performance and worship relate to one court.	The gate is axial and the stage lies to the west; other components are recorded as collapsed.

Yong’an has a recorded area of 605 m² and one courtyard. Its gate occupies the southeastern corner and is separate from the stage. From south to north, the main axis comprises the stage, offering hall and main hall. Lateral access thus coexists with axial ritual and performance buildings (Fig. 7).

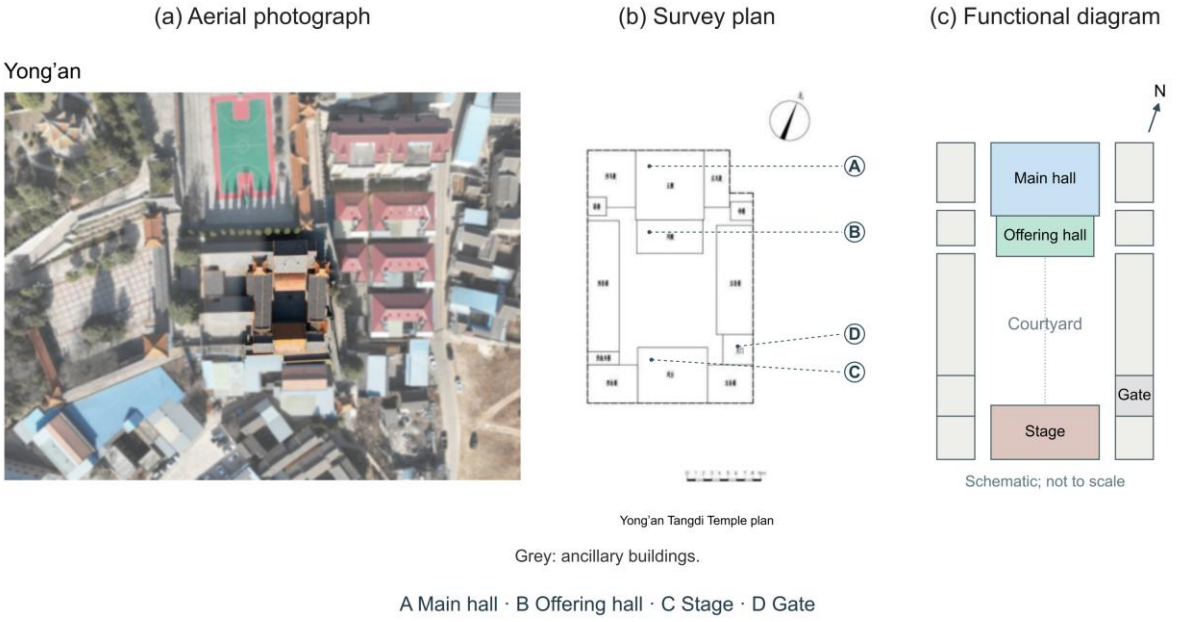


Fig. 7 | Spatial configuration of Yong’an Tangdi Temple. a Aerial photograph; **b** survey plan; **c** functional diagram (not to scale). Letters in b identify the principal buildings; c shows their functional relationships. Photograph: Jianfeng Zhao; plan: Weibing Yuan; both 15 March 2025. Surroundings in a are softened for emphasis.

Beichen has a recorded area of 1,164 m² and one courtyard. Its entrance and stage share one building, followed along the axis by an offering hall and main hall (Fig. 8). Like Yong’an, it organises the stage, offering hall and main hall along the main axis; the difference is whether the entrance building also serves as the stage.

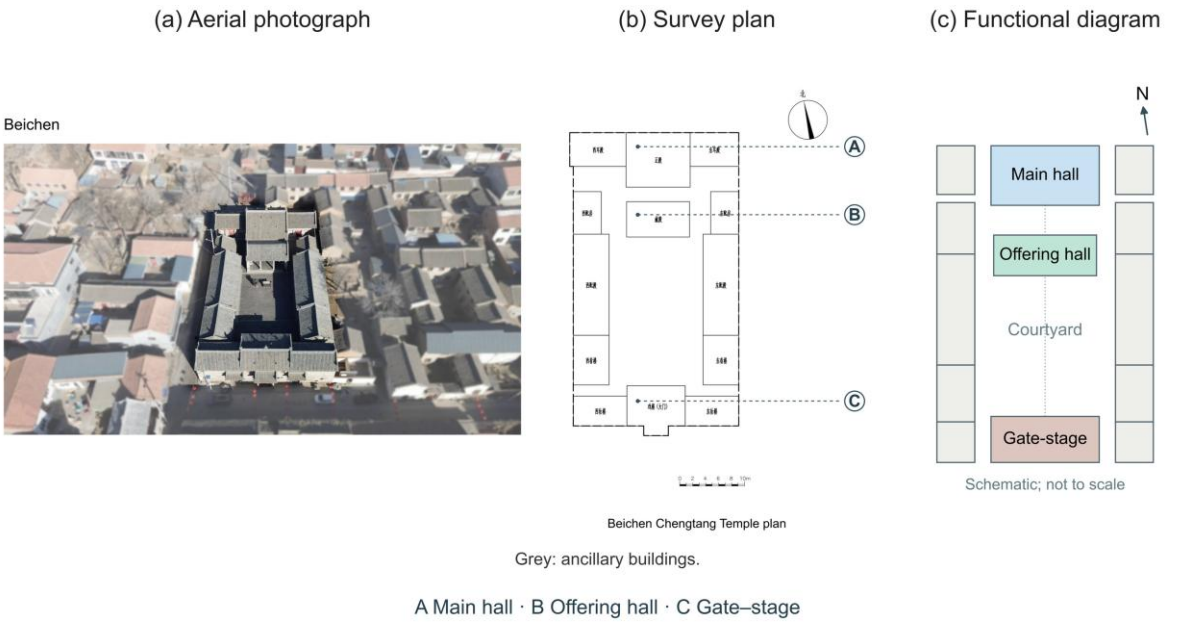


Fig. 8 | Spatial configuration of Beichen Chengtang Temple. a Aerial photograph; **b** survey plan; **c** functional diagram (not to scale). Letters in b identify the principal buildings; c shows their functional relationships. Photograph: Haokai Wang, 17 January 2025; plan: Yiyang Li, 20 February 2025. Surroundings in a are softened for emphasis.

Kangying has a recorded area of 2,117 m². Its axis runs through a gate–stage, Tianqi hall, a second stage and the Chengtang main hall. Earlier research distinguishes front Tianqi and rear Chengtang ritual units, each with a stage[4]. The overall entrance is coded combined, whereas the rear Chengtang unit contains a separate stage and hall. The two stages correspond to successive ritual units. The 1923 inscription reproduced by Zhang[4] (pp. 55–56) recounts additions and repairs to the rear stage and ancillary buildings around 1873; the same study records the conversion of lateral viewing galleries into a school in 1922.

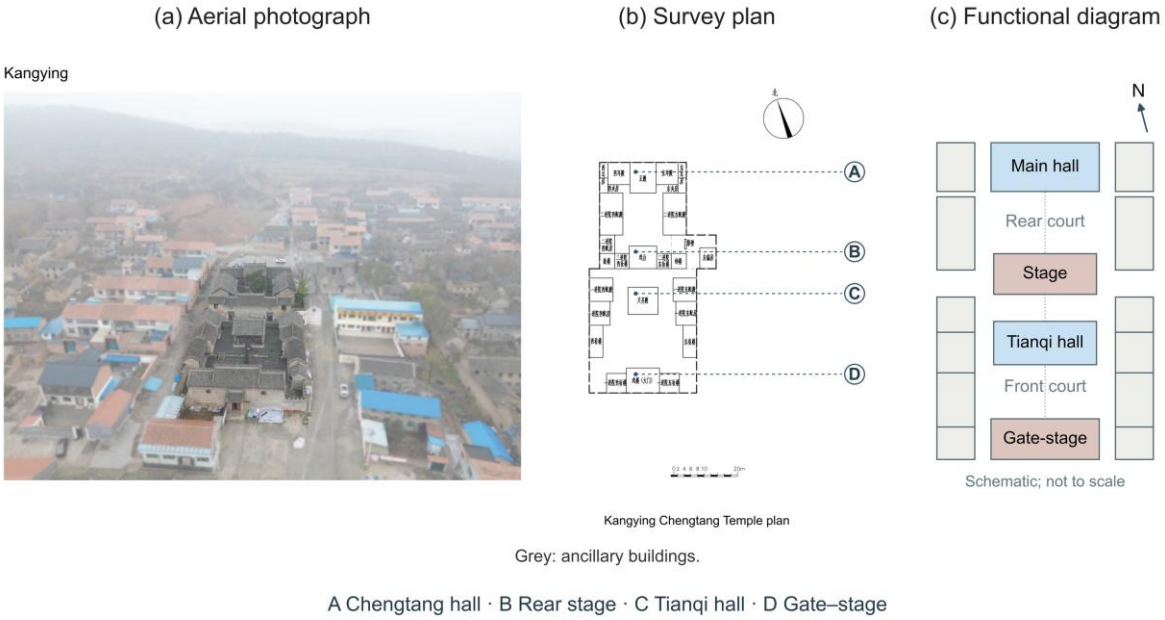


Fig. 9 | Spatial configuration of Kangying Chengtang Temple. a Aerial photograph; **b** survey plan; **c** functional diagram (not to scale). Letters in b identify the principal buildings; c shows their functional relationships. Photograph: Zihong Liu; plan: Keran Yin; both 12 November 2024. Surroundings in a are softened for emphasis.

Xishanling has a recorded area of 476 m². The gate and main hall occupy opposite ends of the main axis, with the stage to the west. It is the only confirmed lateral-stage configuration in the study group. The source plan also marks collapsed eastern subsidiary and flanking halls.

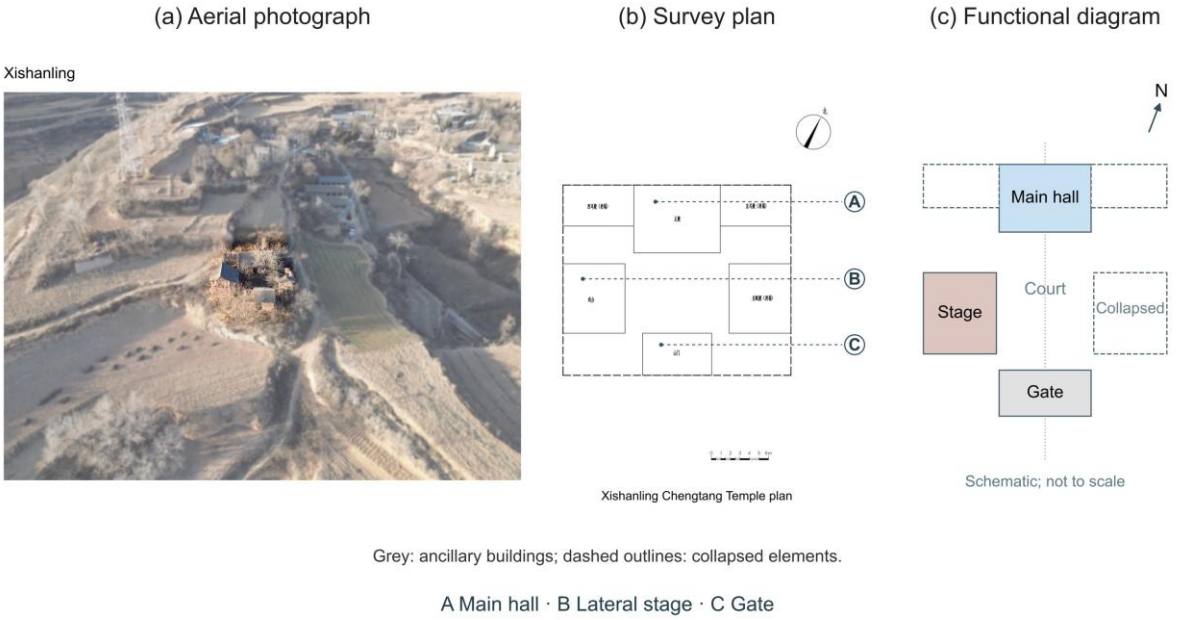


Fig. 10 | Spatial configuration of Xishanling Chengtang Temple. a Aerial photograph; **b** survey plan; **c** functional diagram (not to scale). Dashed outlines in **c** indicate collapsed elements. Letters in b identify the principal buildings; c shows their functional relationships. Photograph: Jianfeng Zhao; plan: Weibing Yuan; both 22 March 2025. Surroundings in a are softened for emphasis.

Yong'an and Beichen show the same axial component sequence across entrance categories. Kangying combines successive ritual units behind a combined entrance, while Xishanling shows lateral stage placement within the separate category. Images therefore document all three gate–stage and axial combinations; ritual-unit use remains case-level evidence.

Discussion

The principal finding is that contrasting entrance arrangements coexist with shared stage–hall organisation in the group with surviving buildings predominantly of the Ming and Qing periods. Combined and separate gate–stage categories distinguish how entry and performance are accommodated, but do not by themselves describe the relationship between performance and principal worship buildings. Thirty-four of the 35 resolved compounds share that axial relationship, while the separate category also includes the lateral stage at Xishanling. Confirmed offering structures occur in both entrance categories. Entrance arrangement and axial organisation should therefore be recorded as distinct dimensions when comparing these compounds.

This finding extends earlier architectural accounts. Li[6] already compared axes and spatial sequences across 12 complexes; Zhu and Yao[5] explained the offering hall and terraced arrangement at Xiajiao, and Zhang[4] documented the composite ritual organisation of Kangying. The present contribution is to locate comparable relationships within a defined regional group: shared-axis arrangements recur across entrance categories, a lateral-stage exception is identified, and confirmed offering structures can be assigned to both categories. All 31 resolved sites remaining after the four illustrated cases

are excluded are axial, so this finding does not depend on those cases alone. The four cases explain the architectural expression of the relationships established by the group comparison.

Yong'an and Beichen clarify why the distinction matters: separate and combined entrances accommodate the same stage–offering hall–main hall sequence. Kangying distinguishes the compound entrance from its internal ritual units, while Xishanling shows that a separate stage need not occupy the main axis. The conversion of Kangying's viewing galleries into a school also shows why component position and use at a particular time need to be distinguished. These cases connect group-level fields to courtyard configurations and support relational interpretation in heritage research[14,15]. They do not establish a uniform inventory of internal ritual units or a historical sequence of whole-layout development.

Geographical testing provides insufficient evidence to interpret the two entrance categories as spatially clustered groups under the tested adjacency rules. This constrains geographical classification but does not establish the absence of geographical influence. The tests concern global same-category adjacency; they neither exclude local patterns nor reconstruct routes of architectural transmission. Their role is to qualify the regional interpretation of entrance categories, not to explain why the layouts formed.

The complete inventory provides a second contribution: it makes the coverage of architectural interpretation measurable. Only 39 of the 112 Jincheng sites enter configuration analysis, and 35 support the joint entrance–axis comparison. The higher proportion of sites in relatively good or fair condition within the selected group describes a difference in evidence composition; chronology and spatial legibility also influence selection. Consequently, the observed shared-axis proportion describes the eligible, interpretable group, not the prevalence of this arrangement among all Shanxi temples or all historical Chengtang temples. Retaining excluded and unresolved sites links the architectural findings to their regional evidence base, consistent with traceable heritage-data practice[16].

The methodological implication for regional architectural comparison is to record entrance arrangement, axial organisation and courtyard combinations separately, avoiding the use of categories at one spatial level to represent entire layouts. Entrance labels alone capture neither the shared axis across categories nor the lateral exception within one category; comparison across spatial levels identifies both. Application to other building groups requires functional definitions suited to those groups and verification of their sources. Comparative studies are still needed to assess transferability and establish whether the observed relationships are specific to Chengtang worship.

The main limitations concern coding and historical inference. Source-linked codes lack independent researcher review, and exclusion checks cannot detect systematic misclassification. Period attribution draws on recorded building dates, stylistic assessments and accounts of building work, which do not uniformly establish foundation dates. The predominance of the Qing group and the small mixed Ming–Qing subgroup prevent conclusions about continuity between the periods or the formation dates of layouts. Offering provision is unresolved at 30 sites, internal ritual units are not

uniformly coded, and there is no comparison group dedicated to other deities. The findings therefore describe the eligible compounds and the coverage of their evidence.

The study establishes shared axial organisation across different entrance arrangements, together with a documented lateral-stage exception, within the 39 Jincheng compounds whose surviving buildings are predominantly of the Ming and Qing periods. Its contribution to regional heritage interpretation is to distinguish recurring relationships from the courtyard configurations that accommodate them. The complete inventory defines the coverage of this conclusion; it does not turn the analytical subset into a census of historical layouts. Recognising both shared relationships and documented variations offers a more precise basis for interpreting the architectural group than an entrance label or a single complete example alone[22].

Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Author contributions

C.W.: Conceptualization; methodology; investigation; resources; data curation; funding acquisition; supervision. S.L.: Conceptualization; methodology; investigation; software; data curation; validation; writing—review and editing. C.H.: Conceptualization; validation; writing—review and editing; supervision. M.L.: Conceptualization; funding acquisition; supervision.All authors have read and agreed to the published version

Competing interests

The authors declare no competing interests.

References

1. You, X. & Feng, X. Pluralistic writing about the story of ‘Rain-praying of ChengTang’ during from Song to Ming Dynasty. *J. Chin. Cult.* no. 4, 160–173, 192 (2023) (in Chinese).
2. Li, S.-Z. & Zhu, W.-G. The historical evolution of tombstones in the Chengtang temples in Yangcheng, Shanxi Province, and the role of grass-roots society in promoting folk beliefs. *J. Shaanxi Norm. Univ. Philos. Soc. Sci. Ed.* **48,** 150–159 (2019) (in Chinese).
3. Cai, M. The influence of Tangwang worship on historical local society in southeastern Shanxi. *Cult. Herit.* no. 3, 95–103 (2016) (in Chinese).
4. Zhang, J. Historical changes in folk shrine worship: the Chengtang temple in Kangying village, Gaoping. *Relig. Cult. World* no. 4, 53–56, 66 (2011) (in Chinese).
5. Zhu, X. & Yao, X. Influence of Shangtang culture on ritual buildings in the southeast of Shanxi during Songjin era: a case study of Xiajiao Tang Emperor’s Temple. *Huazhong Archit.* **29,** 157–161 (2011) (in Chinese).

6. Li, H. A study of Chengtang ritual architecture in southern Shanxi and northern Henan. Master's thesis (Xi'an University of Architecture and Technology, 2009) (in Chinese).
7. Zhu, X.-D., Zhao, Q. & Wang, C.-E. *Folk Ritual Architecture in Shanxi during the Song and Jin Dynasties* (China Building Materials Industry Press, Beijing, 2012) (in Chinese).
8. Moneo, R. On typology. *Oppositions* **13,** 22–45 (1978).
9. Hillier, B. *Space Is the Machine: A Configurational Theory of Architecture* (Space Syntax, London, 2007).
10. Arias Tapiero, J. C. et al. An ICT-enhanced methodology for the characterization of vernacular built heritage at a regional scale. *Int. J. Archit. Herit.* **19,** 966–984 (2025). https://doi.org/10.1080/15583058.2024.2320862
11. Wang, Y. From fragments to system: a research on the mesoscale structure of vernacular landscapes in the Hang-Jia-Hu area, China. *J. Asian Archit. Build. Eng.* **24,** 2191–2210 (2025). https://doi.org/10.1080/13467581.2024.2358209
12. Yang, Q., Guo, Q., Song, C. & Jiang, Y. The influence of ancestral temple on the landscape of traditional Chinese villages: based on landscape pattern analysis and spatial syntax approach. *J. Asian Archit. Build. Eng.* **24,** 4195–4212 (2025). https://doi.org/10.1080/13467581.2024.2397110
13. Kang, F., Li, W., Li, L., Zhou, Z. & Wang, J. Graph-enhanced clustering of late modern churches via multi-dimensional semantic feature integration. *npj Herit. Sci.* **14,** 100 (2026). https://doi.org/10.1038/s40494-026-02360-7
14. He, D. & Liu, Y. Holistic construction and classification of serial heritage corridors using Spatial Design Network Analysis and a minimum cumulative resistance model. *npj Herit. Sci.* **14,** 312 (2026). https://doi.org/10.1038/s40494-026-02542-3
15. Bu, Y. et al. Embedding architectural prototype knowledge in interpretable deep learning for morphological similarity evaluation of traditional villages. *npj Herit. Sci.* (2026). https://doi.org/10.1038/s40494-026-02784-1
16. Larsson, Å. M., Bornsäter, B. & Hacke, M. Developing practices for FAIR and linked data in Heritage Science. *npj Herit. Sci.* **13,** 53 (2025). https://doi.org/10.1038/s40494-025-01598-x
17. Office of the Leading Group of the Fourth National Cultural Heritage Census. *Information Technology Plan for the Fourth National Cultural Heritage Census* (2024) (in Chinese).
18. Carrer, F., Kossowski, T. M., Wilk, J., Pietrzak, M. B. & Bivand, R. S. The application of Local Indicators for Categorical Data (LICD) to explore spatial dependence in archaeological spaces. *J. Archaeol. Sci.* **126,** 105306 (2021). https://doi.org/10.1016/j.jas.2020.105306
19. Anselin, L. & Li, X. Operational local join count statistics for cluster detection. *J. Geogr. Syst.* **21,** 189–210 (2019). https://doi.org/10.1007/s10109-019-00299-x
20. Phipson, B. & Smyth, G. K. Permutation P-values should never be zero: calculating exact P-values when permutations are randomly drawn. *Stat. Appl. Genet. Mol. Biol.* **9,** 39 (2010). https://doi.org/10.2202/1544-6115.1585
21. Holm, S. A simple sequentially rejective multiple test procedure. *Scand. J. Stat.* **6,** 65–70 (1979).
22. ICOMOS. *Charter on the Built Vernacular Heritage* (ICOMOS, 1999).