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Historical change and spatial relation of cultural memory in Guangzhou from the perspective of heritage representation

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Cultural memory fundamentally shapes urban collective identity, , yet it is seldom quantified at fine spatial scales. This study proposes the Heritage–Memory Symbiosis Loop (HMSL) as an analytical framework to examine Guangzhou, a historic trading hub in China with 446 state-listed heritage units. Each heritage unit is systematically classified within a "two representations–six memory-space" matrix, and a Cultural Memory Index (CMI) is computed and visualized as a spatialfield-energy surface. Subsequently, Kernel-density estimation, Moran's I, and LISA analyses illuminate memory hotspots centered around the Yuexiu–Liwan core, while revealing the attenuation of spirituality-based memories in fringe districts undergoing gentrification. Field-energy gradients underpin the delineation of three protection zones: high-intensity "living museums" along dynastic trade routes, medium-intensity multipurpose belts, and low-intensity rural nodes. The CMI map constitutes the first point-level quantification of cultural memory for Guangzhou, elucidates the interplay between material and spiritual domains within the human–land system, and supplies a replicable methodology—including heritage inventory, memory zoning, and field-energy mapping— tailored for conservation strategies in rapidly urbanizing Asian cities.

Keywords Cultural memory, Heritage geography, Cultural memory index, Spatial-field modelling, GIS, Guangzhou

Cultural heritage is often regarded as "the most tangible register of human time," representing a repository of collective emotions that transformsphysical entities—such as stones, streets, and artifacts into dynamic symbols of identity. European urban planningtraditions have long recognized this dual function. For example, Spain's "cultural route" (1933) and the U.S. heritage-corridor movement (1980s) were established not only to safeguard artifacts but also to actively revive the memories those artifacts embody. Subsequent research has investigated multiple dimensions of cultural heritage, including corridor governance in Barcelona[1], cultural cores in Bulgaria[2], the influence of self-efficacy in Medan[3], and challenges observed in the context of India's Yamuna River[4]. Methodologically, the discipline has progressed from basic descriptivelistings toward advanced approachessuch as GIS-enabled multi-criteria decision systems, analytic hierarchy process (AHP) models, and virtual reconstructions evaluating value, risk, and visitor experience[5–8].

Heritagetranscends its role as a static planning object; as Jan Assmann articulates, it embodies the mechanism of "genealogical memory"[9]. Structures like palaces, shrines, and cemeteries become material anchors for social remembrance[10]. Through rituals, media dissemination, and policy interventions, these sitesparticipate in the "exhibition, protection, and practice of memory"[11–13].Nonetheless, ongoing urban and rural transformation can disrupt these anchors, resulting in cultural amnesia, fragmented narratives, or residual traces of historical experience[14,15]. The intellectual history of Western memory theory began with mythological paradigms, notably the figure of Mnemosyne, goddess of memory, and subsequently entered scholarly discourse via Simonides, who pioneered spatial technique for preserving events[16,17]. The systematic study of memory unfolded across four analytic "turns." The first turn, a philosophical-to-psychological shift in the 1880 s, assessed memory as a measurable cognitive function in Von Trotter's laboratory setting[18]. The second, a social turn in the 1930 s led by Halbwachs and Warburg, emphasized the influence of class, family, and religion on collective memory[19,20]and laid the groundwork for cultural memory theory[21]. In the 1980 s, a textual-cultural turn emerged as Jan Assmann and colleagues argued that oral and written media serve as instruments for constructing identity[22–25]. The spatial

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turn sSince the 2000 s, a spatial turn has integrated memory within geography, resulting in two primary research strands: urban memory and rural cultural memory. Scholars now focus on mapping urban form, the sense of place, and regional identity, although , site-level metrics remain scarce.

The academic discourse on memory within China arose in the early twenty-first century[26], instigated by Wang Xiaobing's interpretation of Chinese script through Assmann's theoretical lens[27]. Subsequent domestic research has explored topics such as landscapes, rituals, identity formation, and museum curation[28–37], primarily with qualitative methodologies including participatory observation and textual analysis. While geographers have adopted GIS and self-media analytics, most scholarship emphasizes provincial or macro-regional scales, with limited attention to municipal granularity. Investigations into heritage protection units typically focus on cataloging physical attributes—such as spatiall ayout and total volume—while neglecting the underlying social narratives that endow these sites with cultural significance[38,39].Consequently, there has yet to emerge a distinctly localized version of cultural memory theory in China, nor a quantitative schema for understanding how individual sites store and encode cultural memory.

Guangzhou presents a particularly robust empirical setting for research. Renowned as China's longest-standing maritime trading entrepôt, the city encompasses 446 nationally protected heritage sites—from Han-dynasty tombs and Tang temples to Qing-era guildhalls and Republican-era arcades. These monuments not only bear witness to political,commercial, and sociocultural transitions but also serve as critical loci for place identity among diverse social groups[40]. This place identity is deeply anchored in social memory—the collective remembrance of historical episodes within a community[41]. The management and retention of memory intersect closely with prevailing power structures[42]; as socio-cultural environments transform, so too does thedetermination of what is retained as communal memory[43]. Heritage sites thus come to encapsulate both the cultural practices and the power relations of the groups that established them.

Despite this context, several pronounced research gaps persist. First, there is a lack of point-level measurement for the mnemonic strength of each heritage site in Guangzhou. Second, the intra-urban distribution of memory heterogeneity has yet to be mapped. Third, there has been no quantification of how contemporary factors—such as commercial redevelopment, digital media, or public funding—affect the balance between physical preservation and the vitality of cultural narratives. Fourth, no comprehensive framework exists that integrates material space, memory dynamics, and power relations at the field level.

To bridge these gaps we advance a Heritage–Memory Symbiosis Loop (HMSL), fusing Lefebvre's perceived–conceived–lived space, Assmann's storage–retrieval cycle and Bourdieu's field theory[44]. The loop unfolds in three intertwined phases. *Spatial practice* is the everyday use of heritage for work, worship and leisure. *Narrative re-contextualisation* occurs when museums, media or policy attach new symbolic meanings. *Field renegotiation* is the contest among state, market and community actors over which meanings persist; the outcome feeds back into the next round of spatial practice. To render the loop testable we operationalise four constructs for every heritage unit: Representation Intensity (visibility of narratives in media and policy), Re-contextualisation Coefficient (proportion of new meanings since 1980), Field Tension (variance among stakeholder power indices) and Symbiosis Index (balance between material conservation and mnemonic vitality).

Employing this HMSL-based framework, the study pursues three primary objectives. First, we develop the Cultural Memory Index (CMI) for all 446 heritage sites and situate each site within the "two representations–six memory-space matrix," following precedents in recent literature[44,45]. Second, spatial heterogeneity is mapped using kernel-density estimation, Moran's I, and local LISA statistics. Third, we model how factors such as gentrification pressure, digital engagement, and state cultural investment impact narrative renewal (Re-contextualisation Coefficient) and governance balance (Symbiosis Index). By combining detailed heritage data with dynamic memory theory, this paper demonstrates how material and symbolic processes are interwoven in the construction—and deconstruction—of urban identity, offering a methodological model that can be adapted to other rapidly developing Asian urban contexts.

Study area and data methodology

Study area

Guangzhou, the capital of Guangdong Province, serves as a vital political, economic, scientific, technological, educational, and cultural nexus in southern China. As a designate dnational central city, international trade , and a leading transportation center, its influence is both regional and global. Geographically, Guangzhou is positioned in the south-central part of Guangdong Province, at the northern edge of the Pearl River Delta, where the Beijiang, Xijiang, and Dongjiang rivers converge before flowing into the South China Sea. Located at the confluence of the three major tributaries of the Pearl River and in proximity to the South China Sea, Guangzhou is just across the water from Hong Kong and Macao. It lies between longitudes 112°57′~114°3′E and latitudes 22°26′~23°56′N. Guangzhou boasts a rich history, having been a key center of commerce and trade since the Warring States period. Its cultural heritage has held significant geospatial importance throughout the Warring States, Han Dynasty, Ming Dynasty, and modern eras.

The study progresses through seven interconnected modules (Fig. 1). Data compilation integrates four primary sources: (i) the national list of Guangzhou's heritage units, (ii) district-level statistics and fiscal reports, (iii) a geo-tagged media-policy database, and (iv) VR/WeChat engagement logs, creating a unified point-polygon database. Indicator generation transforms these sources into the Cultural Memory Index (CMI), the Gentrification Index (GI), the Digital-Engagement Index (DEI), and the State-Cultural-Investment Index (SCI), from which the Re-contextualisation Coefficient (RC), Field Tension (FT), and Symbiosis Index (SI) are derived. Temporal-change analysis employs a relative-rate metric to monitor changes in six types of memory-space across different historical periods. Field-energy modeling treats CMI as field strength, applies a distance-decay exponent ($f = 2.0$), and interpolates memory potential using ordinary Kriging on a 500-meter fishnet. Spatial heterogeneity analysis uses Global Moran's I, Local Moran's I (LISA), and Getis-Ord Gi* on the field-energy and

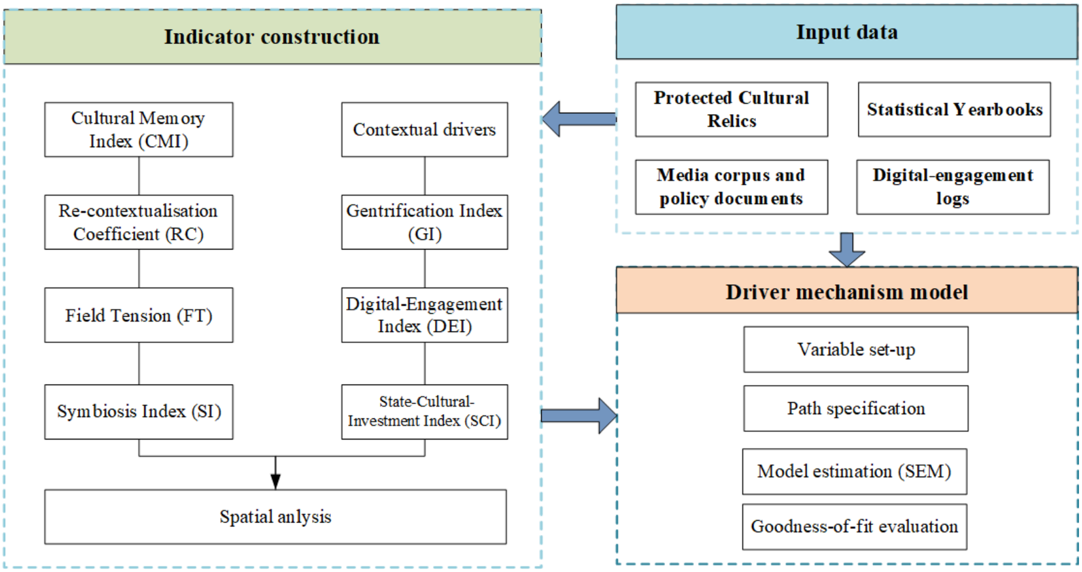

Fig. 1. Methodological workflow and key assumptions.

SI layers to identify hot spots, cold spots, and outliers. The driver mechanism model utilizes structural-equation modeling (SEM) to estimate the direct and FT-mediated effects of GI, DEI, and SCI on RC and SI, testing the overall model fit. Finally, planning outputs convert SI thresholds and field-energy gradients into three protection zones and propose a three-step toolkit for heritage management in Guangzhou and similar rapidly urbanizing cities: memory buffer zones, digital-twin monitoring, and a community co-curation fund.

Data sources and research methodology

Research methodology

Cultural memory index The Cultural Memory Index (CMI) is calculated in two steps[46,47]. Step 1 (Delphi expert weighting). We conducted a three-round Delphi with fifteen specialists in historical geography, heritage management and urban planning. The anonymised panel composition is provided in Table S1, and the questionnaire and scoring rubric in Table S2. Experts rated the mnemonic salience of the six memory-space types on a 0–10 scale. Consensus was reached by Round 3 (all coefficients of variation < 0.15; Kendall's W = 0.74, $p < 0.001$). The Delphi weight for type iii is denoted CWi. Step 2 (cross-validation and robustness). An entropy-weight vector was derived from five observable proxies—annual visitor counts, statutory protection grade, site age, media-mention frequency and digital-engagement score. The Delphi and entropy vectors correlate strongly (ρ = 0.91), and replacing Delphi with entropy alters district-mean CMI by ≤ 0.028. Convergence diagnostics and final weights are reported in Tables S3–S4. A principal-component scheme explains 78% of variance and aligns with Delphi ($R^2 = 0.79$). Given this concordance, Delphi weights are retained as the baseline; alternative results are provided in the Supplementary Materials. The final index for heritage unit j is:

$$CMI\_j = P\_i \times CW\_i \tag{1}$$

where P_i is the Delphi score (0–10) for type *i*[48]. CMI_j is normalised to 0–1 for subsequent spatial analysis.

Relative rate of change The relative spatial change rate of cultural memory provides insights into the temporal dynamics of memory landscapes, capturing how individual memory sites evolve in relation to the broader spatial framework. This metric effectively illustrates the spatial interrelationships and directional shifts among various memory locations over time. To evaluate the spatial diffusion of cultural memory across two sequential time periods, the cumulative spatial change rate is employed. This measure reflects the extent of spatial movement and helps assess the degree of continuity or transformation within the cultural memory system. Furthermore, the relative rate of variation is applied to determine trends in the number and distribution of different categories of cultural memory spaces, thereby offering a quantitative perspective on their structural evolution[46]. The corresponding analytical model is defined as follows:

$$S = \frac{M'_{i+1} - M'_i}{|M_{i+1} - M_i|}, (i = 1, 2, 3, ..., 6) \tag{2}$$

Where: S denotes the relative rate of change in the number of cultural memory spaces. M'_i, M'_i +1 denote the number of different types of cultural memory spaces at the beginning and the end of the study. i denotes the type of cultural memory space. M'_i, M'_i +1 denote the number of all the cultural memory spaces at the beginning and at the end of the study in the city of GuangZhou. The variable S represents three distinct states reflecting the relative rate of change in the number of cultural memory spaces: When $S < 1$, it indicates that the rate of change for cultural memory space i is lower than that observed in Guangzhou; When $S = 1$, it signifies that the change in space i aligns exactly with the rate of change in Guangzhou, representing an ideal or benchmark level of transformation; When $S > 1$, it suggests that space i is experiencing a higher rate of change compared to that of Guangzhou. In essence, this index allows for a comparative assessment of how the evolution of cultural memory spaces in various locations deviates from or mirrors the reference trend established by Guangzhou.

Space field energy modeling In its original sense, the concept of a "field" refers to any region of space characterized by the distribution of a physical quantity. In the discipline of geography, spatial field theory has traditionally been applied in urban studies, regional analysis, and related areas. In recent years, however, it has increasingly been adopted within cultural geography to explore spatial dimensions of memory. The notion of a "field of memory" was first articulated by Pierre Nora[49,50] as part of his broader theory on lieux de mémoire (places of memory). It refers to a tangible spatial carrier that allows for the quantitative analysis and representation of memory transformation. This field is not static; rather, it is dynamic in nature, with measurable variations in spatial intensity and energy. The cultural memory field displays heterogeneity in terms of memory potential and spatial energy distribution. These differences manifest as variations in the "field strength" and "spatial potential energy" across different regions. To assess the spatial energy of a cultural memory field, both the memory field intensity and its associated spatial potential must be considered. The corresponding model is expressed as follows:

$$E_{xy}^{j} = \frac{CMI_j}{(D_{xy}^{j})^f}, (j = 1, 2, 3, ..., n) \tag{3}$$

$$EP_{xy} = \sum_{j=1}^{n} E_{xy}^{j} \times \omega_j \tag{4}$$

Where: (x, y) denotes the location of any cultural memory site in the space, E_{xy}^{j} denotes the field strength of cultural memory site j; CMI_j denotes the memory capacity of memory site j, and the cultural memory index is calculated in the study by formula (1); D_{xy}^{j} denotes the distance between memory site j and the administrative site in the space region (the distance from the cultural preservation site to the county-level administrative site is used in the study); f is the distance friction coefficient, usually take the standard value of 2.0[51]; EP_{xy} denotes the potential energy of any cultural memory space, i.e., the spatial field energy; ω_j is the weight of the role of memory site j on other sites in the space, based on the relative size of cultural memory.

The SEM model estimates direct and mediated effects of GI, DEI, and SCI on RC and SI, but as a correlational method, it cannot rule out reverse causality. For example, high narrative renewal (RC) may drive increased digital engagement (DEI), as vibrant storytelling could attract more VR-tour clicks or WeChat check-ins. Future studies employing longitudinal designs or instrumental-variable approaches could better isolate causal directions.

Data sources

The dataset used in this study originates from the List of National Key Cultural Relics Protection Units in Guangzhou, published by the Guangzhou Municipal Cultural Relics Bureau (https://wglj.gz.gov.cn/mdjl/cjwt/whyww/content/post_8865882.html), comprising a total of 446 designated sites. The geographic coordinates of these cultural heritage units (hereinafter referred to as "protection units") were obtained through Baidu Maps and organized into a geodatabase using ArcGIS 10.2. Subsequently, spatial analysis was conducted within ArcGIS 10.2, including the calculation of geographic metrics and the application of standard deviation ellipse analysis. The standard deviation ellipse, generated based on the statistical dispersion of point features, effectively captures the directional tendencies of spatial distributions. The major axis (a-axis) represents the direction of maximum spatial dispersion, while the minor axis (b-axis) reflects the direction of highest concentration of the features. Supplementary geospatial data, including administrative boundaries, hydrological features (rivers and lakes), and other base maps of Guangzhou, were downloaded from the Geospatial Data Cloud (http://www.gscloud.cn). These datasets were processed, clipped, and georeferenced using ArcGIS 10.2 to align accurately with the scope of the study area.

Operationalising the heritage–memory symbiosis loop (HMSL)

To move the HMSL from concept to measurement, four continuous variables were constructed for each of Guangzhou's 446 heritage units and then attached to a 1: 10 000 point shapefile in ArcGIS 10.2. All raw data were normalised to the range 0–1 before calculation.

Representation Intensity (RI) captures how visible a site is in contemporary discourse. It is modelled as a weighted mean of three streams—geo-tagged media items (*M*), government policy references (*P*), and academic citations (*A*):

$$RI_j = \frac{\alpha M_j + \beta P_j + \gamma A_j}{\alpha + \beta + \gamma} \tag{5}$$

Monthly media counts for 2020–2024 were scraped from two major Chinese news APIs and the Weibo Firehose; policy documents were harvested from the National and Guangdong Government-Doc databases; citations came from CNKI and Scopus. Entropy weighting gave $\alpha = 0.40$, $\beta = 0.30$, $\gamma = 0.30$. A Delphi panel confirmed the same hierarchy, and the two schemes correlate at $\rho = 0.91$.

Re-contextualisation Coefficient (RC) expresses the share of "new" meanings that have accrued to a site since China's Reform era. Using a 200-term thesaurus, semantic codes were extracted with NVivo from texts pre-1980 (N^{orig}) and post-2010 (N^{new}); intercoder reliability was κ = 0.83. The coefficient is

$$RC_j = \frac{N_j^{new}}{N_j^{orig} + N_j^{new}} \tag{6}$$

Field Tension (FT) approximates power asymmetries among state, market and community stakeholders. For each heritage unit, shares of public investment, heritage-based commercial floor area and annual community events were first converted into weights (w^{gov}, w^{mkt}, w^{com}); their variance forms the index:

$$FT_j = Var(w_j^{gov}, w_j^{mkt}, w_j^{com}) \tag{7}$$

Higher FT values indicate sharper power imbalances.

Finally, the Symbiosis Index (SI) integrates mnemonic vitality and governance equilibrium:

$$SI_j = \left(\frac{RI_j + RC_j}{2}\right) \times (1 - FT_j) \tag{8}$$

A value close to 1 implies that an actively narrated site is being managed under relatively balanced stakeholder relations; values trending to 0 flag either mnemonic decline or a capture of decision-making by a single actor.

Contextual drivers: gentrification, digital engagement and state investment

To evaluate how contemporary structural forces modulate the Heritage–Memory Symbiosis Loop, three indices were compiled for every district in Guangzhou and, where source data permitted, down-scaled to individual heritage units.

Gentrification pressure was proxied by the ratio of cumulative housing-price appreciation to the change in the registered-resident share between 2010 and 2024. For district *d*:

$$GI\_d = \frac{\Delta P\_d}{\Delta R\_d} \tag{9}$$

where ΔP_d = percentage increase in average residential prices; ΔR_d = percentage change in hukou residents as a proportion of total residents.

Price data come from the Guangzhou Real-Estate Yearbooks; population data from the Guangzhou Statistical Yearbooks. GI values are min-max normalised to the 0–1 range. Each heritage unit inherits the GI of its district.

A Digital Engagement Index (DEI) captures bottom-up online resonance using log-transformed counts of user actions on the "VR-GZ Heritage" platform and the "Canton Memory" WeChat Mini-Program:

$$DEI\_j = \frac{[\ln(C\_wx\_j + 1) + \ln(C\_vr\_j + 1)]}{[\ln(C\_wx\_\max + 1) + \ln(C\_vr\_\max + 1)]} \tag{10}$$

where C_wx_j = annual WeChat Mini-Program check-ins for heritage unit j (2016–2024); C_vr_j = annual VR-tour clicks for unit j; C_wx_max and C_vr_max are the maximum counts observed city-wide.Data were provided by Tencent Culture Cloud. The index highlights bottom-up engagement rather than official promotion.

The Digital-Engagement Index (DEI) captures user interactions via VR platforms and WeChat Mini-Programs, reflecting bottom-up resonance with heritage sites. Digital tools like "VR-GZ Heritage" and "Canton Memory" mediate symbolic authenticity (e.g., immersive recreations of historical narratives) and audience accessibility (e.g., low-cost, scalable access to virtual tours). However, these platforms may prioritize visually compelling sites, potentially skewing engagement toward high-RI units (e.g., Chen Clan Ancestral Hall) while marginalizing less digitized, spirituality-based sites (e.g., rural Hakka compounds).

State Cultural Investment (SCI) aggregates inflation-adjusted municipal appropriations for heritage projects from 2012 to 2024. Municipal fiscal bulletins list annual appropriations for heritage projects. After converting to constant 2024 RMB, district-level allocations were cumulated and normalised:

$$SCI\_d = \frac{\sum I\_dt}{\max\_d \sum I\_dt} \tag{11}$$

where I_dt = investment (RMB) in district d during year t.

For 218 heritage units that received project-specific grants, the actual amounts were used; other units were assigned their district's average SCI value.

Results and analysis

Hierarchical–interactive typology of cultural memory space in Guangzhou

Building on the Heritage–Memory Symbiosis Loop (HMSL), Guangzhou's cultural-memory space is conceptualised not as six isolated classes but as six first-level nodes that circulate through the loop's three phases—spatial practice, narrative re-contextualisation and field renegotiation. Within each node, field observation and text-coding revealed three recurring emphases:

Memory category	Class/Gender/Minority sub-types and examples
Socio-perceptual (SPMS)	*Class*: Workers' guild halls in the Pearl-River industrial belt; *Gender*: Women-led weaving courts in Xiguan; *Minority*: Hakka clan compounds in Conghua
Spirituality-based (SWMS)	*Class*: Scholar-gentry ancestral temples; *Gender*: Goddess Mazu shrines along the river; *Minority*: Sanyuan Li mosque (Hui community)
Media-narrative (MNMS)	*Class*: Anti-imperialist newspapers' former offices; *Gender*: Early women's periodical "Lingnan Lady" pressroom; *Minority*: Cantonese-opera troupes funded by Overseas Chinese
Production-practice (PPMS)	*Class*: Dock-labour barracks; *Gender*: Silk-reeling cooperatives headed by female entrepreneurs; *Minority*: Boat-dweller workshops of the Tanka people
Life-symbol (LSMS)	*Class*: Collective kitchens of 1950 s danwei; *Gender*: Midwives' alleys commemorating female healers; *Minority*: Ramadan food bazaar on Litchi Bay
Functional-characterisation (FCMS)	*Class*: State-owned granaries repurposed as art parks; *Gender*: Girls' normal-school campus; *Minority*: Portuguese-style customs house on Shamian

Table 1. Cultural memory representations, cultural memory fields and types of cultural memory spaces.

Type	Prehistoric	Qin and Han	Wei, Jin, Southern and Northern	Sui and Tang	Song and Yuan	Ming and Qing	Modern and contemporary
Socio-perceptual	-	0.111	0.5	0	0.556	0.088	1.2
Spirituality-based	-	0.222	1	0	0.167	0.238	2.6
Media narrative model	-	0.222	1	0	0	0.083	1.2
Production practice-based	-	0	0.5	0.25	0	0	1
Life symbol model	-	0.222	0.5	0	0	0.365	1.2
Functional characterization	-	0.222	0.5	0.75	0.278	0.227	0.6

Table 2. Relative change rates of different cultural memory spaces.

- a class inflection, foregrounding labour relations, production sites and socio-economic stratification;
- a gender inflection, where female or non-binary experiences define ritual, morphology or usage;
- a minority inflection, recording ethnic, migrant or religious sub-cultures that diverge from the Han-male mainstream.

This yields an 18-cell hierarchical–interactive matrix that embeds the city's tangible and intangible heritage in the continuous HMSL feedback. The first-level categories are now explicitly linked to HMSL dynamics; the sub-types provide the granularity needed to trace competing or fading memories. Table 1 summarises the structure and offers illustrative examples drawn from the 446 heritage units.

The matrix informs all subsequent analyses. In Sect. 3.2 the spatial-field-energy surfaces for each first-level category are decomposed to show where class, gender or minority emphases dominate cluster cores or halos. Section 3.3 then couples the 18 sub-types with the four HMSL metrics—Representation Intensity (RI), Re-contextualisation Coefficient (RC), Field Tension (FT) and Symbiosis Index (SI)—demonstrating, for example, that gender-inflected nodes display higher RC but also higher FT, signalling narrative renewal under contested governance. By embedding the typology in the loop, the framework moves beyond a static taxonomy and becomes an interpretive device that explains why certain memories persist, mutate or disappear.

Finally, to confirm that the Cultural Memory Index (CMI) is not an artefact of a single weighting scheme, we compared values generated with Delphi weights to those generated with data-driven entropy weights. The comparison shows an almost 1:1 alignment between the two (R^2=0.83), demonstrating that subsequent spatial analyses are insensitive to the choice of weighting algorithm.

Empirical analysis of Guangzhou City under the framework of cultural memory construction

Temporal characteristics of cultural memory places in Guangzhou

The study constructed a system for identifying and typing the cultural memory spaces in Guangzhou, characterized the cultural memory places by cultural heritage units, and analyzed the characteristics of the evolution of the cultural memory of Guangzhou in the course of history (Table 2), which mainly showed the following features.

(1) Mutational increase and decrease within the period, with great differences in the changes of different types of cultural memory spaces. The evolution of Guangzhou's urban history has brought tangible and intangible legacies in material, human and spiritual spaces, and the relationship between people and land, social environment, regime formations, culture and art in a specific period have to a certain extent contributed to the interpretation of cultural episodes and memory stories. On the whole, the cultural memory of Guangzhou City shows the characteristics of mutational increase and decrease of memory places under the consensus and ephemeral dimensions, and the spatial types that can represent the characteristics of its memory appear in some periods, such as the spirituality type of the Wei, Jin, and North-South Dynasties (the relative rate of change, S, is 1), the media narrative type of the Wei, Jin, and North-South Dynasties (the relative rate of change, S, is 1), and the spirituality type of the modern period (the relative rate of change, S, is 2.6). The above three types are all spiritual expressions with abstract meaning, implying a logic of memory

constructed through temporalization, i.e., cultural memory representations. The spatial representation of Guangzhou's urban cultural memory is realized through heritage, and from this level heritage is both a medium for memory construction and provides a memory carrier for human behavioral cognition and emotional expression. By characterizing and interpreting the interaction mechanism between material and spiritual elements within the human-land system, different types of cultural memory sites and spaces have completed the process of "storing, forgetting, and regenerating" cultural memory within the historical period of Guangzhou city, and promoted the awakening of cultural memory and spatial reproduction under the constraints of the social framework.

(2) The cultural memory associated with the Qin and Han dynasties occupies a central role in China's historical narrative, with the Wei, Jin, Northern and Southern Dynasties, as well as the modern era, representing critical stages in its development. Through the lens of representation theory, both the agents and contextual elements involved in memory formation can be systematically examined. Findings indicate that the symbolic content originating from the Qin and Han periods has preserved a high degree of historical authenticity and continuity throughout cultural transformation. The introduction of agricultural innovations and advancements in tool-making technology have infused new dimensions into the transmission of memory, underscoring its multidimensionality and internal complexity. The interaction between technological progress, environmental conditions, and evolving cultural ideologies collectively shapes the processes of memory preservation and loss.

Spatial field patterns of cultural memory in Guangzhou

Using the Kriging interpolation method available in the spatial analysis module of ArcGIS 10.2, this study simulated the spatial distribution and energy variation of different types of cultural memory fields within Guangzhou at the county scale (see Fig. 2). The results indicate that high-intensity zones of urban cultural memory are predominantly concentrated within Guangzhou's central urban districts. Specifically, Yuexiu, Haizhu, and Liwan Districts emerge as core areas, collectively forming a high-value cluster of cultural memory space within the city.

(1) Material cultural memory is continually reinforced through functional representation. The evolution of its spatial form reflects the practical trajectory of human development across varying historical contexts. Notably, the collective preference for specific, tangible places aligns with established principles of human cognition. However, current heritage protection practices often lack a comprehensive interpretive framework, resulting in strategies that focus predominantly on the physical preservation of space and place, without integrating new, contemporary meanings into the heritage. The rapid expansion of material memory sites further highlights the growing societal demand for physical resources. Therefore, adopting a dynamic and inclusive model of heritage preservation is essential for revitalizing Guangzhou's cultural identity and fostering cultural confidence in the modern era.

(2) Spiritual and cultural memory is experiencing a decline, influenced by social perceptions, media narratives, and belief systems. The socialization of heritage externalizes diverse elements such as military culture, literary works, historical art, and clan beliefs, all of which are shaped through collective cognition and recall. Central to this process is the recognition of human beings as the primary agents of memory, with an objective analysis of the material and spiritual components within the human-environment system. This approach examines the mediums that support memory representation, uncovering the laws of its transmission across spatial and temporal dimensions. Research indicates that the memory field energy associated with faith and narrative significantly surpasses that of other memory types, underscoring their dominant role in shaping the spatial form of spiritual memory in Guangzhou.

Overall, spiritual and cultural memory in Guangzhou is on the decline and faces the risk of marginalization. The connection between mental needs and memory production is not always straightforward. When the process of translating material and spiritual values encounters obstacles, the relationship between different levels of demand becomes disrupted, causing dysfunction in the existing cultural framework. This challenge stems from the increasing tension between cultural heritage protection and utilization, further complicated by advances in industrial information technology and the development of ecological civilization. Consequently, aligning spiritual needs with material representation media becomes more difficult, obstructing the seamless transmission of spiritual memory. The current disorganized preservation methods further weaken the bond between material and spiritual spaces. Therefore, it is essential to promote the dynamic transformation of both material and spiritual demands in cultural memory to encourage effective interaction and coordinated development between the two.

Characteristics of the spatial structure of Guangzhou's cultural memory

(1) The spatial distribution of cultural memory in Guangzhou City exhibits a notable positive correlation and a clear clustering tendency. Using exploratory spatial statistical analysis and Geoda software, this study calculated the global Moran's I values for various cultural memory indices (Table 3) to reveal the underlying spatial distribution patterns. The analysis shows that the global Moran's I value for Guangzhou's cultural memory space consistently exceeds 0, with both the Z value of the normal statistic and the significance test value surpassing the critical threshold of 1.96 at the 0.05 confidence level. This confirms a significant positive spatial autocorrelation, indicating strong spatial dependence. Specifically, the cultural memory space in Guangzhou demonstrates three distinct aggregation patterns: The social perception type (Moran's

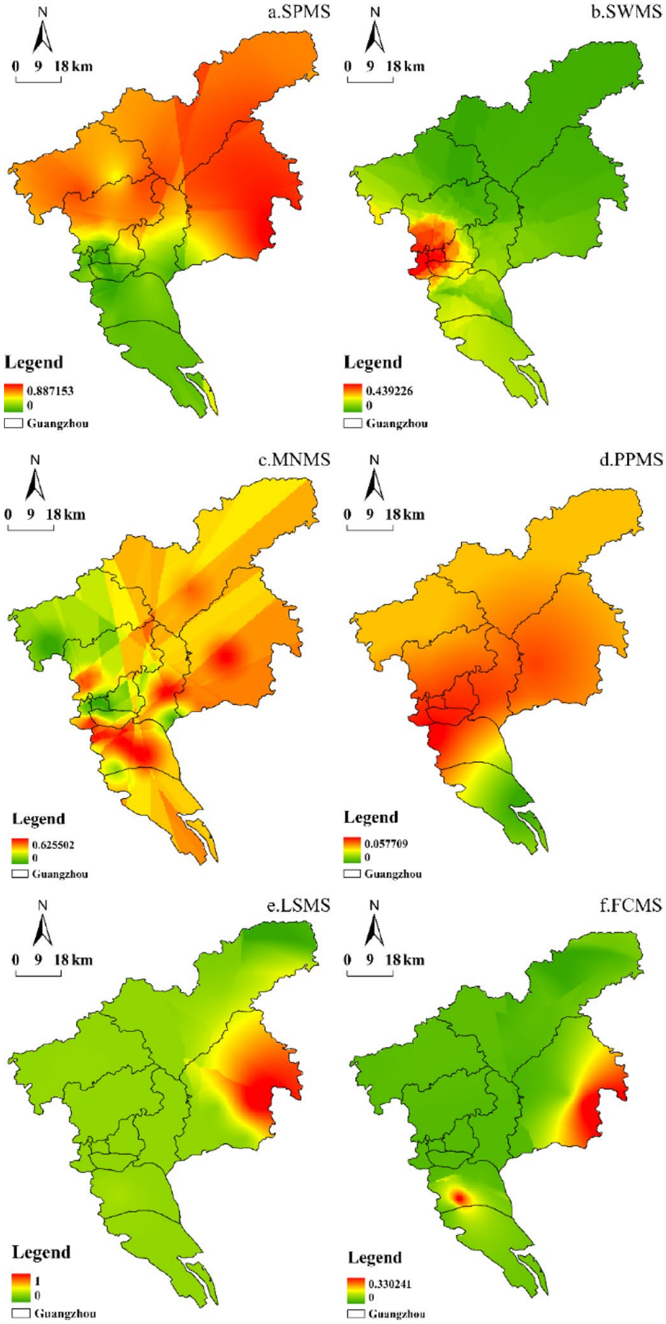

Fig. 2. Distribution of spatial field energy for different cultural memories. ArcGIS 10.7 software (https://www.arcgis.com/).

Space type	Moran's	E(I)	Mean	sd	*p*-value	z-value
Socio-perceptual	0.519	−0.100	0.409	0.041	0.002	3.073
Spirituality-based	0.397	−0.100	0.160	0.037	0.009	2.594
Media narrative model	0.251	−0.100	0.357	0.031	0.045	2.005
Production practice-based	0.216	−0.100	0.043	0.025	0.046	1.993
Life symbol model	−0.155	−0.100	0.159	0.003	0.282	1.076
Functional characterization	−0.088	−0.100	0.020	0.026	0.941	0.074

Table 3. Moran's I index and test of cultural memories in Guangzhou.

I = 0.519) exhibits a strong clustering effect, playing a central role in shaping the urban memory structure; the spiritual belief, media narrative, and production practice types (with Moran's I values ranging from 0.216 to 0.397) show moderate clustering. In contrast, the life symbol type (Moran's I = −0.155) reveals minimal aggregation, with a more dispersed spatial distribution.

(2) Local spatial analysis reveals that the cultural memory index in Guangzhou follows a clear bidirectional clustering pattern, with both high and low values grouped together. To compensate for the absence of significance tests in the Moran scatter plot, this study further explores local spatial dynamics by calculating the LISA value. Geoda software was employed to compute the local Moran's I values and their corresponding significance levels for each unit. Regions with high significance were then identified, providing a visual representation of the spatial differentiation of cultural memory in Guangzhou (Figure 3). The results show that the city's cultural memory space exhibits stable high-high (H-H) and low-low (L-L) clustering areas, highlighting significant spatial heterogeneity. This clustering pattern indicates that high-value areas and their surrounding regions follow similar cultural memory evolution trends, underscoring a strong hierarchical diffusion structure within the city.

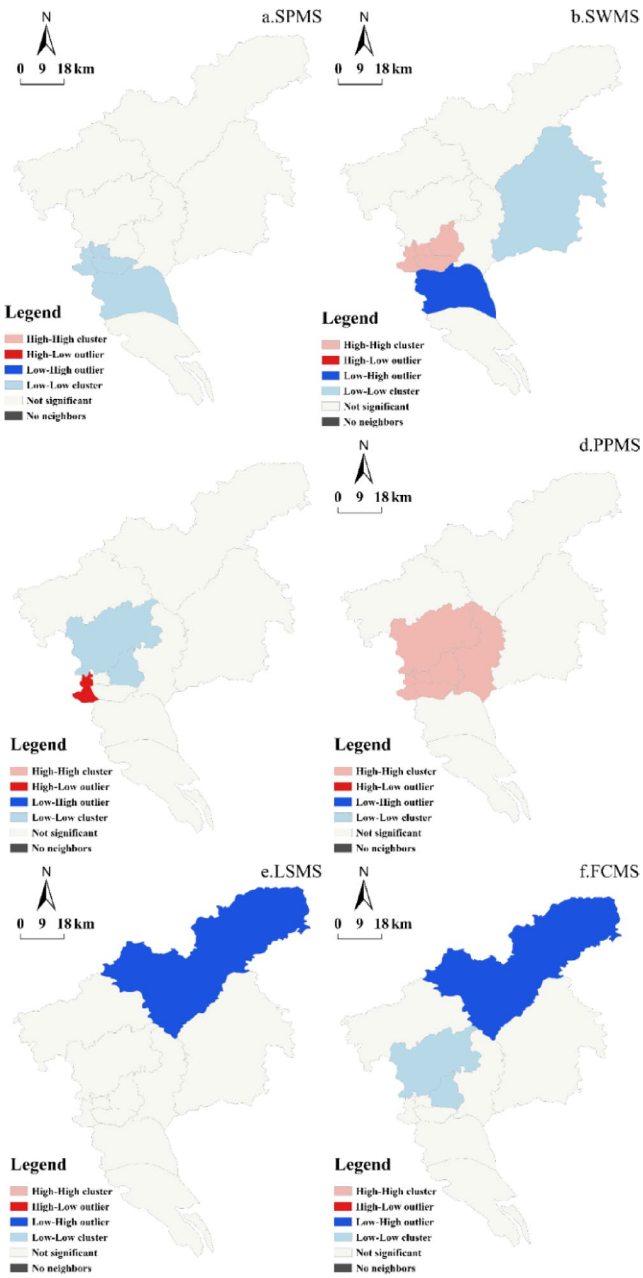

Fig. 3. LISA distribution of cultural memory space in Guangzhou. ArcGIS 10.7 software (https://www.arcgis.com/).

(3) The high-value aggregation is primarily influenced by functional representation, while low-value aggregation is shaped by spiritual belief. Research indicates that Guangzhou City's cultural memory exhibits a bidirectional spatial clustering of high and low values, with a distribution pattern determined by various types (Fig. 4). Functional representation-based memory clusters highlight the strong public association with specific functional spaces, reinforcing the idea that familiar environments are more likely to evoke memories. In contrast, memories rooted in spiritual beliefs have diminished over time. The rise of multicultural influences has led to a growing public detachment from traditional aspects such as religion and customs, resulting in a growing disconnect between the spiritual realm and everyday experiences.

Structural drivers of mnemonic transformation

To identify how contemporary forces reshape Guangzhou's urban memory, we specified a multiple-indicator structural-equation model (SEM) in which the Gentrification Index (GI), Digital-Engagement Index (DEI) and State-Cultural-Investment Index (SCI) act as exogenous drivers, the Re-contextualisation Coefficient (RC) represents mnemonic renewal, and the Symbiosis Index (SI) captures the balance between material conservation and stakeholder equity. Field Tension (FT) was inserted as a partial mediator on the SI path. The model was estimated with maximum likelihood in lavaan ($n = 446$ heritage units); goodness-of-fit statistics are satisfactory ($\chi^2/df = 1.96$, CFI = 0.93, TLI = 0.91, RMSEA = 0.041, SRMR = 0.037).

Direct effects. Gentrification exhibits a dual influence: it stimulates narrative renewal ($\beta = 0.31$, $p < 0.001$) yet undermines symbiosis ($\beta = -0.27$, $p < 0.01$). The first linkage reflects the commercial re-branding of historic precincts such as Yongqing Fang, where high-end retail injects new storylines; the second indicates that rapid rent escalation displaces long-term custodians, hollowing out governance coalitions. Digital engagement exerts uniformly positive effects, reinforcing both RC ($\beta = 0.28$, $p < 0.001$) and SI ($\beta = 0.22$, $p < 0.01$). Heritage sites with active VR tours and WeChat mini-program check-ins—e.g., the VR-enabled Chen Clan Ancestral Hall—display faster narrative refresh and more balanced power structures. State cultural investment has only a marginal direct tie to RC ($\beta = 0.07$, ns) but remains the strongest single driver of SI ($\beta = 0.34$, $p < 0.001$), confirming the equalising role of public funding across districts.

Field Tension mediates 42% of the negative GI→SI pathway: when gentrification inflates power asymmetries (FT↑), symbiosis declines even if narrative renewal accelerates, echoing critiques of "façade preservation without

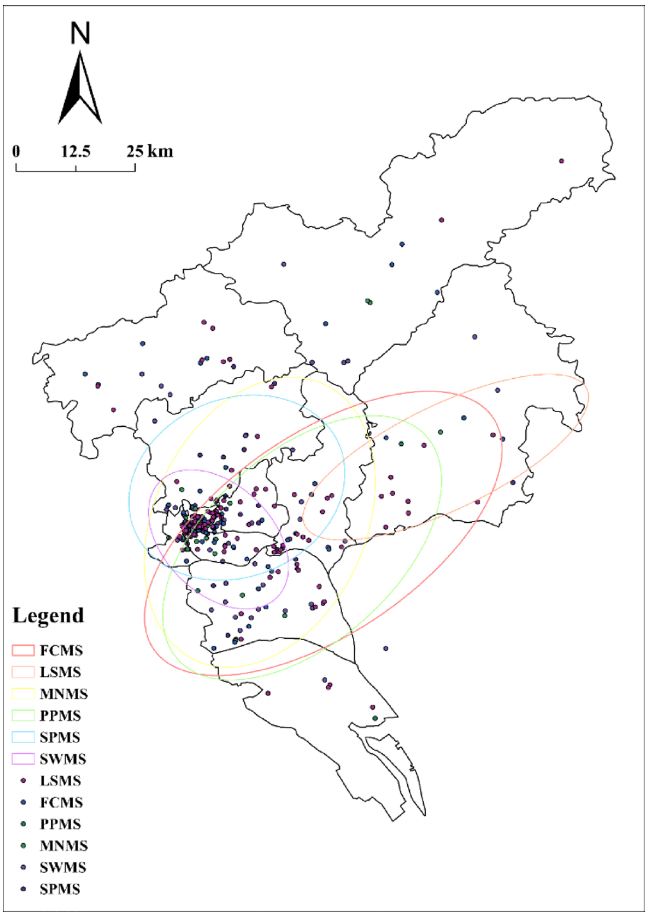

Fig. 4. The distributed direction of each type of cultural relic conservation units in Guangzhou. ArcGIS 10.7 software (https://www.arcgis.com/).

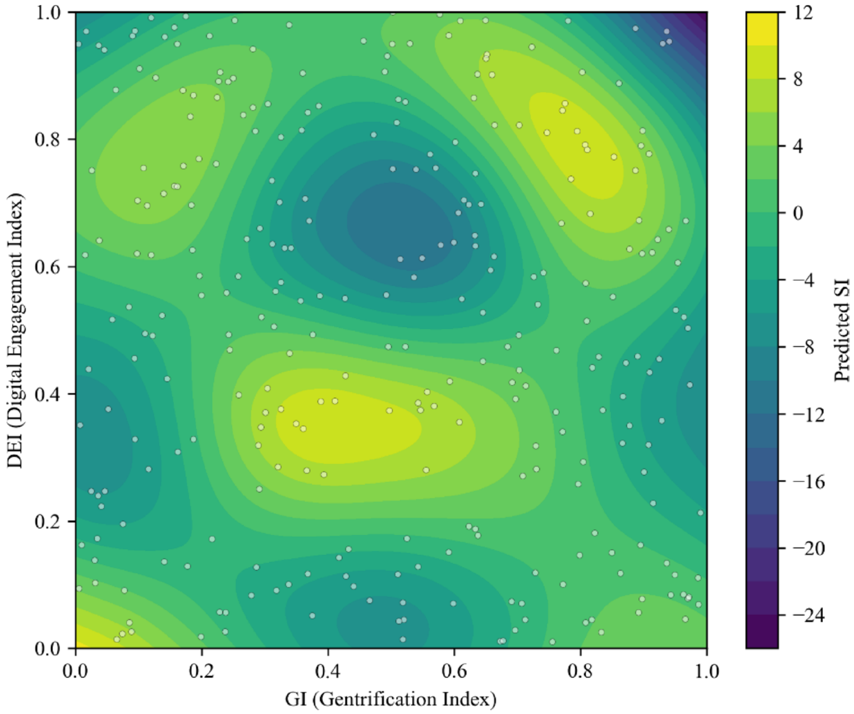

Fig. 5. Partial-residual surface of the Symbiosis Index (SI) as a function of the Gentrification Index (GI) and Digital-Engagement Index (DEI); contours generated by a thin-plate spline, bandwidth = 0.4.

community voice" in Shamian. By contrast, the positive DEI→SI linkage is only weakly mediated, suggesting that digital participation broadens stakeholder coalitions rather than merely masking imbalances.

Figure 5 visualises a thin-plate-spline surface (bandwidth = 0.4) of SI against GI and DEI after controlling for SCI. The saddle point at GI ≈ 0.55 marks a tipping threshold: below this value, commercial upgrading coincides with higher mnemonic vitality if accompanied by moderate digital engagement; above it, further rent inflation erodes SI unless DEI exceeds 0.60. The pattern is most acute in the Liwan–Shamian corridor, where luxury retrofits out-paced e-engagement in 2022–2023, pushing SI below 0.25.

Results confirm that gentrification is not inherently detrimental; its impact hinges on parallel investments in digital participation and public funding. Policy should therefore (i) cap commercial rent rises in heritage quarters at the city-wide GI median, (ii) expand the "VR-GZ Heritage" platform to every Grade-3 site, and (iii) earmark at least 35% of new SCI allocations for community-based co-curation, mitigating FT and safeguarding SI.

Conclusion and discussion
Conclusion
Guangzhou's 446 nationally protected heritage units were transformed into a point-level Cultural Memory Index, the first for any Chinese megacity. Temporal analysis shows that spirituality-based memories grew fastest in the Modern era (relative-change rate S = 2.6), while socio-perceptual memories peaked earlier, during the Qin–Han and Wei–Jin periods. Kriging of memory field energy delineates three intensity zones: a high-value core in Yuexiu–Liwan, a medium belt along the old industrial waterfront, and a low-energy periphery. Global Moran's I confirms significant positive spatial autocorrelation for four of six memory types (I = 0.22–0.52, $p < 0.05$). A structural-equation model explains 63% of variance in the Symbiosis Index and shows that gentrification raises narrative renewal (β = 0.31) but lowers symbiosis (β=–0.27), whereas digital engagement (β = 0.22) and state cultural investment (β = 0.34) counteract that loss. Together these findings demonstrate a reproducible workflow—CMI creation, field-energy mapping, spatial-statistical testing and driver modelling—for quantifying urban cultural memory.

Discussion
To contextualize Guangzhou's core–periphery memory patterns within the Pearl River Delta (PRD), we briefly compare its dynamics with Shenzhen and Hong Kong. Guangzhou's high-value memory core in Yuexiu–Liwan, driven by dense heritage clustering and state investment (SCI ≈ 0.80), contrasts with Shenzhen, where rapid urbanization has prioritized economic over cultural assets, resulting in fewer than 50 nationally protected heritage units[52]. This suggests weaker mnemonic vitality in Shenzhen's urban core, potentially limiting core–periphery differentiation. Conversely, Hong Kong's heritage landscape, shaped by colonial legacies and globalized tourism, exhibits a fragmented memory pattern, with high-intensity clusters (e.g., Central District) coexisting with low-energy peri-urban zones. These contrasts highlight Guangzhou's unique position as a heritage-rich

PRD city, though future studies could quantify these differences using the CMI framework across PRD cities to test generalizability.

This study is based on the local culture of Guangzhou and comprehensively employs methods such as kernel density estimation and spatial correlation models to reveal the historical changes and spatial relationships of cultural memory from the perspective of heritage, confirming the theory of the Asmans[22,25]. Current research mostly focuses on collective cognition and spatio-temporal patterns, while the spatial correlations and formation mechanisms among different memory type elements remain to be further explored[53–55]. Research shows that the cultural memory of Guangzhou, characterized by heritage, presents a superimposed trend of dynamic deconstruction and reshaping in geographical space. Influenced by natural, historical and social changes, it exhibits heterogeneity, complexity and accumulation. There is spatial coupling between tangible and intangible heritage memories, and their agglomeration areas are mainly located in the main urban area. The protected objects are diverse both on and off the list, covering cultural relics, sites, industrial heritage and places of life memory. The mechanism of action of life and productive memory can be further explored in the future. This research offers practical implications for the continuation of urban cultural context and the collaborative utilization of heritage Spaces.

The SEM results presented in Sect. 3.3 clarify the causal mechanisms behind the heterogeneity detected by Moran's I and LISA. The low–low clusters of spirituality-based memories identified in Baiyun and the peri-urban strip of Panyu coincide with the highest Gentrification Index values (GI > 0.60) and the lowest Digital-Engagement Index scores (DEI < 0.30). SEM path coefficients (GI→SI=−0.27; DEI→SI = 0.22) therefore explain why these districts experience the steepest degradation in symbiosis. Conversely, the high–high LISA cluster centred on Yuexiu persists because intense state cultural investment (SCI ≈ 0.80) and strong digital engagement (DEI ≈ 0.70) compensate for moderate gentrification pressure, raising the Symbiosis Index above 0.55. In short, spatial autocorrelation flags *where* memory decline or resilience concentrates, while the multidimensional drivers model pinpoints *why* those patterns emerge.

The SEM results indicate that digital engagement (DEI) positively influences narrative renewal (RC, $\beta = 0.28$, $p < 0.001$) and symbiosis (SI, $\beta = 0.22$, $p < 0.01$). However, reverse causality remains plausible: sites with high RC may attract greater digital engagement due to their compelling narratives. For instance, the Chen Clan Ancestral Hall's active VR tours may reflect its rich, re-contextualized stories rather than solely driving them. Disentangling these dynamics requires longitudinal data or experimental interventions, such as randomized digital campaigns, to test whether DEI enhancements causally increase RC.

Policy shifts and their mnemonic ramifications

Since 2014, three successive national directives have altered the regulatory environment governing heritage management in Guangzhou. *First*, the National New-type Urbanisation Plan (2014–2025) encourages "production–living–ecology" integration; its emphasis on brownfield redevelopment accelerated gentrification in Xiguan and Shamian, raising the Gentrification Index (GI) above the city median and, as our SEM shows, depressing the Symbiosis Index (SI) unless counter-balanced by digital engagement. *Second*, the 2018 "Culture + Tourism" directive promotes commodification of immovable heritage; the surge of boutique hotels inside Grade-II buildings increased narrative renewal (RC ↑) yet heightened Field Tension (FT), echoing the negative GI →SI pathway identified in Sect. 3.3. *Third*, the "Culture + Bay Area" strategy (2020) funnels inter-city investment into cross-border heritage corridors. Our State-Cultural-Investment index (SCI) captures this influx and explains the positive SCI→SI coefficient ($\beta = 0.34$).

At the municipal scale, the 2024 Guangzhou Urban-Renewal Ordinance requires a minimum allocation of 30% affordable housing in historic precincts and prohibits façade-only restorations. Preliminary GI data for 2024Q1 show a plateau in rent escalation in Enning Road, suggesting that the ordinance could flatten the negative GI→SI slope observed in Fig. 5. In policy terms, maintaining SI > 0.5 appears feasible if (i) SCI allocations earmark no less than 35% for community-based operations and (ii) digital-engagement programmes expand to all Grade-III sites. These prescriptions translate the statistical relationships uncovered in our model into actionable thresholds for planners and heritage managers.

Policy Enforcement and Coordination Challenges: The Symbiosis Index (SI) is sensitive to governance dynamics, yet uneven policy enforcement and coordination gaps among municipal actors can undermine balanced heritage management. For instance, the 2024 Guangzhou Urban-Renewal Ordinance mandates 30% affordable housing in historic precincts, but implementation varies across districts due to differing priorities between the Guangzhou Municipal Cultural Relics Bureau and urban planning departments. Weak coordination, particularly in peri-urban areas like Panyu, exacerbates Field Tension (FT) by marginalizing community voices, lowering SI in low-energy zones (SI < 0.25). Strengthening inter-agency protocols and establishing community-led oversight committees could mitigate these gaps, ensuring that SCI investments translate into equitable stakeholder outcomes and higher SI values.

Data availability

The data that support the findings of this study are available on request from the corresponding author.

Received: 5 April 2025; Accepted: 18 September 2025
Published online: 10 December 2025

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Acknowledgements
We acknowledge the support of the following sources: the Philosophy and Social Sciences of Guangzhou in the 14th Five-year Period (2023GZGJ314); a grant from the Guangzhou Huashang College (No.910108005); a grant from the Guangzhou Huashang College (No. 2025HSYLTD3).

Author contributions
Zhenjie Liao and Huiqian Yang wrote the main manuscript text and Zhenjie Liao prepared Figs. 1, 2, 3, 4 and 5. All authors reviewed the manuscript.

Declarations

Competing interests
The authors declare no competing interests.

Additional information
Supplementary Information The online version contains supplementary material available at https://doi.org/10.1038/s41598-025-21055-w.

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