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A Data-Driven Method for Constructing the Spatial Database of Traditional Villages—A Case Study of Courtyard Residential Typologies in Yunnan, China

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Abstract: A digital civilization rising on silicon-based technology is predicted to replace carbon-based spaces with virtual ones, leading to the decline of rural regionalism. Reconciling the benefits of globalization through data-driven methods while preserving the locality of rural areas is crucial. The extensive collection of traditional villages in the Yunnan Province possesses abundant natural heritages and diverse regional cultural resources. However, the existing assessment and identification index system for these traditional villages primarily relies on qualitative measures, which lack a consistent and quantifiable data system that can provide scientific, data-driven analysis. This study focuses on the mainstream types of traditional villages in the Yunnan Province as its research subject. Based on empirical research methods and architectural typology principles, two data acquisition and vectorization procedures are implemented, combining tilt photography and digital mapping technology. This approach addresses the inconsistency problem of the current system's complex information and multiple data. This study aims to establish an efficient, objective, and consistent method of generating a database that comprehensively represents the environmental and architectural characteristics of the villages. Once established, this database could serve as a consistent and objective basis for subsequent quantitative analyses across different types of villages. Hence, setting up a consistent, quantifiable database is the first step to future data-driven policymaking, which is essential for sustainable preservation. In conclusion, the repeatability and reproducibility of these research findings are intrinsically tied to the meticulous methodology employed in the process of data acquisition and vectorization. The valid result was demonstrated after the verifying of the correlation analysis. Finally, a challenge to the universality came from adding different worldwide villages to the database and revealing underlying patterns.

Keywords: architectural typologies; data-driven method; spatial database construction; Yunnan traditional villages

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1. Introduction

1.1. Rural Digitization in the Context of Sustainable Renewal

The trend of varied globalization, coupled with the advancements in digital information technology, has brought attention to the significance of regionalism and has underscored the distinctive characteristics of vernacular settlements and architecture. The exploration of digital transformation in rural areas within the context of globalization by using digital technology to address sustainable development challenges has emerged as a complex and dynamic research problem.

In China's western region, the Yunnan Province is characterized by its hilly terrain and encompasses a land area spanning 394,100 square kilometers [1]. Most of its territory (approximately 93.6%) is occupied by mountains [2], posing development-related challenges. Based on the findings presented in the Third National Land Survey Main Data Bulletin of Yunnan Province (22 December 2021), it is revealed that the land area allocated to villages amounts to a mere 7480 square kilometers [3], constituting a meager 1.89% of the province's total land area.

To examine the global significance of the Yunnan vernacular research within the internationalization framework, it is imperative first to examine the existing research on rural problems in other regions. Over the past two decades, there has been a notable increase in research focused on the distinctive features of vernacular settlements in Europe, particularly in countries such as Italy, Spain, and others [4]. Interdisciplinary researchers have devised methodologies to digitalize traditional buildings [5] and have developed identification files [6], printed or computerized [7], in which a description of the surroundings appears as well as the location, type, materials used, and graphic documents. In the Italian countryside, a classification analysis of traditional farm buildings based on agricultural activities and utilization functions summarizes the relationship between typological diversity and region for digital reconstruction [8]. The study of digital archiving of villages in Spain classifies and recognizes historic rural houses in the Almeria province and provides data-driven criteria for dynamic and rational selections [6]. In Peru and Poland, researchers have analyzed different associations under homogeneous patterns by factors which include materials and construction methods [9] and summarized the spatial patterns of the existing vernacular villages [10], which can be utilized for digitally guiding heritage preservation [11]. Studies have expanded from micro-typological elements to urban-scale digital spatial pattern preservation [12] and have established a three-dimensional database [13] in Turkey and Russia with a broad geographical range and extremely varied topography features. BIM has become prevalent in vernacular digital technology research for documenting and managing urban spatial data [13]. Spatiotemporal statistics and mathematical modeling also have the potential to digitize rural heritage via BIM-GIS (Building information modeling-Geographic Information System) integration [14]. The adoption and implementation of BIM (Building information modeling) and IDD (Integrated Digital Delivery) contribute measurable value to the entire life cycle of heritage protection [15].

As evidenced in the literature above, global scholars have used diverse methodologies to classify, extract, and preserve data from regional-oriented viewpoints [16]. This trend presents both opportunities and limitations, as employing similar methodologies with differing datasets can lead to unanticipated outcomes. Different data processing methods may also result in diverse conclusions.

Therefore, locality and universality are mutually supportive concepts. Peering into the issue of Yunnan's locality from the world's vernacular perspective is also a reciprocal process of regional methods to universal values. Thus, the theoretical contribution of this study centers on examining the macroscopic within the microscopic, identifying distinctions within similarities, and validating and evaluating the method of vernacular spatial databases.

However, the rural regions of the Yunnan Province, to a significant extent, encompass many varied natural and cultural assets. Information on such assets is complex and diverse. How this information is handled is currently reliant on simplistic and rudimentary methods. Much of this type of information is highly inconsistent across different types of villages. Such an inconsistent database yields intricate difficulties for sustainable conservation and digital administration. Due to this inefficiency [17], a wide range of concerns emerges, including the urban–rural imbalance characterized by binary distinction [18]. Currently, the following problem has been highlighted: the assessment and recognition of traditional villages in the Yunnan Province is predominantly reliant on qualitative measures in the index system [19], namely traditional characteristics control and conservation criterion [20]; a post-village design evaluation system [21]; and architectural style guidance [22]. Furthermore, the absence of quantitative judgment standards [23] and the lack of an established database system hinder the scientific assessment process [24]. Additionally, the local government has adopted a less proactive approach toward conducting coordinated research on digitalizing villages across the province. They prefer waiting for guidelines from the competent authorities and passively following them. This approach often leads to incomplete or ineffective digitalization efforts. However, in underdeveloped regions such as Yunnan where there a dearth of specialized knowledge through which research discoveries can be effectively applied, the utilization of digital methodologies remains a relatively nascent research topic. One crucial prerequisite for overcoming this challenge entails establishing a consistent information database that policy and decision-makers could utilize. Such a database is essential for ensuring the efficient prioritization and effective allocation of development resources. Hence, the following consensus has been reached: digitalizing such information is an effective strategy.

1.2. Purpose of Spatial Databases Construction

The recent studies on the macro scale summarize the research trends and technologies for digital transformation in the context of urban–rural integration issues. The analysis focuses on the spatial evolution of villages, considering factors such as the natural environment, native resources, and territorial distribution. Some findings offer valuable insights for decision-making processes and planning analyses [25] by applying satellite data to examine urban land usage [26] and employing quantitative and qualitative analysis techniques to validate statistical findings empirically. Additionally, a digital management platform is developed by integrating the collected data [27], and a series of decision-making systems that consider both growth and conservation are created [28]. Research on developing typology models that utilize databases to facilitate the classification and administration of villages and the efficient distribution of resources between urban and rural regions has also been conducted [29].

At the meso level of digital technological methods, a variety of data batch extraction techniques are applied, such as tilt-shift photography, to address various practical problems and assist in the identification of the urban fabric, which is subsequently utilized to visualize and analyze the connection between urban form and social sustainability [30]. The combination of aerial photography and GIS technology enables the comprehensive and efficient identification and scientific analysis of spatial environmental elements [31]. This data set is also suitable for analyzing traditional villages' distribution patterns and the relationships of spatial elements. Hence, the significance of traditional village datasets primarily lies in their contribution to establishing a scholarly foundation for village classification. These datasets often delve into development prospects and formulate long-term plans, such as employing digital analytical frameworks to transform rural areas and urban–rural dynamics. This approach aims to achieve the urbanization of village spaces and to effectively integrate urban and rural areas in the development context [32]. The study conducted in Yunnan mainly focuses on localized studies that examine quantitative markers of regional village types.

At the micro level, the primary focus is on digital modeling methods for traditional building units. Most research has centered on data processing, mining, and extracting traditional building elements to guide green building design [33]. Alternatively, using spatial models, one might attain a quantitative synthesis of the classification of architectural forms [34].

Based on the above three levels of dissection, it is evident that several experts representing diverse perspectives concur that the implementation of digital archiving for traditional villages is an emerging trend characterized by the primary objective of curating digital archival materials for practical utilization [23]; consequently, replicable and repeatable strategies that can be implemented across the entire life cycle of village conservation efforts are proposed [35]. In the interdisciplinary collaboration between architecture and computer science, it is imperative to not only elucidate the influence of factors such as the climate environment on sustainability [36], but also to focus more on the ontological aspects of architecture, which encompass elements such as the spatial structural texture and the architectural design of the village. Consequently, it becomes necessary to incorporate additional quantitative measures through which precise descriptions can be provided, thereby increasing the demands for data quantity and accuracy.

The Yunnan Province comprises 708 traditional Chinese villages, geographically distributed throughout 16 prefectures or municipalities [37]. The current research stage on the construction of the Traditional Villages Database (TVD) is characterized by exploration, which poses challenges to preserving the spatial characteristics of traditional villages [38]. Hence, the TVD is constructed to facilitate the comprehensive analysis, efficient processing, and convenient feedback of spatial information on the protection [39], planning, and development of traditional villages [40]. This initiative aims to facilitate the transition of traditional village spatial protection towards digitization, informatization, and scientification [41], while establishing a robust data platform to support the sustainable development of traditional villages [41].

Based on the need for comprehensive rural protection measures [31], this study aims to investigate TVD construction techniques. Applying these methods makes it possible to promptly and efficiently enhance the overall data volume and geographical coverage. Consequently, this approach facilitates the extraction of valuable quantitative and comparative findings based on the database. The systematic categorization and analysis of traditional village dwelling styles, interconnections, and developmental patterns [42] are essential for preserving and transmitting information about Yunnan's traditional villages. Furthermore, exploring a database method that offers a systematic framework for digitizing evidence-based governance in traditional rural communities is imperative.

1.3. Scientific Significance as a Data-Driven Decision-Making Process

Using digital technologies can significantly facilitate governmental decision-making processes and expand the applicability of several academic fields [43]. However, this approach exhibits a limited capacity to address multiple objectives. If subjected to a multi-objective-oriented decision-making process, it lacks the indicators of 3D spatial dimensions at the architectural level [44]. Due to the abundance of village samples in the Yunnan Province, the existing data samples mainly concentrate on investigating macro-medium urban design perspectives. These samples are solely utilized for examining the two-dimensional correlations between the land patterns and features of urban–rural integration [45]; the current limitations of two-dimensional analysis hinder its ability to comprehensively and precisely evaluate the traditional characteristics of villages, thereby impeding future policymaking in the field of assessments and the ability to implement traditional style designs.

The primary objective of employing digital technology in the decision-making process entails establishing a comprehensive database that comprises regional characteristics data [46]. However, in the Yunnan Province, no specific construction methodology can directly facilitate the practical implementation of this database-building process [47], and there is an apparent lack of attention toward digital technology regulation [48] and the formulation of a spatial paradigm [49]. The "14th Five-Year Plan for Urban and Rural Construction and Historical and Cultural Protection and Inheritance in Yunnan Province" [50] explicitly states, "the intention to conduct a comprehensive census of various protected objects. This census aims to ascertain the objects' archiving needs and to facilitate the digital transformation for their preservation." This provision also highlights a research gap in digital governance, which presents an opportunity for further investigation by other researchers.

However, translating these policies into effective practical implementation remains inadequate [51]. Hence, developing a TVD in the Yunnan Province is a multifaceted and interdisciplinary endeavor [52]. The significance of this study lies in its potential to address the lack of empirical research in the digital domain and to summarize the influencing factors of the spatial environment of the rural areas in Yunnan.

Thus, the primary scientific significance of this study is its potential to fill the existing research gap in Yunnan village research by employing a comprehensive methodology for establishing a database of traditional village-style features in two-dimensional and three-dimensional formats. The available literature demonstrates that no prior studies have undertaken a similar endeavor.

2. Research Route

2.1. Sample Selection

The ethnic composition of 708 traditional villages in the Yunnan Province comprehensively represents the region's diverse cultural and ethnic traits. There exist 311 traditional villages that are primarily inhabited by individuals of Han ethnicity, constituting 43.93% of the overall count [37]. Traditional Han villages predominantly adopt an enclosed courtyard residential style (Figure 1) [53]; thus, it becomes the main layout within Yunnan's traditional villages (The asterisks in Figure 2) [54]. This form serves as a prominent representation of Han culture [53]. Consequently, this study has opted to focus on this mainstream village type (Figure 3) as the primary investigation subject, ensuring the research's representativeness and persuasive power.

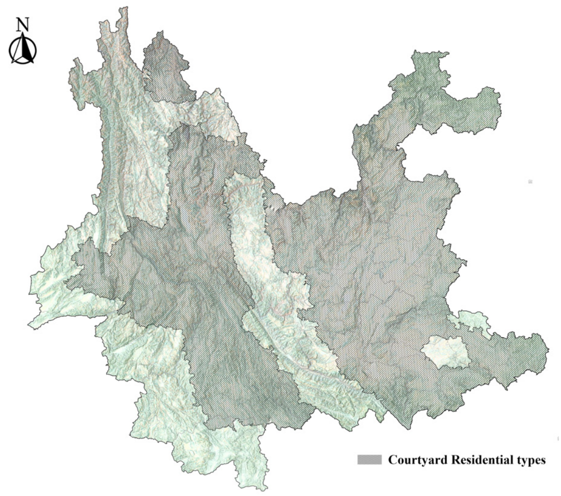


Figure 1. Schematic distribution of courtyard residential types in Yunnan.

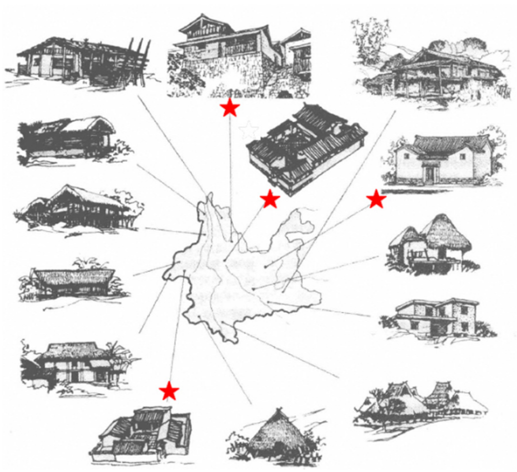


Figure 2. Relationship between residential type and regional distribution (the asterisks represent the main traditional village residential types in Yunnan.) [54].

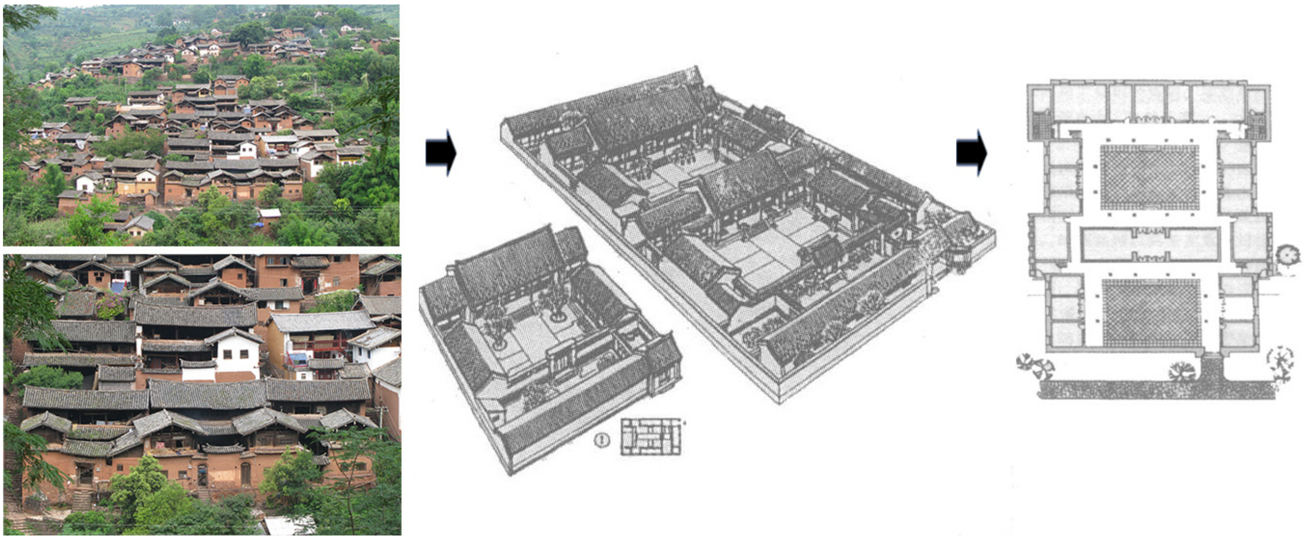


Figure 3. Main courtyard residential layout of Yunnan's traditional villages (Photo credits: project drawings, tilt-photography models, and site study photos) [54].

This dwelling type is mostly concentrated in five central dam hinterlands within the Yunnan Province. Consequently, this study opted to sample from the prominent dams in Yunnan, considering their geographical distribution. The selected samples aimed to reflect the four distinct forms of "courtyard-style" [54] houses in Yunnan (Table 1). The first site, namely Laogao Village (S1), is located in Erjie Township, Jinning District, Kunming City, and was selected as the representative sample for the "single seal" type (1S) in central Yunnan. The second site, namely Zhudi Village (S2), is located in the Luoshui Village Committee in Yongning Township, Ninglang County, Lijiang City, and was selected as a representative example of the "three houses plus one wall" (3H1W) dwelling style that is prevalent in northern Yunnan. The third site, namely Yuanfu Village (S3), is located in the Wuhe Community, Wuhe Township, Tengchong Country, Baoshan City, and served as a representative sample of the "one main house plus two"(1M2H) type in western Yunnan. The fourth site, Jintang Village (S4), is located in the Jintang Community, Wuhe Township, Tengchong Country, Baoshan City, in Western Yunnan Province, and served the same representative as S3. The last site, namely Yangxinzhai Village (S5), is located in the Baoxiu Township, Shiping County, Honghe City, and represented the "one main three sides" (4H) type commonly found in Southern Yunnan.

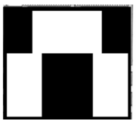
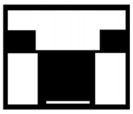
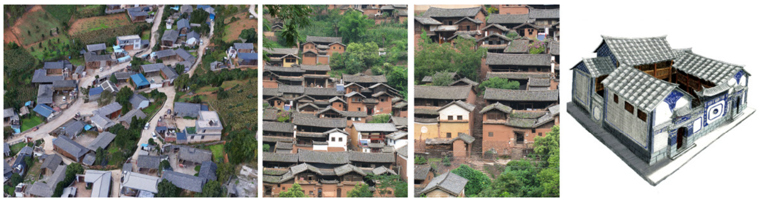
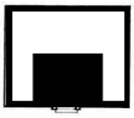
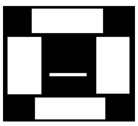
The site environment and building typology selections were based on many environmental factors, including climate [55], precipitation, altitude, slope, and building density (Table 2). Furthermore, these villages exhibit patterns, annual precipitation, average temperature, and construction density similarities. These similarities enable the convenient comparisons of different spatial elements within the same contextual conditions by minimizing non-physical variables and improving future judgment accuracy.

2.2. Categorization Principles

The categorization precondition involved analyzing various aspects such as the sample villages' macro-scale patterns, planning, environment, spatial integrity of architectural material cultural heritage, identification of style types, and micro-scale regional architectural characteristics.

This categorization was conducted by dissecting the aspects above and combining them with the fundamental principles of hierarchical categorization in architectural typology [34]. The systematic classification and analysis of buildings or architectural forms based on common characteristics, functions, and design principles is widely employed in village building categorization studies (Table 3). Hence, based on the extent of preservation, the clarity of tilted images, and the completeness of 3D models, a comprehensive selection of 432 exemplary traditional compound buildings obtained from five villages was identified as a singular spatial sample. Subsequently, a classification table was developed to extract and aggregate data from the research samples.

Table 1. Planar form, spatial patterns, and sample types numbering.

Planar Form	Type	Sample	Architectural Pattern
	single seal (1S)	S1	
	three houses plus one wall (3H1W)	S2	
	one main house plus two (1M2H)	S3 S4	
	one main three sides (4H)	S5	

(Photo credits: project drawings, tilt-photography models, and site study photos of the five village plans).

Table 2. Basic environmental characteristics of the five sampled villages.

	Annual Precipitation	Annual Temperature	Density	Total Building Footprint Area (m^2)	Village Boundary (m^2)
S1	1000–1500	12–16	0.51	130,560.10	256,337.60
S2	800–1000	12–16	0.40	25,750.65	64,128.95
S3	800–1000	16–20	0.33	35,672.45	107,373.00
S4	800–1000	16–20	0.34	36,586.54	107,781.79
S5	1000–1500	16–20	0.30	37,825.48	125,928.00
Data sources	Climate Bulletin	Climate Bulletin	Calculating	Mapping	Mapping

It is important to emphasize that establishing the database on Class B significantly advances the study's methodology. This development effectively addresses the constraints observed in most prior studies that relied solely on two-dimensional geographical data. Based on prior research and village space design experience, it is evident that the digital research predominantly focused on the broader aspects of the natural environment, siting patterns, historical context, and cultural influences when examining traditional village patterns. Nevertheless, within the "Traditional Village Evaluation and Recognition Indicator System" framework, there is a notable absence of statistical data on the spatial characteristics of traditional buildings. However, the "Traditional Village Evaluation and Recognition Indicator System" lacks specific information regarding "traditional architectural spatial features".

Table 3. Category tables for data extraction and aggregation.

Class	Norm		Description
A Environmental characteristic	A1: slope		Environmental related elements
	A2: elevation		
	A3: density		
B Spatial elements	B1 Basic size	B1a: footprint areas	External Morphological Characteristics
		B1b: courtyard areas	
		B1c: total area	
		B1d: proportion of courtyards	
		B1e: percentage of homesteads	
	B2 three-dimensional size	B2a: side room height	The "prototype" of residential buildings depends on two factors: (1) the spatial logic related to construction technology. (2) Space and place related to life and production
		B2b: cornice of the main house	
		B2c: main room height	
		B2d: single house slope	
		B2e: single house elevation	
	B3 styling elements	B3a roof slope	
		B3b roof angle	
		B3c roof camber	
		B3d gables overhang	
		B3e enclosing material	
		B3f roofing material	

Therefore, this study primarily focused on extracting data that is categorized based on the attribute features of the objective spatial typology associated with the construction technology and the environment of the village. The first set of significant variables for identifying the environmental aspects of the village comprises A1 (the average slope value) and A2 (the average elevation value). These variables are classified under the Class A environmental features category. The Class B1-related characteristics associated with the fundamental two-dimensional basic size encompass B1a, which represents the footprint areas; B1b, which denotes the courtyard areas; B1c, which signifies the total area; B1d, which quantifies the ratio between the courtyard areas and the footprint areas; and B1e, which measures the ratio between the footprint areas and the sum of B1a plus B1b. The three-dimensional architectural space size parameters can be categorized into two groups. The first group, denoted as B2, includes parameters such as B2a (side room height), B2b (the height of the cornice of the main house), B2c (the height of the highest part of the main house), B2d (single house slope), and B2e (single house elevation). The second group, denoted as B3, encompasses parameters related to styling elements such as B3a (roof slope), B3b (roof angle), B3c (roof camber), B3d (gables overhang), B3e (enclosing material), and B3f (roofing materials).

During this process, it was essential to enhance the logical rigor of the statistical process. This involved establishing a basic information system resembling the "one village, one library" model. Additionally, aggregating data from five villages was crucial for maximizing the refinement of stylistic characteristics in the vernacular architecture. Furthermore, this aggregation was a significant process in constructing the dataset's fundamental architectural form and logical unit. The procedure above served as the fundamental support component in this investigation.

2.3. Research Steps

The spatial characteristics of the five traditional villages have been categorized. The environmental components (Class A) and architectural spatial components (Class B) of the 432 architectural monolithic samples were converted into a vector format to capture and review data. This procedure encompasses the comprehensive spatial data of the village's two-dimensional (2D) and three-dimensional (3D) elements.

This research route explains the critical aspects of collecting spatial data information in traditional villages. Furthermore, it attempts to address the aforementioned existing research gaps in the database construction methods by investigating techniques for processing and transforming the acquired two-dimensional planar and three-dimensional spatial data information [23]; thus, it facilitates the completion of the database construction. In the context of future applications, we analyzed the database's theoretical and methodological significance. Additionally, we proposed an intuitive visual method for analyzing databases to demonstrate that the construction of the database is a replicable process. Furthermore, the closed loop provides researchers from other countries with a framework for collaborating on a deeper inquiry into the expansion of traditional village databases in Yunnan (Figure 4).

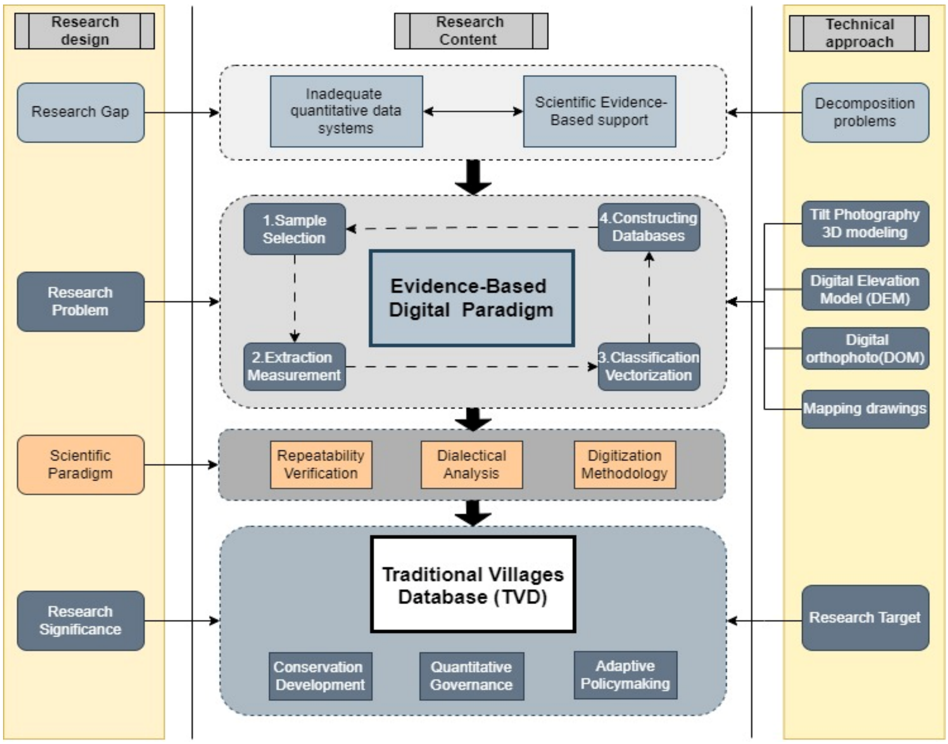


Figure 4. Research route.

3. Methodology

Two parts composed the methodology for constructing traditional village databases (Figure 5). Initially, data collecting was carried out in several steps to capture the topographic parameters and extract the spatial characteristics of traditional villages. The second stage was data processing: through model measurement, vectorization, and attribute matching, the data were finally unified and aggregated.

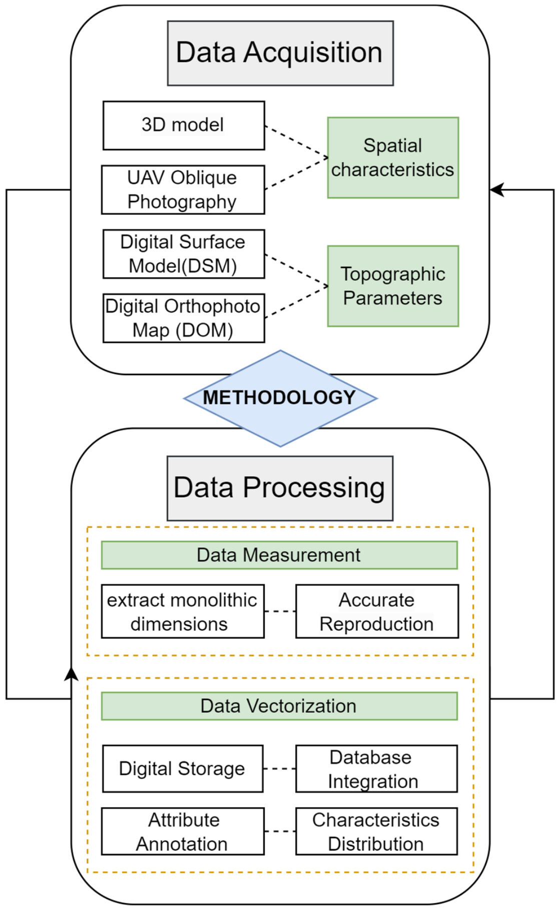


Figure 5. Database construction methodology.

3.1. *Data Acquisition Method*

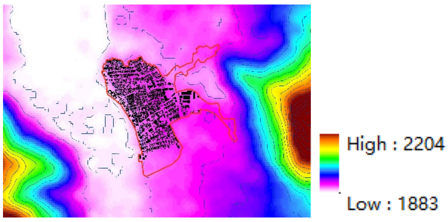
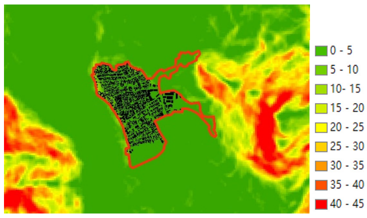
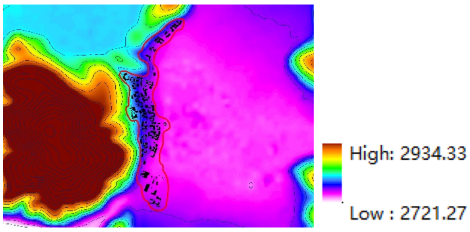
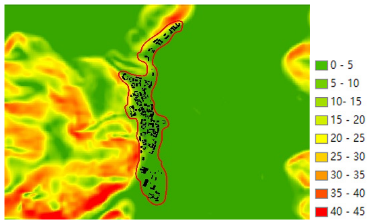
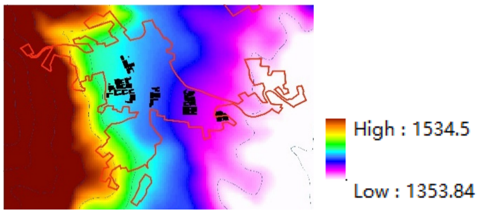
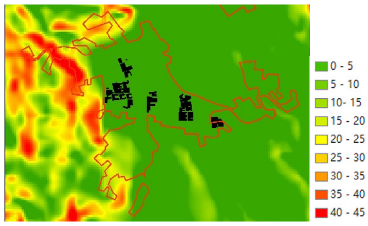
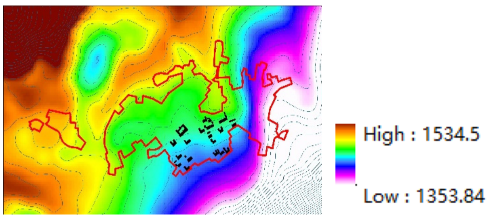
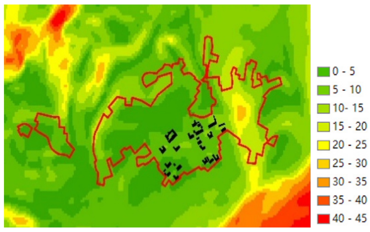
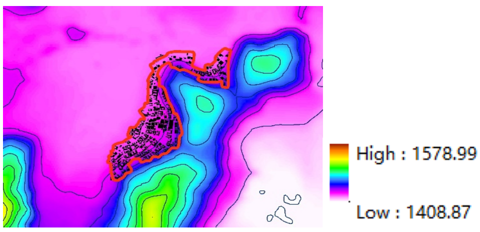
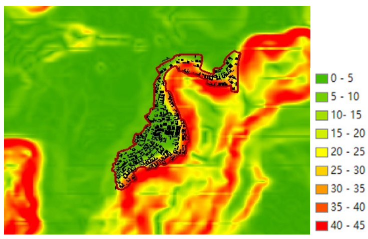
Before processing began, this stage required raw data from several drawing kinds (Table 4). Detailed data acquisition techniques such as laser scanning, photogrammetry, and manual measurements, were used [56].

Table 4. Different data acquisition methods.

Space Typology	Data Name	Data Type	Data Source
Village environment	Village Development Boundary	Line	GIS
	building density	Float	Calculating
	terrain slope	Raster	DEM
	terrain elevation	Raster	DEM
	Aerial top view	Raster	DOM
	Site plan	Polygons	Mapping
Architectural Information	building footprint areas	Polygons	Mapping
	courtyard areas	Polygons	Mapping
	The base elevation of a single building	Raster	DEM
	The base slope of a single building	Raster	DEM

The application of modern digital mapping and photographic technologies facilitates the objective depiction of a village's entire elemental material space dimensions, styles, locations, and relationships. These technologies enable observations of the village space from perspectives that are challenging for human beings to achieve. Consequently, they expedite the modeling and presentation of information and collect relevant data (Table 5).

Table 5. Spatial data extraction from the DEM and DOM.

Sample No.	Sample Elevation (m/Meters)	Sample Slope(°/Degree)
S1		
S2		
S3		
S4		
S5		

(1) Building a genuine three-dimensional (3D) model [57] can be achieved by concurrently capturing images from vertical and numerous slanted angles. Image acquisition with tilt-photography technology involves capturing images from different angles and combining these images with panoramic data to accomplish a comprehensive three-dimensional model [30]. This model accurately represents the captured scene's valuable three-dimensional information. A genuine three-dimensional (3D) model is generated

using fused tilted images and panoramic data, encompassing authentic 3D information such as elevation, slope, and coordinates. This model enables the analysis and mapping of the village's environmental and architectural elements within a virtual reality setting.

Moreover, this model can accurately represent the height, length, slope, and other pertinent data associated with the actual features of the village [58]. By using this technology, the authenticity of traditional villages can be preserved. With its efficient and lightweight rapid modeling capabilities, inclined photogrammetry technology offers a novel technical approach; thus, traditional villages can be digitally preserved in three-dimensional form. This method also addresses the inefficiencies associated with traditional three-dimensional modeling and manual mapping.

(2) The Digital Orthophoto Map (DOM) is a type of image data produced by using a digital elevation model on scanned and processed digitized aerial or remote sensing images. This data is corrected at the pixel level and subsequently combined into a mosaic based on the desired color scheme for the image. The use of orthophoto imagery, which provides a top-down perspective as well as image attributes and geometric measurements, enables the visualization of the village's extent and the spatial arrangement of its natural elements, cluster relationships, and overall pattern. By employing orthophoto images, the distinctive layout characteristics of the village can be effectively depicted (Table 5).

(3) The Digital Elevation Model (DEM) is a comprehensive representation of the Earth's surface and utilizes a set of digital surfaces composed of the coordinates (x, y, and z) of several terrain features. These surfaces effectively depict the ground's topographical variations. The DEM is a technique that employs a numerical array to depict geomorphic data [59]. This approach enables the computation of earthwork quantities, spatial distances, covered areas, and the extraction of diverse topographic parameters such as slope, slope direction, and roughness (Table 5).

3.2. Data Processing Method

(1) Data Measurement

The conventional approach to producing building plans, elevations, and sections entails manually utilizing tools such as total stations, rangefinders, and tape measures, which are employed to measure the following dimensions: length, width, and height. Thus, the generation of a preliminary outline of the building becomes possible. The technique above exhibits a substantial initial investment, limited effectiveness, and extended duration. Manual measurement errors, particularly regarding the roof structure of buildings, pose challenges that limit the achievement of accurate measurements. This issue leads to increased workload, reduced accuracy, limited result formats, discrepancies between architectural mapping drawings and the actual building, and the inadequacy of traditional geographic data for meeting the digital transformation demands.

Using this paper's methods, 3D models of the five selected villages were subsequently imported into software applications such as Acute3D Viewer and LocaSpace Viewer 4. This importation aimed to conduct measurements and extract monolithic dimensions from the models directly. Based on the procedures above, as indicated in Table 1, the spatial attributes of the B2 and B3 building categories were extracted. This methodology demonstrated a high level of precision in data extraction, exhibited immense attention to detail, and effectively reproduced the primary structure of the village and its spatial context within the virtual reality setting.

(2) Data Vectorization

The vectorization process involves converting 3D data into a structured vector format. This step transforms point clouds and 3D meshes into vector-based representations of polygons, lines, and points. This format is essential for efficiently storing, retrieving, and manipulating spatial data [60].

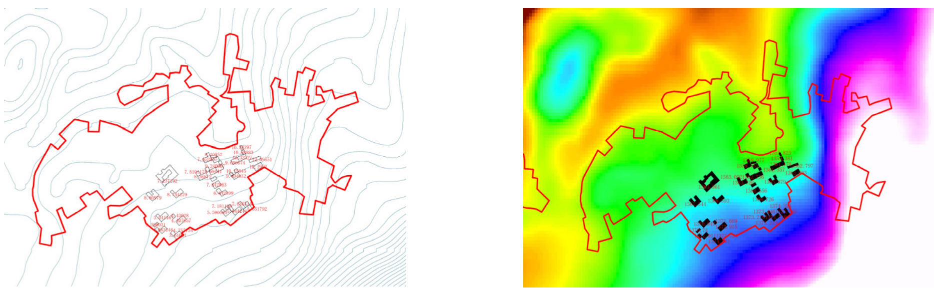
1. Obtain the building surface's slope and elevation vector data

In the first stage, the statistics of the average DEM raster value in the area where the specified building face is located are partitioned and displayed in a table. The second phase, which entails analyzing a substantial amount of building face element data, identifies the central coordinates of each building unit's face domain. This is achieved by extracting the average values of the elevation and slope for each building unit. The third step, namely, extraction to point, is based on previous steps and involves assigning the elevation and slope data to the point and recorded them in the attribute table of the output element class. Finally, the utilization of spatial connection through the implementation of a "control point" to align the geographic data of the building, followed by the application of this spatial connection to allocate values to the surface elements, represents an effective method with a low error probability and significant efficiency.

In summary, the data vectorization process in the GIS platform is the basis for transforming spatial geographic data on traditional villages into a digital format that is both versatile and precise; thus, its utilization in diverse spatial analysis and decision-making endeavors is facilitated. From a macroscopic to a microscopic perspective, it is possible to dimensionally reduce the 3D models into 2D datasets, which is advantageous for facilitating database integration and storage.

2. Attribute Annotation

The proper distribution of characteristics pertaining to traditional rural data information is crucial for efficiently administering and examining rural spatial data. Attributes refer to the non-spatial data associated with geographic features or objects, and by accurately assigning these attributes, well-informed decisions can be made. This study utilized the ArcGIS operating platform to accomplish the attribute connection of the village and its associated vector objects. The process involved several steps. First, the building samples were labeled with serial numbers in CAD (Computer-Aided Design) (Figure 6). Simultaneously, the building-related vector elements were imported into the GIS platform. Subsequently, the vector elements (points, lines, and polygons) were connected to the corresponding serial numbers in CAD. This connection enabled the establishment of correspondence between the village boundaries, building base plots, and their respective serial numbers. Additionally, this process facilitated the examination and analysis of the average elevation and slope of each building.



Value extraction to point Attribute matching

Figure 6. Attribute connection of characteristics.

The pertinent characteristic of the attribute table can be determined by utilizing the critical field, which may consist of either the object ID or name. Upon further examination, it may be concluded that every column within the village database signifies a distinct characteristic. When incorporating newly imported attribute elements into the database, it is possible to link them to the critical field (ID or name object) corresponding to the attribute table's pertinent characteristic. This cyclic procedure can provide other researchers with a repeatable and expandable database construction reference.

4. Results and Conclusions

The production of the TVD involved collecting and processing information to obtain "raw materials" related to traditional villages. This raw material was subsequently managed and extracted using evidence-based methods. Thus, the TVD was developed, and the desired objective was achieved (Figure 7). The critical conclusion points are succinctly outlined as follows:

Building No.	B1 Basic size					B2 three-dimensional size						B3 styling elements					
	B1a	B1b	B1c	B1d	B1e	B2a	B2b	B2c	B2b/B2c	B2d	B2e	B3a	B3b	B3c	B3d	B3e	B3f
1	51.11	44.27	102.22	0.87	53.59%	4.21	0.00	0.00	0.00	2.46	1423.96	40.23%	21.92	1	0	1	1
2	36.07	44.27	36.07	1.23	44.90%	2.34	0.00	0.00	0.00	2.43	1423.71	17.11%	9.71	0	0	2	1
3	24.90	44.27	49.80	1.78	36.00%	4.33	0.00	0.00	0.00	3.02	1423.74	43.51%	23.51	1	0	1	1
4	36.12	44.27	72.24	1.23	44.93%	4.51	0.00	0.00	0.00	4.37	1424.05	43.05%	22.08	0	0	1	1
5	16.45	44.27	32.90	2.69	27.09%	5.08	0.00	0.00	0.00	4.60	1424.38	43.05%	22.08	1	0	1	1
6	37.55	44.27	37.55	1.18	45.89%	4.19	0.00	0.00	0.00	4.60	1425.02	23.89%	13.44	0	0	1	1
7	57.17	44.27	114.34	0.77	56.36%	0.00	3.69	5.70	0.65	4.47	1424.44	41.95%	22.76	1	0	1	1
8	15.04	78.21	15.04	5.20	16.13%	2.28	0.00	0.00	0.00	5.10	1425.01	45.77%	24.59	1	0	2	1
9	92.30	78.21	184.60	0.85	54.13%	0.00	3.55	5.38	0.66	6.51	1425.87	44.19%	23.84	1	0	1	1
10	55.61	67.97	111.22	1.22	45.00%	4.55	0.00	0.00	0.00	6.16	1426.94	39.94%	21.77	1	0	1	1
11	87.18	67.97	174.36	0.78	56.19%	0.00	3.95	5.94	0.66	7.72	1428.14	42.23%	22.89	1	0	1	1
12	36.45	67.97	36.45	1.86	34.91%	2.36	0.00	0.00	0.00	7.14	1427.17	38.56%	21.08	0	0	1	1
13	64.22	40.48	192.66	0.63	61.34%	0.00	0.00	9.94	0.00	12.67	1433.28	29.52%	16.45	0	0	2	1
14	22.67	40.48	22.67	1.79	35.90%	3.78	0.00	0.00	0.00	13.79	1431.94	0.00%	0.00	0	0	2	1
15	23.45	40.48	46.90	1.73	36.68%	7.04	0.00	0.00	0.00	12.73	1432.02	0.00%	0.00	0	0	2	2
16	84.35	19.74	168.70	0.23	81.04%	0.00	0.00	7.03	0.00	6.24	1435.36	0.00%	0.00	0	0	2	2
17	23.11	27.83	46.22	1.20	45.37%	4.77	0.00	0.00	0.00	6.56	1435.22	34.72%	19.15	0	0	1	1
18	73.00	27.83	146.00	0.38	72.40%	0.00	3.60	5.46	0.66	6.93	1436.17	43.22%	23.37	1	0	1	1
19	30.79	27.83	30.79	0.90	52.52%	2.59	0.00	0.00	0.00	6.55	1435.64	0.00%	0.00	0	0	2	2
20	41.32	34.64	82.64	0.84	54.40%	5.08	0.00	0.00	0.00	14.66	1438.75	42.38%	22.97	1	0	1	1
21	17.41	34.64	34.82	1.99	33.45%	0.00	0.00	0.00	0.00	16.09	1440.79	44.51%	23.99	1	0	1	1
22	72.61	34.64	145.22	0.48	67.70%	0.00	3.71	5.95	0.62	16.39	1440.91	42.07%	22.81	1	0	1	1
23	24.46	34.64	48.92	1.42	41.39%	0.00	0.00	0.00	0.00	18.46	1441.31	40.66%	22.13	1	0	1	1
24	39.42	34.64	78.84	0.88	53.23%	5.10	0.00	0.00	0.00	15.87	1439.28	39.86%	21.73	1	0	2	1
25	14.61	34.64	14.61	2.37	29.66%	2.73	0.00	0.00	0.00	15.87	1439.28	0.00%	0.00	0	0	2	2
26	19.27	183.93	38.54	9.54	9.48%	0.00	0.00	0.00	0.00	16.53	1437.06	44.36%	22.96	1	0	1	1
27	66.30	183.93	132.60	2.77	26.50%	0.00	3.60	5.50	0.65	10.54	1436.52	38.36%	20.98	1	0	1	1
28	30.82	183.93	61.64	5.97	14.35%	0.00	0.00	0.00	0.00	8.92	1436.41	38.94%	21.28	0	0	1	1
29	63.36	183.93	126.72	2.90	25.62%	4.85	0.00	0.00	0.00	9.01	1435.14	39.32%	21.47	1	0	1	1
30	18.24	183.93	36.48	10.08	9.02%	4.78	0.00	0.00	0.00	6.30	1434.15	37.41%	20.51	1	0	2	2

Figure 7. Final TVD aggregation (partially shown).

(1) This study proposes an approach for implementing digital transformation in traditional courtyard residential types, utilizing case studies from several geographical contexts. The framework encompasses these key stages: categorical data collection, vectorized processing and attribute matching, and database repository development.

(2) The crucial factors for effectively implementing this method include refining the data by categorizing classes A and B into vectorized subcategories (A1 to B3) with three-dimensional spatial attributes. Database construction and architectural morphology are combined in the processing stage. When the available data samples are limited, enhancing the level of detail in dataset labeling can enhance the accuracy and validity of the data analysis.

(3) This study relies on spatial vector data obtained from the TVD; thus, it enhances the traditional villages' scientific, systematic, standardized, intuitive, and practical protection and sustainable development through quantitative analysis and research.

The initial efficacy of this methodology was demonstrated after the validation of correlation analysis methods such as Pearson Spearman for each data element. The results depict the data regularity portrayal (Figure 8).

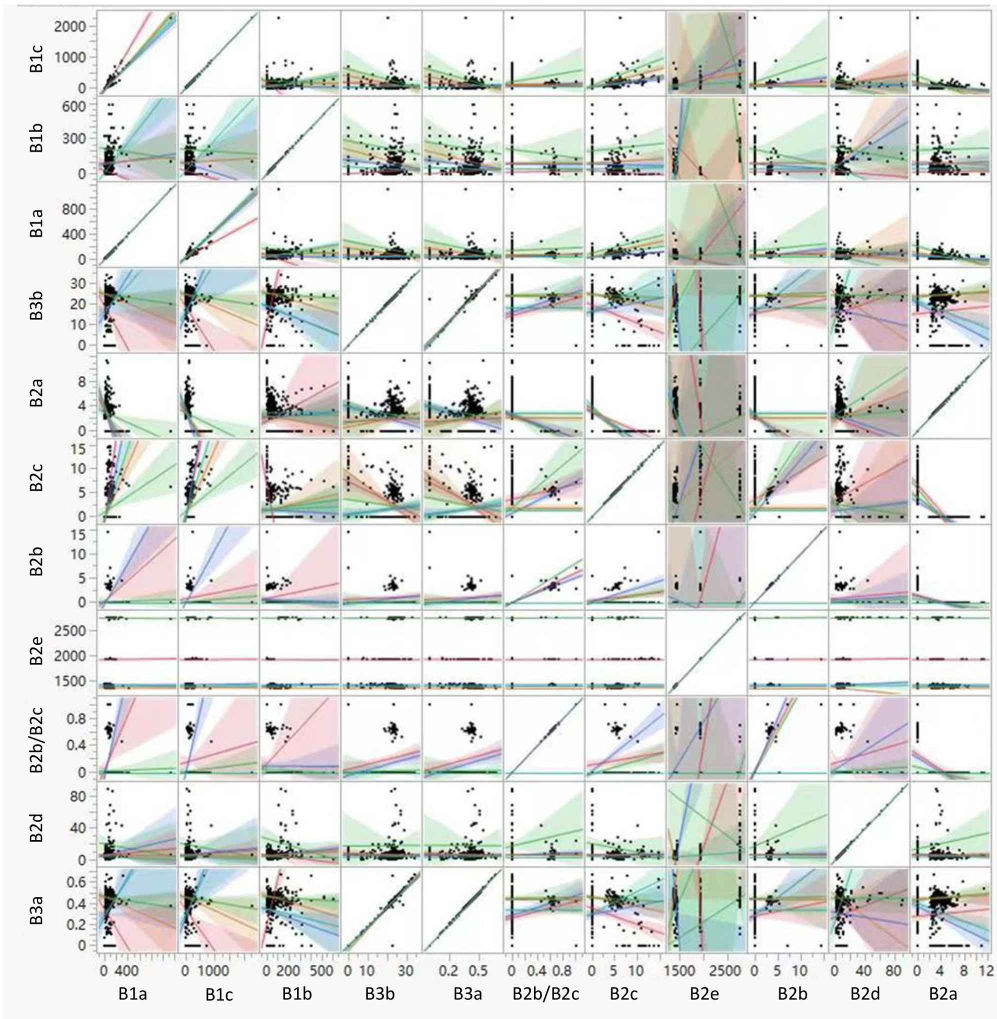


Figure 8. TVD-based visual data analysis (Generated from JMP, statistical software).

The repeatable advantages of this approach are rooted in the diverse range of available spatial data types and in the seamless integration and timeliness of these data. This approach enables the inclusion of additional village data from another region, thereby enhancing the precision of the results and facilitating the recognition of supplementary evidence. Thus, the TVD can facilitate the pursuit of sustainable development in rural areas.

(4) The efficacy of this database method can be reaffirmed through numerous practical applications:

This system can fulfill the requirement for collaborative efforts and data exchange among diverse entities and interested parties. Additionally, the material can be accessed by other researchers who require its utilization or interpretation. This database enables researchers to integrate geographic attributes in order to conduct comprehensive spatial queries, analyses, and processing. These operations include, but are not limited to, slope, slope direction, visibility, and accessibility. This database facilitates the comparisons of various features among similar elements and the comparisons of similar elements within different categories. Ultimately, this database aims to provide decision-making support for rural planning and assessment based on empirical evidence [61].

The inclusion of transparency in the TVD serves two important goals: guaranteeing integrity and offering a clear framework for replication. Moreover, our dedication to ensuring reproducibility is emphasized by the accessibility of the entire dataset, enabling other worldwide researchers to scrutinize, verify, and expand the database. The TVD enables the identification of critical values that align with the assessment standards of the villages, as well as fundamental values based on upper and lower limits. It can be disseminated repeatedly and utilized by researchers on a broad scale.

Multi-dimensional data statistical analysis procedures can be repeated to sort, categorize, and summarize sample characteristics. Importing the TVD into different machine-learning algorithms for visual reproduction strengthens the robustness of research findings. Therefore, visualizing and digitizing the spatial variability problems in village protection is feasible. The application of visual analytic techniques (Figure 6), assisted by the TVD, enables the creation of thematic maps, graphs, or charts. These visual representations enhance data replicability, practical analysis, and the communication of spatial information [49]. Additionally, this supports decision-making processes across diverse domains, including urban planning, environmental management, and resource allocation. These results are important for assisting leaders to perform evaluations and make decisions.

5. Discussion

Within the context of the substantial digital transformation requirements of traditional villages in Yunnan, establishing a TVD for these villages poses several obstacles.

Future research may pursue the following objectives:

(1) Limitation-oriented solutions: The initial implementation of the methodology is in Yunnan. Further studies may prioritize the augmentation and timely integration of other Yunnan regions and other global locations into the database. Expanding the database to include historical, cultural, and religious traits is crucial. However, collecting such data and comparing communities of different world types is challenging.

(2) Problem-solving technology: Rural planning involves the utilization of a TVD to examine traditional settlement patterns, provide guidance for spatial buildings via machine learning methodologies [62], and integrate traditional design ideas into modern urban development analysis. Scholars could examine the progression of architectural styles, construction methods, and cultural impacts within various periods and geographical areas. Utilizing a TVD in architectural conservation facilitates restoration endeavors by furnishing precise spatial data to support reconstructing and renovating traditional structures and to assist with the automation of data annotation [63].

In summary, this study focuses on the physical appearance of traditional villages. It explores various techniques for constructing databases that align with the regional features of traditional villages in Yunnan. Moreover, it aims to establish a framework for policy-makers and leaders who are involved in rural development to assist them in identifying the characteristics of traditional villages. The study offers a systematic and evidence-based approach for determining the characteristics and scope of traditional spaces, thereby facilitating their preservation and development and revealing the underlying patterns and principles governing traditional villages through their physical representations [49].

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References

1. Department of Natural Resources of Yunnan Province, Territorial Spatial Planning of Yunnan Province, Kunming, China. 2021. Available online: http://www.gui-hua.com/post/342.html (accessed on 20 August 2023).
2. Yang, Z.; Zhao, Q. Study on Dividing Flatland County, Semi-mountainous & Semiflatland County and Mountainous County in Yunnan Province Based on the Second National Land Survey. *J. Nat. Resour.* **2014**, *29*, 1–3.
3. Yunnan Third National Land Survey Leading Group. *Yunnan Province Third National Land Survey*; Department of Natural Resources of Yunnan Province, Statistics Bureau of Yunnan Province: Kunming, China, 2023.
4. Bianco, I.; Del Giudice, M.; Zerbinatti, M. A database for the architectural heritage recovery between Italy and Switzerland. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.* **2013**, *40*, 103–108. [CrossRef]
5. Fuentes, J.M. Methodological bases for documenting and reusing vernacular farm architecture. *J. Cult. Heritage* **2010**, *11*, 119–129. [CrossRef]
6. Sabatino, M. Documenting Rural Architecture, by Giuseppe Pagano. *J. Archit. Educ.* **2010**, *63*, 92–98. [CrossRef]
7. Pardo JM, F.; Guerrero, I.C. Study and characterization of vernacular buildings in rural areas. Processing and management of data. *Inf. Construcción* **2003**, *55*, 13–21. [CrossRef]
8. Ruggiero, G.; Parlavecchia, M.; Sasso, P.D. Typological characterisation and territorial distribution of traditional rural buildings in the Apulian territory (Italy). *J. Cult. Heritage* **2019**, *39*, 278–287. [CrossRef]
9. Prus, B.; Król, K.; Gawroński, K.; Sankowski, E.; Hernik, J. From Classic (Analogue) to Digital Forms of Cultural Heritage Protection in Poland. In *Digital Cultural Heritage*; Springer International Publishing: Cham, Switzerland, 2020; pp. 255–278. [CrossRef]
10. Trocka-Leszczynska, E. The Contemporary Rural Landscape in the South-Western Region of Poland (Sudeten Region)—A Search for Spatial Order. In Proceedings of the Design, User Experience, and Usability. User Experience Design for Everyday Life Applications and Services: Third International Conference, DUXU 2014, Held as Part of HCI International 2014, Heraklion, Greece, 22–27 June 2014; pp. 470–481.
11. Peña-Huaman, F.; Sifuentes-Rivera, D.; Yarasca-Aybar, C. Architectural typology of rural housing in Jaen, Peru. *Built Heritage* **2022**, *6*, 2. [CrossRef]
12. Acar Bilgin, E. Rural Architectural Characteristics and Conservation Issues of Alaaddinbey Village in Bursa, Turkey. In *Conservation of Architectural Heritage*; Springer International Publishing: Cham, Switzerland, 2019; pp. 161–178. [CrossRef]
13. Costamagna, E.; Spanò, A. Spatial models for architectural heritage in urban database context. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.* **2011**, *38*, 13–18. [CrossRef]
14. Liu, Z.; Lu, Y.; Peh, L.C. A Review and Scientometric Analysis of Global Building Information Modeling (BIM) Research in the Architecture, Engineering and Construction (AEC) Industry. *Buildings* **2019**, *9*, 210. [CrossRef]
15. Liu, Z.; Lu, Y.; Shen, M.; Peh, L.C. Transition from building information modeling (BIM) to integrated digital delivery (IDD) in sustainable building management: A knowledge discovery approach based review. *J. Clean. Prod.* **2021**, *291*, 125223. [CrossRef]
16. Khunthong, T.; Kerdnoonwong, S. Valuable Modern Architecture Database for Conservation and Lifelong Learning. *Pegem J. Educ. Instr.* **2023**, *14*, 1–10. [CrossRef]
17. Cornadó, C.; Vima-Grau, S.; Garcia-Almirall, P.; Uzqueda, A.; de la Asunción, M. Decision-Making Tool for the Selection of Priority Areas for Building Rehabilitation in Barcelona. *Buildings* **2022**, *12*, 247. [CrossRef]
18. Yin, C.; Xiao, J.; Qian, X. Understanding urban planning failure in China: Identifying practitioners' perspectives using Q methodology. *Cities* **2023**, *134*, 104193. [CrossRef]
19. Notification of Ministry of Housing and Urban-Rural Development. *Traditional Village Evaluation and Recognition Indicator System*; Ministry of Housing and Urban-Rural Development, Ministry of Culture, National Cultural Heritage Administration, Ministry of Finance: Beijing, China, 2012; pp. 2–9. Available online: https://www.mohurd.gov.cn/gongkai/zhengce/zhengcefilelib/201208/20120831_211267.html (accessed on 15 August 2023).
20. Notification of Chinese Ministry of Housing and Urban-Rural Development. *Basic Requirements for the Preparation of Planning for the Protection and Development of Traditional Villages (Trial)*; Chinese Ministry of Housing and Urban-Rural Development: Beijing, China, 2013; pp. 2–7.
21. Design and Research Institute of Kunming University of Science and Technology. *Practical Village Planning for 'Multi-Planning in One' in Yunnan Province Review Points*; Department of Natural Resources of Yunnan Province: Kunming, China, 2021.
22. Abbasabadi, N.; Ashayeri, M. Urban energy use modeling methods and tools: A review and an outlook. *J. Affect. Disord.* **2019**, *161*, 106270. [CrossRef]
23. Chen, Y.; Wu, Y.; Sun, X.; Ali, N.; Zhou, Q. Digital Documentation and Conservation of Architectural Heritage Information: An Application in Modern Chinese Architecture. *Sustainability* **2023**, *15*, 7276. [CrossRef]
24. Escolar, S.; Rincón, F.; Barba, J.; Caba, J.; de la Torre, J.A.; López, J.C.; Bravo, C. A Methodological Approach for the Smartification of a University Campus: The Smart ESI Use Case. *Buildings* **2023**, *13*, 2568. [CrossRef]
25. Xie, Y.; Ward, R.; Fang, C.; Qiao, B. The urban system in West China: A case study along the mid-section of the ancient Silk Road—He-Xi Corridor. *Cities* **2007**, *24*, 60–73. [CrossRef]
26. Wenfu, P.; Huixi, X.; Wanrong, X.; Cunjian, Y. Urban Land Use Change in Chengdu City Using Satellite Data. In Proceedings of the 2010 International Forum on Information Technology and Applications, Beijing, China, 16–18 July 2010; pp. 226–229. [CrossRef]

27. Wang, X.; Zhou, J.; Zhou, W.; Wu, K.; Tu, Q.; Wu, J. Technological Path of Platform Governance of Central Government Departments in the Digital Era: A Case Study of the Ministry of Natural Resources. In Proceedings of the 9th International Conference on Management of e-Commerce and e-Government, New York, NY, USA, 7–9 July 2022; pp. 7–11. [CrossRef]
28. Liu, S.; Ge, J.; Bai, M.; Yao, M.; He, L.; Chen, M. Toward classification-based sustainable revitalization: Assessing the vitality of traditional villages. *Land Use Policy* **2022**, *116*, 106060. [CrossRef]
29. Bański, J.; Mazur, M. Classification of rural areas in Poland as an instrument of territorial policy. *Land Use Policy* **2016**, *54*, 1–17. [CrossRef]
30. Zhou, W. Research on the Application of UAV Oblique Photography Algorithm in the Protection of Traditional Village Cultural Heritage. In Proceedings of the 2022 6th International Conference on Computing Methodologies and Communication (ICCMC), Erode, India, 29–31 March 2022; pp. 1303–1306.
31. Al-Kheder, S.; Haddad, N.; Fakhoury, L.; Baqaen, S. A GIS analysis of the impact of modern practices and polices on the urban heritage of Irbid, Jordan. *Cities* **2009**, *26*, 81–92. [CrossRef]
32. Li, L.; Song, T. Enabling In-Situ Urbanization through Digitalization. *Land* **2023**, *12*, 1738. [CrossRef]
33. Gao, X. Modern design of rural green buildings based on big data technology. *Cities* **2023**, *141*, 104387. [CrossRef]
34. Nie, Z.; Li, N.; Pan, W.; Yang, Y.; Chen, W.; Hong, C. Quantitative Research on the Form of Traditional Villages Based on the Space Gene—A Case Study of Shibadong Village in Western Hunan, China. *Sustainability* **2022**, *14*, 8965. [CrossRef]
35. Qi, T.; Ma, L.; Zhou, W.; Dai, L. Traditional village digital archival conservation: A case study from Gaoqian, China. *Arch. Rec.* **2023**, *44*, 202–220. [CrossRef]
36. Anna-Maria, V. Evaluation of a sustainable Greek vernacular settlement and its landscape: Architectural typology and building physics. *J. Affect. Disord.* **2009**, *44*, 1095–1106. [CrossRef]
37. Book Editorial Committee. *Memory and Nostalgia: Approaching to Yunnan Traditional Villages*; Department of Housing and Urban-Rural Development of Yunnan Province, Urban and Rural Planning and Design Institute of Yunnan Province: Kunming, China, 2020.
38. Lin, X.; Wu, Y. Architectural Spatial Characteristics of Fujian Tubao from the Perspective of Chinese Traditional Ethical Culture. *Buildings* **2023**, *13*, 2360. [CrossRef]
39. Yang, Y.; Wang, Y. Exploring Rural Resilient Factors Based on Spatial Resilience Theory: A Case Study of Southern Jiangsu. *Land* **2023**, *12*, 1677. [CrossRef]
40. Ukabi, E.B.; Akçay, A. Conserving the Historical Identity of North Nicosia Walled City: Exploring Design Approaches and Implications from 1983 to 2003. *Buildings* **2023**, *13*, 2199. [CrossRef]
41. Bárkányi, Á.; Chován, T.; Németh, S.; Abonyi, J. Modelling for digital twins—potential role of surrogate models. *Processes* **2021**, *9*, 476. [CrossRef]
42. Chen, X.; Xie, W.; Li, H. The spatial evolution process, characteristics and driving factors of traditional villages from the perspective of the cultural ecosystem: A case study of Chengkan Village. *Habitat Int.* **2020**, *104*, 102250. [CrossRef]
43. Luo, X.; Yuan, M. Special Issue on "Machine-Learning-Assisted Intelligent Processing and Optimization of Complex Systems". *Processes* **2023**, *11*, 2595. [CrossRef]
44. Pedro, J.; Silva, C.; Pinheiro, M.D. Integrating GIS spatial dimension into BREEAM communities sustainability assessment to support urban planning policies, Lisbon case study. *Land Use Policy* **2019**, *83*, 424–434. [CrossRef]
45. Zasada, I.; Loibl, W.; Köstl, M.; Piorr, A. Agriculture under Human Influence: A Spatial Analysis of Farming Systems and Land Use in European Rural-Urban-Regions. *Eur. Countrys.* **2013**, *5*, 71–88. [CrossRef]
46. Shu, Y.; Ma, X.; Liu, Z.; Li, J.; Zhang, Y. Potential of the Digital Information Platform Applied in Promotion of Rural Landscape in China: From Preliminary Practices to Framework Conception. *Land* **2023**, *12*, 1667. [CrossRef]
47. Li, Z.; Miao, X.; Wang, M.; Jiang, S.; Wang, Y. The Classification and Regulation of Mountain Villages in the Context of Rural Revitalization—The Example of Zhaotong, Yunnan Province. *Sustainability* **2022**, *14*, 11381. [CrossRef]
48. Xia, H.; Liu, Z.; Maria, E.; Liu, X.; Lin, C. Study on city digital twin technologies for sustainable smart city design: A review and bibliometric analysis of geographic information system and building information modeling integration. *Sustain. Cities Soc.* **2022**, *84*, 104009. [CrossRef]
49. Wen, Q.; Yang, F.; Peng, L.; Liang, L.; Wu, S.; Xu, F. Evolutionary mechanism of vernacular architecture in the context of urbanization: Evidence from southern Hebei, China. *Habitat. Int.* **2023**, *137*, 102814. [CrossRef]
50. Department of Housing and Urban-Rural Development of Yunnan Province. *14th Five-Year Plan for Urban and Rural Construction and Historical and Cultural Protection and Inheritance in Yunnan Province*; Department of Housing and Urban-Rural Development of Yunnan Province: Kunming, China, 2021. Available online: https://www.yn.gov.cn/bsfw/ztfw/zfly/zflywyk/202210/t20221012_248616.html (accessed on 15 August 2023).
51. Lu, Y.; Xu, S.; Liu, S.; Wu, J. An approach to urban landscape character assessment: Linking urban big data and machine learning. *Sustain. Cities Soc.* **2022**, *83*, 103983. [CrossRef]
52. Chen, K.; Long, H.; Liao, L.; Tu, S.; Li, T. Land use transitions and urban-rural integrated development: Theoretical framework and China's evidence. *Land Use Policy* **2020**, *92*, 104465. [CrossRef]
53. Liu, X. *A study on Courtyard-Style Dwellings in Yunnan, China*; University of Technology Sydney: Sydney, Australia, 2006.
54. Yang, D.; Zhu, L. *Yunnan Dwellings*; China Architecture & Building Press: Beijing, China, 2009.

55. Yunnan Meteorological Report. *Yunnan Provincial Climate Bulletin 2022*; Yunnan Provincial Meteorological Bureau: Kunming, China, 2023. Available online: http://yn.cma.gov.cn/zfxxgk/zwgk/qxbg/202306/t20230608_5565610.html (accessed on 15 August 2023).
56. Hu, S.; Ge, Y.; Liu, M.; Ren, Z.; Zhang, X. Village-level poverty identification using machine learning, high-resolution images, and geospatial data. *Int. J. Appl. Earth Obs. Geoinf.* **2022**, *107*, 102694. [CrossRef]
57. Muñiz, O.; García, F.F. Recent urban development in Gijón (Spain). Historic aerial photography as a tool for sustainability assessment of the process. *Cities* **2017**, *67*, 1–8. [CrossRef]
58. Wang, W.; Shi, Y.; Zhang, J.; Hu, L.; Li, S.; He, D.; Liu, F. Traditional Village Building Extraction Based on Improved Mask R-CNN: A Case Study of Beijing, China. *Remote. Sens.* **2023**, *15*, 2616. [CrossRef]
59. Siart, C.; Bubenzer, O.; Eitel, B. Combining digital elevation data (SRTM/ASTER), high resolution satellite imagery (Quickbird) and GIS for geomorphological mapping: A multi-component case study on Mediterranean karst in Central Crete. *Geomorphology* **2009**, *112*, 106–121. [CrossRef]
60. Bobylev, N.; Syrbe, R.-U.; Wende, W. Geosystem services in urban planning. *Sustain. Cities Soc.* **2022**, *85*, 104041. [CrossRef]
61. Xu, T.; Gao, J.; Li, Y. Machine learning-assisted evaluation of land use policies and plans in a rapidly urbanizing district in Chongqing, China. *Land Use Policy* **2019**, *87*, 104030. [CrossRef]
62. Yazdi, H.; Vukorep, I.; Banach, M.; Moazen, S.; Nadolny, A.; Starke, R.; Bazazzadeh, H. Central Courtyard Feature Extraction in Remote Sensing Aerial Images Using Deep Learning: A Case-Study of Iran. *Remote. Sens.* **2021**, *13*, 4843. [CrossRef]
63. Alba-Rodríguez, M.D.; Machete, R.; Gomes, M.G.; Falcão, A.P.; Marrero, M. Holistic model for the assessment of restoration projects of heritage housing. Case studies in Lisbon. *Sustain. Cities Soc.* **2021**, *67*, 102742. [CrossRef]