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A Multi-Sensory Value Perception Deep Map model for smell–sound heritage in historic districts

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Article

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Abstract

Historic districts embody heritage value beyond visual form, yet quantitative assessment has overlooked soundscape and smellscape. This study proposes a Multi-Sensory Value Perception Deep Map (MVC-DepthMap) model integrating soundscape, smellscape and Historic Land-Use Assessment to quantify sensory heritage value through Time Depth and Historical Richness. Using Kunming Old Street as a case study, data from soundwalks, smellwalks, questionnaires and interviews were analysed with GIS. Results reveal a spatial pattern of core-node clustering, traditional-lane extension and peripheral decline. The Yunnan Confucian Temple, Guanghua Street East and Wenming Street form high-value clusters (MVC = 1.00, 0.65 and 0.65). Significant sound–smell interaction effects were observed: “traditional vending calls–food aromas” and “temple bells–incense smoke” produced sensory synergy, whereas “modern traffic noise–historic odours” generated sensory conflict. The model supports differentiated conservation and inclusive urban regeneration.

Introduction

Historic districts are products of local character, culture and tradition anchored in urban memory. They play a significant role in fostering urban renewal and enhancing public spaces while facing pressures from urbanisation and functional transformation. Authenticity is a fundamental criterion for assessing the value of cultural heritage, encompassing both the factual integrity of historical components and the holistic representation of cultural significance. UNESCO has emphasised that heritage protection should extend beyond tangible heritage—architectural styles and street patterns—to intangible heritage such as oral traditions, social practices and environmental sounds [1].

A paradigm shift is underway in heritage conservation. The 2011 UNESCO Recommendation on the Historic Urban Landscape treats heritage as an integrated system of tangible and intangible, natural and cultural, material and spiritual elements [4]. Within this framework, heritage value cognition shifts from preserving physical fabric to understanding dynamic human–place relations. However, existing authenticity research on historic districts has predominantly focused on visual aspects, with the significance of sound and smell in authenticity preservation remaining underexplored [2, 3]. Sound and smell surpass temporal and societal transformations, awaken memories and carry cultural significance, thus enhancing the heritage value of historic districts. Soundscapes and smellscapes with social value are regarded as having cultural heritage significance, reflecting the intrinsic properties of the heritage itself [5].

Multisensory heritage research has emerged as a growing field. The Multimodal Hong Kong project systematically records soundscape and smellscape at culturally meaningful places, building a multisensory cultural heritage database [1, 5]. Empirical research at Wong Tai Sin Temple demonstrated that soundscape and smellscape play indispensable roles in shaping cultural inclusiveness, vitality and sustainability of cities [6]. Sensory heritage encompasses culturally valued practices, rituals and everyday activities experienced through all senses; although vision dominates heritage research, hearing

and smell are generally more immersive and pervasive [6]. In historic districts, soundscape and smell serve as vital indicators of authenticity and cultural identity, offering insights into bygone eras and living quarters [7].

Despite these advances, three critical gaps persist. First, existing heritage value quantification models focus on visual material carriers—land use, buildings, streetscapes—with insufficient attention to sound and smell as non-material heritage elements [8–11]. Second, soundscape and smellscape research has developed separately, lacking an integrated framework for assessing their combined heritage value [12–14]. Third, while crossmodal research demonstrates that smell and sound interact to shape environmental perception [24–28], this interaction has not been incorporated into spatial heritage assessment. The Odeuropa project has advanced olfactory heritage digitisation by applying state-of-the-art AI techniques to 43,000 historical images and 167,000 textual resources in six European languages, extracting over 2.5 million olfactory references into the European Olfactory Knowledge Graph [22, 23]. However, its focus remains on textual knowledge extraction rather than real-world spatial assessment.

The concept of sensory heritage, defined as the sum total of culturally valued sensorial experiences of a community manifested through practices, rituals and everyday activities, provides a theoretical foundation for this study [6]. This study addresses three core questions: How can the heritage value of sound and smell in historic districts be quantified? How can an evaluation model applicable to multisensory heritage be constructed? How can multisensory heritage value assessment support decision-making for historic district conservation and regeneration?

This study aims to construct a Multi-Sensory Value Perception Deep Map (MVC-DepthMap) model applicable to historic districts, integrating soundscape, smellscape and Historic Land-Use Assessment through two indicators: Time Depth and Historical Richness. Using Kunming Old Street as a case study, data were collected through soundwalks, smellwalks, questionnaires and semi-structured interviews, and analysed with GIS. The model advances historic district conservation from visual priority to multisensory synergy by providing a systematic quantification framework for sensory heritage.

Methods

Study area

Kunming Old Street is located in Huguo Subdistrict, Wuhua District, Kunming, Yunnan Province. It extends from Zhengyi Road in the east to Yunrui West Road and Wuyi Road in the west, and from Huashan South Road in the north to Dongfeng West Road in the south. It is the core area of Kunming as a national historical and cultural city and the best-preserved and largest traditional historic district in the urban area [32]. The district dates back to 1119 AD during the Dali Kingdom period and has more than 900 years of historical accumulation through the Yuan, Ming, Qing, Republican and contemporary periods.

The spatial structure consists of “six streets and fifteen lanes.” The six main streets are Qianwang Street, Wenming Street, Yongdao Street, Guanghua Street, Wenmiao Zhijie and Jingxing Street. The district covers approximately 13.33 ha and contains 15 cultural relic protection units at various levels, including two national key units—the Victory Memorial Hall of the Anti-Japanese War and Fulin Tang—and three provincial units—the former residence of Nie Er, the former site of Fuchunheng Firm and the Ma Family Courtyard. The architectural character is dominated by traditional dwellings and modern shop buildings from the late Qing and Republican periods, including Yunnan “Yikeyin” courtyard houses and arcade buildings combining Chinese and Western styles.

Sampling sites

Ten representative nodes were selected as sensory sampling points (Fig. 1). Selection followed four principles: coverage of at least one representative point on each of the six main streets; inclusion of both areas around cultural relic protection units and ordinary commercial blocks; coverage of residential, commercial and mixed functional types; and inclusion of special scenes such as catering concentrations, cultural performance spaces and flower-and-bird markets. Table 1 presents the basic information of each site.

Table 1
Information of ten sensory sampling sites in Kunming Old Street

ID	Street	Type	Key sound sources	Key smell sources	Heritage designation
S01	Zhengyi Rd	Mixed commercial–residential	Vehicle traffic, shop calls	Food odours, exhaust	Old buildings along Zhengyi Rd
S02	Guanghua St.	Traditional commercial	Wok frying, visitor conversation	Rice-noodle aroma, herbal medicine	Fulin Tang (national)
S03	Yongdao St.	Cultural exhibition	Guide narration, footsteps	Old timber, incense	Nie Er Former Residence (provincial)
S04	Jingxing St.	Flower-and-bird market	Birdsong, calls, parrot mimicry	Flowers, bird droppings	Old buildings along Jingxing St.
S05	Wenming St.	Time-honoured commercial	Shop greetings, wok sounds	Rice-noodle broth, pastry aroma	Dongfang Dongfang Bookstore, Ouyang residence
S06	Wenmiao Zhijie	Residential	Resident conversation, bicycle bells	Old timber, home cooking	Wang Chi Former Residence (district)
S07	Qianwang St.	Modern commercial	Background music, coffee machine	Coffee, tea	Fuchunheng Firm (provincial)
S08	Zhengyi Rd	Historic cultural building	Reading, traditional instruments, civic activity, birdsong	Tea, flowers, agarwood	Lingxing Gate (provincial)
S09	Qianwang St / Yin Gui Lane	Cultural performance	Drama dialogue, audience	Old timber, tea	Ma Family Courtyard (municipal)
S10	Yunrui East Rd	Cultural activity	Instrumental performance, singing	Ink, paper	Old buildings on Wenming St.

Historical sensory heritage identification

Historical sensory heritage identification provides the basis for Time Depth calculation. Because direct records of everyday sensory experience in historical documents are scarce, this study combined historical document analysis with semi-structured interviews, extracting sound- and smell-related information from gazetteers, old photographs, oral histories and local cultural-historical materials, and classifying it by historical period [13, 35, 36]. Key historical documents consulted include the New Compilation of Yunnan General Gazetteer, the Daoguang Kunming County Gazetteer (1835 edition), the

Republican Kunming City Gazetteer, Luo Yangru‘s Ji Wo Suo Zhi Ji and recent compilations such as Kunming Old Street Visual Ethnography.

Historical sound heritage was identified in three categories (Table 2). Itinerant vendors’ calls, centred on the cries of street hawkers from the Republican period to the 1950s and accompanied by teahouse storytelling and opera singing, formed the everyday auditory foundation. Folk festival drumming was concentrated during Spring Festival and temple fairs. Production and daily-life implement sounds included the copper scale collision and medicine grinding at Fulin Tang, and the wooden mallet for pounding erkuai.

Table 2
Historical sound heritage of Kunming Old Street

Heritage category	Sub-category	Description	Periods	Typical space
Historical sound	Itinerant vendors’ calls	Hawkers calling food and goods; teahouse Storytelling and opera singing	Republican–1950s	Yongdao St, Guanghua St, Zhengyi Rd junction
Historical sound	Folk festival drumming	Drums, firecrackers and performance accompaniment during festivals	festival periods	Guanghua St, Yongdao St, Jingxing St.
Historical sound	Production and daily-life implement sounds	Copper scale collision, medicine grinding; erkuai pounding; rice milling; knife sharpening pounding; rice milling; knife sharpening	Late Qing–mid-20th century	Fulin Tang, lane workshops
Special spatial sound	Dongfang Bookstore	Page-turning, low voices contrasting with Street traffic	1926 onward	Wenming St / Guanghua St junction

Historical smell heritage was summarised in four categories (Table 3). Erkuai and grilled tofu aromas originated from traditional snack stalls. Fulin Tang‘s herbal aroma mixed multiple Chinese medicines with aged wooden cabinet scents. Jingxing Street’s flower-and-bird market has formed a composite olfactory character of floral, grassy and bird-dropping odours since the mid-20th century. Incense from candle shops near the Victory Memorial Hall drifted as background odour during festivals.

Table 3
Historical smell heritage of Kunming Old Street

Heritage category	Sub-category	Description	Periods	Typical space
Historical smell	Erkuai and grilled tofu aroma	Roasted erkuai and grilled tofu with chilli oil and sweet sauce	At least since Qing	Guanghua St, Er Lane, Wenming St entrance
Historical smell	Fulin Tang herbal medicine aroma	Chenpi, danggui, huangqi, gancao mixed with aged wooden cabinets	From 1857	Fulin Tang, Guanghua St.
Historical smell	Flower-and-bird market smell	Composite of floral, grassy and bird-dropping odours	From mid-20th century	Jingxing St flower-and-bird market
Historical smell	Religious and domestic incense	festival incense drifting as background odour	festival periods	Victory Memorial Hall, Yongdao St

Current smell-sound heritage assessment

Soundwalk and smellwalk surveys were conducted at the ten nodes from July to December 2025, repeated across seasons and time slots [31, 37]. Sound sources were classified into three types—natural environmental sounds (birdsong, wind, vegetation), human life sounds (resident conversation, commercial operation, food preparation) and cultural marker sounds (traditional vending calls, cultural activities, religious activities)—with cultural weights of 0.20, 0.35 and 0.45, respectively [38, 39]. Smell sources were similarly classified into natural ecological odours (plants, flowers, post-rain), life and production odours (food, tea, medicinal herbs, timber) and cultural symbolic odours (incense, time-honoured brand aromas, local specialty food odours), with weights of 0.20, 0.35 and 0.45 [17–19]. Sound source diversity (SD) and smell source diversity (OD) were calculated as:

$$SD_i = \sum (C_{ij} \times W_{sj})$$

$$OD_i = \sum (C_{ij} \times W_{oj})$$

Where *Cij* indicates presence or absence of sensory type *j* at site *i*, and *Wsj*, *Woj* are the cultural weights. The integrated sensory richness base value was calculated as

HRi'=05*SDi + 05*ODi

Jingxing Street and the Panlong District Cultural Centre scored highest ($HR' = 1.00$), followed by Guanghua Street, Wenming Street and the Ma Family Courtyard ($HR' = 0.80$).

Time Depth quantification

Time Depth (TD) reflects the historical continuity and accumulation of sensory elements and their spatial carriers [10, 11, 13]. The historical periods of Kunming Old Street were divided into four phases with assigned values: *traditional formation (Qing and earlier) = 5; modern commercial development (Republican) = 4*; *life continuity (1949–reform and opening up) = 3*; *conservation and renewal (contemporary) = 2*. *TD* was calculated as:

TD=historical period value × number of sensory carrier layers

Where sensory carriers include traditional buildings, historic lanes, cultural facilities, commercial remains and living spaces. Results showed that the Yunnan Confucian Temple (S08) had the highest TD (standardised TD = 1.00; Fig. 2). Guanghua Street (S02), Wenming Street (S05) and the Ma Family Courtyard (S09) also showed high TD (standardised TD = 0.67; Fig. 2). Qianwang Street (S07) had the lowest TD (standardised TD = 0.00; Fig. 2).

Historical Richness Quantification

Historical Richness (HR) evaluates the horizontal compounding of sensory types and cultural themes within a spatial unit [11, 13]:

HR=number of sensory themes × type weight

The Yunnan Confucian Temple (S08) had the highest HR (standardised HR = 1.00; Fig. 3), combining architectural culture, religious ritual, traditional sounds and symbolic smells. Wenming Street (S05) and Guanghua Street (S02) scored 0.62 (Fig. 3).

Multi-Sensory Value Perception Deep Map construction

After Standardisation of *TD* and *HR*, the *MVC* index was calculated as(Table 4):

$$MVC_i = 0.5 \bullet TD_i\prime + 0.5 \bullet HR_i\prime$$

Table 4
MVC indices for ten sites

ID	Site	Standardised TD	Standardised HR	MVC
S01	Zhengyi Road	0.21	0.00	0.11
S02	Guanghua St. East	0.67	0.62	0.65
S03	Yongdao Street	0.31	0.35	0.33
S04	Jingxing Street	0.21	0.53	0.37
S05	Wenming Street	0.67	0.62	0.65
S06	Wenmiao Zhijie	0.25	0.18	0.22
S07	Qianwang Street	0.00	0.00	0.00
S08	Yunnan Confucian Temple	1.00	1.00	1.00
S09	Ma Family Courtyard	0.67	0.41	0.54
S10	Panlong Cultural Centre	0.10	0.18	0.14

Results

Historical sensory heritage identification

The historical sensory heritage identification revealed distinct spatial concentrations of sound and smell heritage across the district. Itinerant vendors' calls were concentrated at the junction of Yongdao Street, Guanghua Street and Zhengyi Road, where commercial activity has historically been most intense (Table 2). Folk festival drumming was distributed across Guanghua Street, Yongdao Street and Jingxing Street, corresponding to the main festival procession routes. Production and daily-life implement sounds were localised at Fulin Tang and adjacent lane workshops. Dongfang Bookstore formed a unique "quiet–noisy" auditory contrast at the Wenming Street/Guanghua Street junction. For smell heritage, erkuai and grilled tofu aromas were concentrated along Guanghua Street and Er Lane (Table 3). Fulin Tang's herbal medicine aroma has been a defining olfactory feature of Guanghua Street since 1857. Jingxing Street's flower-and-bird market formed a composite smellscape from the mid-20th century. Incense from candle shops near the Victory Memorial Hall created a seasonal olfactory layer during festivals. These historical sensory elements provide the foundation for Time Depth calculation and reveal the deep historical roots of the district's multisensory character.

Spatial distribution of multisensory heritage value

The MVC index reveals a spatial pattern of core-node clustering, traditional-lane extension and peripheral decline (Fig. 4). The Yunnan Confucian Temple (S08) forms the highest-value core (MVC = 1.00), combining deep historical accumulation with diverse sensory resources including bells, chanting,

incense and plant odours. Guanghua Street East (S02) and Wenming Street (S05) form a traditional commercial composite value zone (MVC = 0.65), where commercial activity sounds overlay with food and herbal medicine odours, embodying a life-continuity multisensory heritage character [40, 41]. The Ma Family Courtyard (S09) and Jingxing Street (S04) represent cultural performance and market-type nodes (MVC = 0.54 and 0.37). Qianwang Street (S07) has the lowest value (MVC = 0.00); Zhengyi Road (S01) is also low (MVC = 0.11) because modern traffic sounds and vehicle exhaust weaken its historical sensory value expression [42, 43].

Model validation and comparison

To evaluate the validity and advancement of the MVC-DepthMap model, we compared its assessment results with a conventional visual-based heritage assessment approach. The conventional approach evaluates heritage value based solely on building age, historical events and spatial pattern, whereas the MVC-DepthMap additionally incorporates soundscape and smellscape dimensions through Time Depth and Historical Richness. As shown in Table 5, the MVC-DepthMap identified the Yunnan Confucian Temple (S08) as the highest-value node (MVC = 1.00), which is consistent with the conventional assessment that also ranks it highest due to its deep historical accumulation. However, for nodes such as Guanghua Street East (S02) and Wenming Street (S05), the conventional visual-based assessment would assign lower ranks because their architectural value is less prominent than that of the Confucian Temple. In contrast, the MVC-DepthMap elevated these two nodes to high-value clusters (MVC = 0.65) by capturing the rich multisensory combinations of commercial sounds and food/herbal medicine aromas that are integral to their heritage character. Similarly, Jingxing Street (S04), which is unremarkable from a purely architectural perspective, received a moderate MVC value (0.37) due to its distinctive flower-and-bird market soundscape and composite smellscape. These results demonstrate that the MVC-DepthMap captures sensory heritage dimensions that conventional visual-based assessments fail to recognise, thereby providing a more comprehensive understanding of heritage value in historic districts.

Table 5
Comparison between conventional visual-based assessment and MVC-DepthMap results

Site	Conventional visual-based assessment	MVC-DepthMap assessment	Key sensory heritage contribution
S08 Yunnan Confucian Temple	High (deep historical accumulation)	High (MVC = 1.00)	Bells, chanting, incense, plant odours
S02 Guanghua St East	Medium (moderate architectural value)	High (MVC = 0.65)	Commercial sounds, food and herbal medicine odours
S05 Wenming St	Medium (moderate architectural value)	High (MVC = 0.65)	Shop greetings, wok sounds, rice-noodle [broth, pastry aroma
S04 Jingxing St	Low (limited architectural value)	Medium (MVC = 0.37)	Birdsong, calls, floral and bird-dropping odours
S07 Qianwang St	Low (modern commercial)	Low (MVC = 0.00)	Limited historical sensory resources

Smell–sound interaction effects

Sound and smell do not function independently but form synergistic or conflicting effects through crossmodal correspondences [24–28]. Traditional vending calls with food aromas, temple bells with incense, and lane life sounds with traditional catering odours were evaluated by respondents as harmonious, authentic and having a sense of place, while modern traffic sounds with historical odours and mechanical noise with traditional timber scents were evaluated as conflicting. This finding aligns with the dual mechanism identified in soundscape heritage research, where quietness activates positive emotion while culturally emblematic sounds convert that emotion into attachment [32, 34]. Recent multisensory research in heritage contexts has confirmed that sound and smell are not perceived in isolation but interact through crossmodal correspondences to shape place identity and emotional engagement [2, 4]. Studies in Hong Kong's wet markets and Chinese temples have further demonstrated that the strongest associations between soundscape and smellscape are with emotion, culture and place attachment [2, 20]. Conventional heritage assessment treats sound and smell as independent environmental elements, whereas their combination can produce synergy or conflict, meaning conservation must maintain the cultural relatedness between sensory elements.

Discussion

The MVC-DepthMap reveals that multisensory heritage value in Kunming Old Street is not homogeneously distributed but shows core clustering along traditional lanes and decline toward the periphery. High-value areas concentrated around the Yunnan Confucian Temple derive their value from deep historical accumulation and the superposition of multiple sensory resource types. The integration of architectural remains, traditional cultural activities and associated soundscapes and smellscapes

constitutes a continuous historical perceptual environment, embodying the fusion of material heritage and non-material perceptual experience [14, 20].

Higher-value areas including Guanghua Street East, Wenming Street and the Ma Family Courtyard combine traditional commerce, residential life and cultural display functions. Guanghua Street produces commercial soundscapes with local food and herbal medicine odours; Wenming Street extends historical environmental characteristics through traditional dwellings and lane life; the Ma Family Courtyard forms stable spatial memory through architectural heritage and cultural display [7, 15, 16]. Medium-value areas such as Jingxing Street and Yongdao Street, although relatively weak in historical time depth, still possess strong life-type sensory heritage characteristics through market activities, resident interaction and environmental perceptual resources [19, 29]. Lower-value areas including Zhengyi Road, Qianwang Street and the Panlong District Cultural Centre have reduced multisensory value mainly because modern traffic functions and spatial functional transformation have reduced the continuity of sound, smell and life activities in the traditional historical environment [33].

Conventional historic district assessment focuses on building age, historical events and spatial pattern—visual elements—with insufficient attention to non-visual perceptual factors [8–11]. The MVC-DepthMap introduces soundscape and smellscape resource assessment on the basis of traditional historical value assessment, achieving integrated expression of historical value and multisensory experience through Time Depth and Historical Richness [13]. Compared with single-visual or single-soundscape assessment models, this model transforms originally subjective and dynamic sensory experience into spatialised indicators, expanding the dimensions of historical heritage value assessment [29, 30]. Through GIS spatial analysis, it further transforms node assessment results into continuous spatial distribution, achieving a shift from point-based assessment to regional value expression [12, 35]. The model validation results further confirm that the MVC-DepthMap captures sensory heritage dimensions that conventional visual-based assessments fail to recognise, as demonstrated by the elevated rankings of Guanghua Street East, Wenming Street and Jingxing Street (Table 5).

The model also has good potential for wider application. The indicator system can be adjusted according to the cultural characteristics of different historic districts and can be embedded as a multisensory data layer in urban spatial information platforms. However, multisensory environments exhibit significant temporal variation and individual differences; sound and smell assessment remains influenced by season, activity type and subjective perception [31, 37]. Future research could combine long-term monitoring data and intelligent sensing technologies to improve the accuracy and dynamic expressive capacity of multisensory heritage value assessment [6, 44].

The finding that sound and smell form synergistic or conflicting effects through crossmodal correspondences has important theoretical implications [24–28]. This aligns with research demonstrating that the visual and auditory environments are interdependent in shaping human perception of heritage soundscapes [32, 33]. As demonstrated in studies of the Grand Song of the Dong, audio-visual interaction produces a more complex perceptual structure than single-sensory stimulation

alone, with visual elements introducing spatial limitation perception and positively influencing heritage value evaluation [34]. Similarly, soundscape authenticity research has established that sound characteristics such as low strength and slow tempo tend to evoke historical authenticity in historic districts [32].

The smell–sound interaction effect provides a new dimension for heritage value assessment and a new criterion for conservation decision-making: interventions should preserve not only the individual sound or smell but also the meaningful pairings that constitute place identity. In the case of Kunming Old Street, traditional vending calls paired with food aromas and temple bells paired with incense represent culturally encoded sensory combinations that have developed over centuries of everyday practice. Recent multisensory research in heritage contexts has confirmed that sound and smell are not perceived in isolation but interact through crossmodal correspondences to shape place identity and emotional engagement [2, 4]. Studies in Hong Kong's wet markets and Chinese temples have further demonstrated that the strongest associations between soundscape and smellscape are with emotion, culture and place attachment [2, 20].

Conventional historic district regeneration typically prioritises visual landscape improvement, while non-visual environmental factors are easily overlooked. The MVC-DepthMap offers a new perspective for inclusive urban regeneration. First, multisensory environments can provide auxiliary spatial cognitive cues for people with visual impairments. In Kunming Old Street, commercial activity sounds, traditional lane sounds and distinctive local odours can serve as environmental cues beyond vision, enhancing the accessibility and recognisability of historical space [17, 18]. Second, multisensory assessment promotes a shift in conservation philosophy from visual priority to multisensory synergy. By identifying multisensory value grades in different areas, differentiated conservation strategies can be proposed. For high-value areas such as the Yunnan Confucian Temple, historical soundscape and cultural environment should be prioritised; for composite-value areas such as Guanghua Street and Wenming Street, traditional commercial activity and life atmosphere should be strengthened; for lower-value areas, overall perceptual quality can be improved by restoring distinctive activities and optimising public space [19, 36].

This study has several limitations. The sample size was limited to ten representative nodes; although covering the main streets and functional types, it did not encompass all spatial units of the district [31]. Time dimension data were insufficient because historical documents rarely record everyday sensory experience, and Time Depth assessment relied mainly on indirect inference and oral interviews [13, 35]. Sensory assessment remains subjective; sound and smell perception is influenced by individual differences, cultural background and immediate context [17, 19]. Smell–sound interaction effects were assessed mainly through qualitative analysis; a systematic quantitative model has not yet been established [24–28]. This study focused on smell–sound interaction; future research could extend to visual–olfactory and visual–auditory–olfactory combinations [34, 44]. Future research could also develop dynamic multisensory heritage value assessment models by combining long-term monitoring and intelligent sensing, establish quantitative models of smell–sound interaction, apply the model to

more historic district cases to test its generality, and develop multisensory heritage experience and guidance systems using virtual and augmented reality [6, 22, 30].

Conclusion

This study introduced the Multi-Sensory Value Perception Deep Map (MVC-DepthMap) model, a novel methodological framework that extends conventional heritage assessment by integrating soundscape and smellscape into spatial value quantification. The model addresses a critical gap in existing heritage evaluation tools, which have predominantly privileged visual material carriers while neglecting the sensory dimensions that fundamentally shape human experience of historic places.

The methodological contribution of this study is threefold. First, it operationalises the concept of sensory heritage through two measurable indicators—Time Depth and Historical Richness—thereby transforming subjective sensory experience into spatialised, comparable metrics. Second, it provides an integrated analytical workflow combining historical document analysis, sensory fieldwork, questionnaire surveys and GIS spatial analysis, offering a replicable framework for assessing multisensory heritage value in other historic districts. Third, by embedding crossmodal interaction effects into spatial assessment, the model captures the synergistic and conflicting relationships between sound and smell that conventional single-sensory approaches fail to recognise.

From a policy perspective, the MVC-DepthMap offers a practical tool for differentiated conservation and inclusive urban regeneration. The identification of high-value sensory heritage clusters can inform priority-setting in conservation planning, while the recognition of sensory conflict zones can guide interventions to mitigate the adverse effects of modernisation on historical atmospheres. The model can be embedded in urban spatial information platforms to support decision-making that goes beyond visual appearance control toward the creation of multisensory place atmospheres.

Future research should extend the model to other historic districts with diverse cultural contexts, incorporate longitudinal monitoring and intelligent sensing technologies to capture dynamic sensory changes, and develop quantitative models of smell–sound interaction to deepen theoretical understanding of crossmodal heritage perception.

Declarations

Competing interests

The authors declare that they have no competing of interests.

Ethical statement

This study was conducted in strict compliance with ethical research principles. All participants signed informed consent forms. The risk of the study is extremely low, only anonymous data is collected, and according to the guidelines of the author's institution, it has obtained ethical approval from the Institutional Review Committee of Kunming University of Science and Technology (Ethics Number: Kmust-MEC-2025-155). All procedures follow the principles of the Declaration of Helsinki. Informed consent was obtained from all participants.

Author Contribution

XL: Writing – Review & Editing, Formal Analysis, Visualization. SL: Data collection, Writing – original draft. NT: Methodology, Resources, Project Administration, Funding Acquisition. All authors read and approved the final manuscript.

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Data Availability

The datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

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Figures

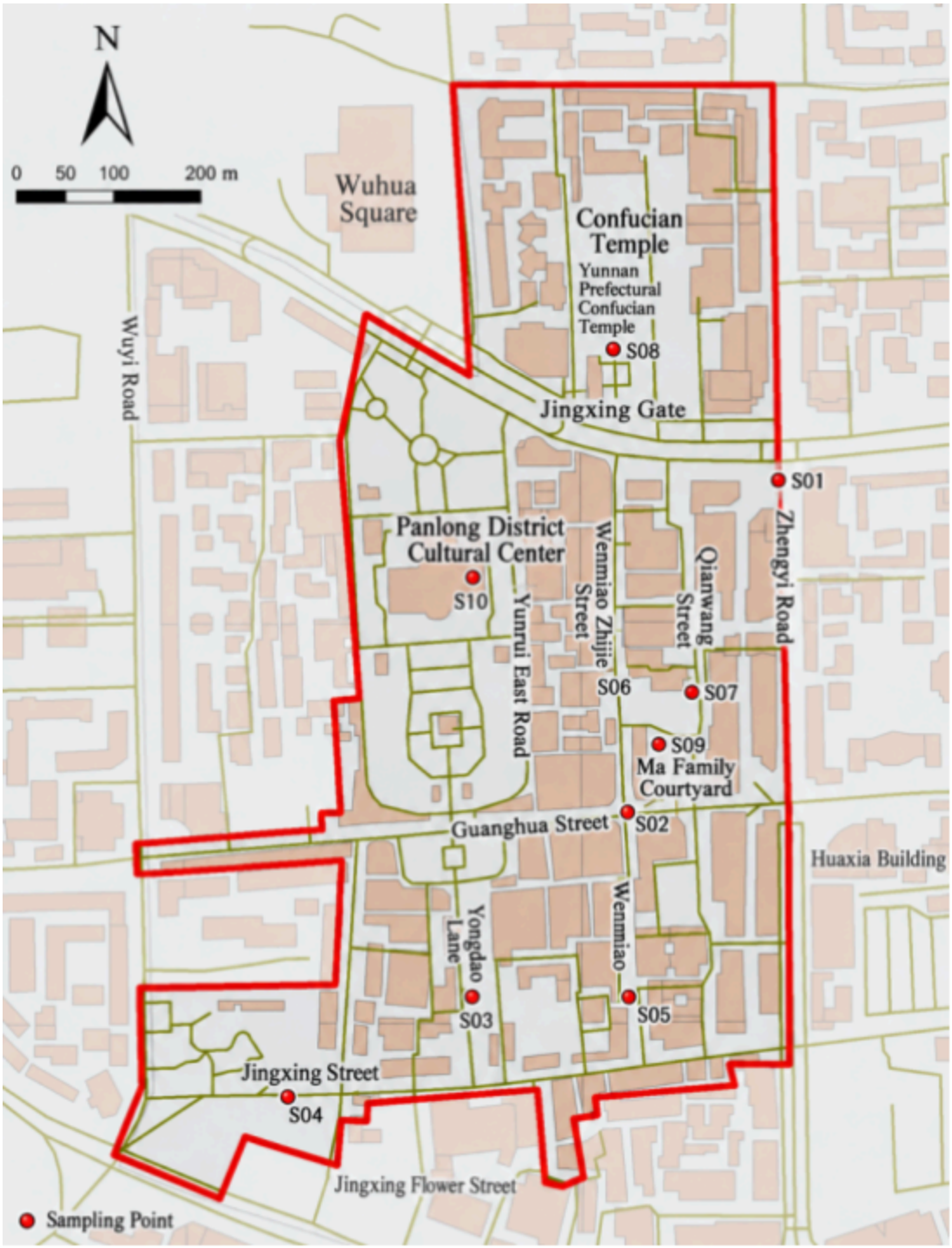


Figure 1

Location and spatial structure of Kunming Old Street with ten sensory sampling sites

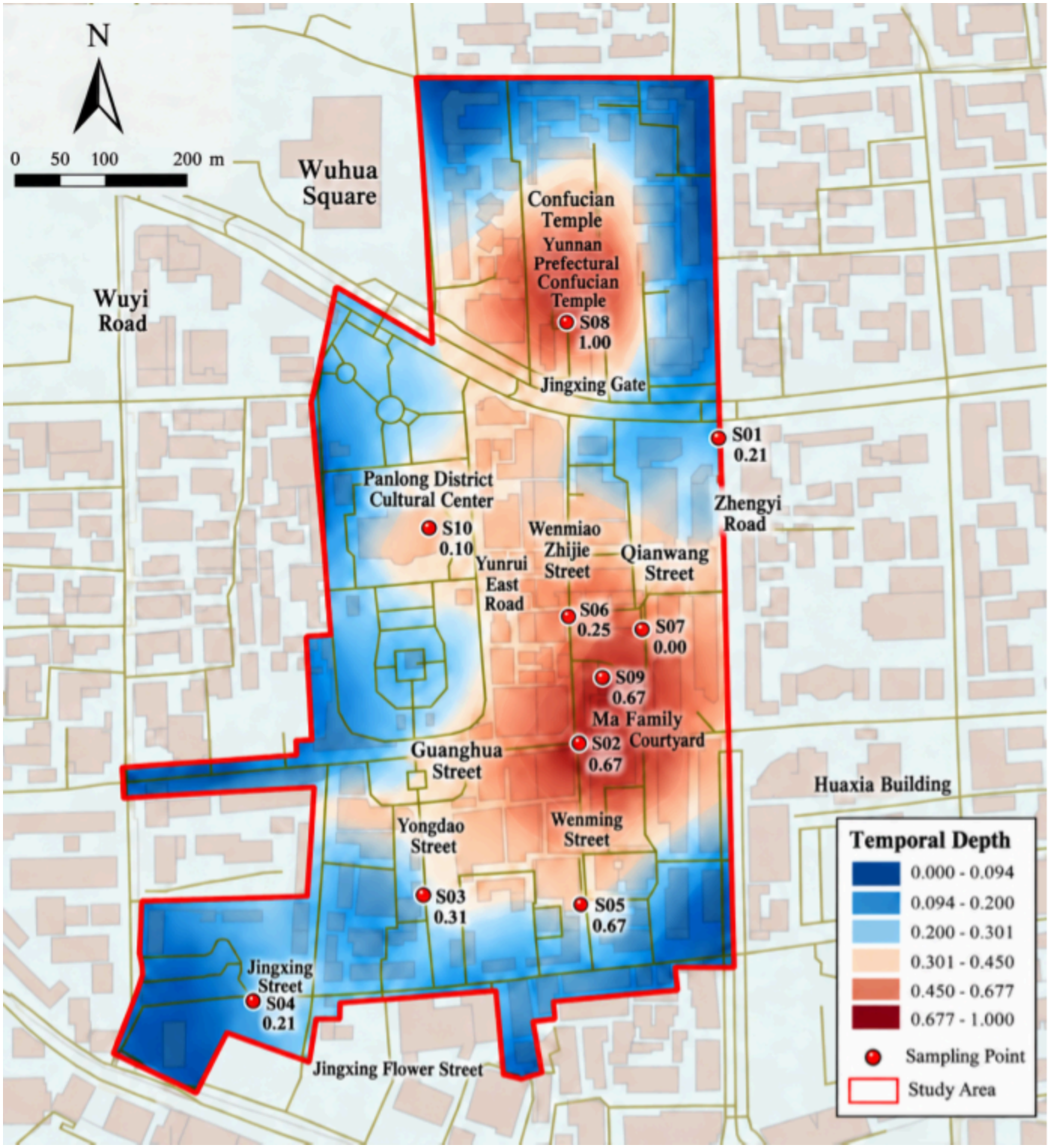


Figure 2

Time Depth quantification of Kunming Old Street

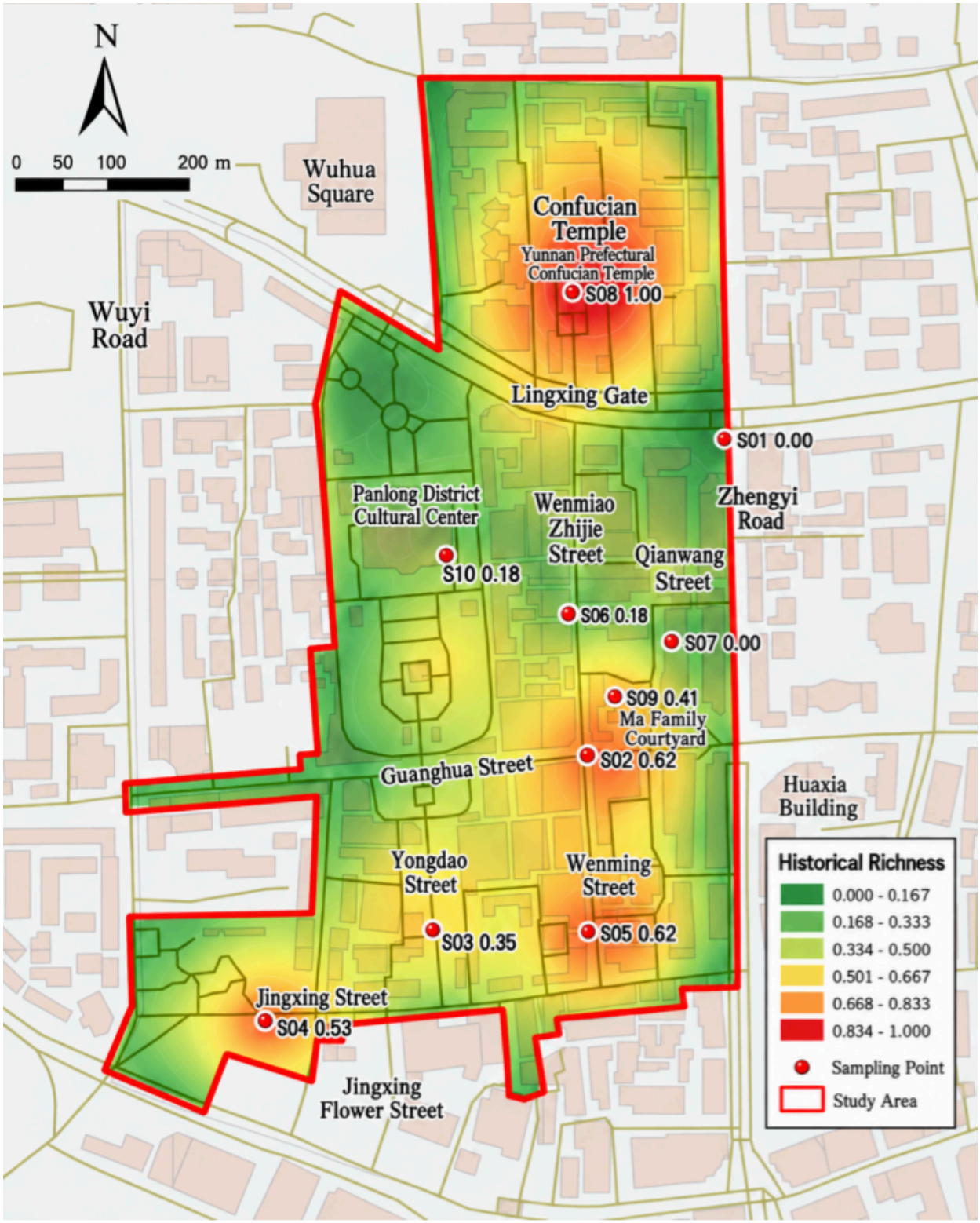


Figure 3

Historical Richness Quantification of Kunming Old Street

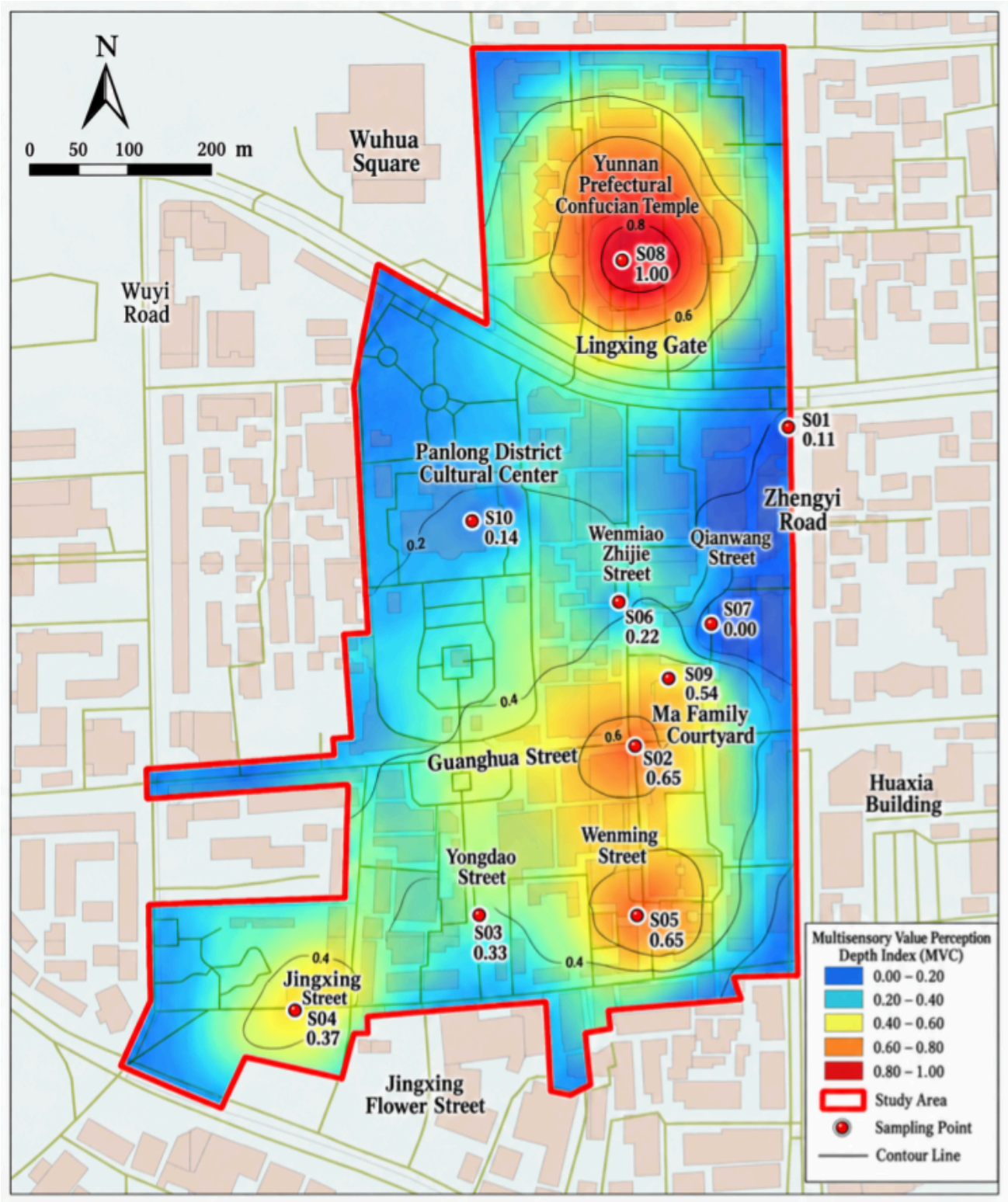


Figure 4

Multi-Sensory Value Perception Deep Map of Kunming Old Street