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Defining Inner-City Transitional Street Typology Using Point of Interest (PoI) Data in Hillside Cities of China

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Abstract: Transitional streets serve as intermediary spaces between the Central Business Districts (CBDs) and surrounding residential areas, offering diverse functions and activities within urban interiors. However, a practical methodology for accurately classifying these streets has been lacking, due primarily to transitional areas' spatial constraints and functional complexities. This study leverages Point of Interest (PoI) data from 2023 to develop an innovative methodological framework that addresses these challenges. This framework analyses transitional streets' functional distribution and typology, employing PoI frequency density and functional type ratios to identify and classify functional zones. It generally delineates eight main types of transitional streets in the CBD of Chongqing, a prototypical hillside city. Utilising advanced data technology from internet maps, this research pioneers new approaches for identifying and analysing the functionality of transitional streets. The findings underscore the effectiveness of PoI data in precisely recognising the functional types of transitional streets, thereby providing a robust theoretical and practical foundation for the in-depth study of transitional streets. Moreover, the results enhance urban spatial planning in hillside cities of China, effectively demonstrating the advantages of PoI data in defining street typology compared to traditional methods. This approach provides a more detailed understanding of urban functional dynamics by allowing for a more nuanced data analysis of street functions.

Keywords: urban design; transitional streets; Point of Interest; comparative analysis

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1. Introduction

Urban streets are fundamental to the morphology and structure of a city, serving as interconnected linear public spaces bordered by buildings and infrastructure [1]. They perform diverse urban functions—from transportation and commerce to entertainment and public health—reflecting their multifunctionality [2]. Streets primarily fulfil transportation and place functions, dividing urban space rationally and providing varied spaces for transit, leisure, and social interaction. This variety ensures the quality of the urban living environment and supports the city's pedestrian traffic network [3]. The urban core—typically known as the Central Business District (CBD)—is the city's most economically and functionally concentrated area. The CBD, characterised by a high density of corporate headquarters, financial institutions, and service providers, plays a pivotal role in the urban fabric [4,5]. The agglomeration effect of the CBD is significant, exerting a profound influence on the surrounding environment and notably enhancing urban economic development. This dynamic is particularly relevant in Chongqing, where the city's distinctive topographical challenges and rapid urbanisation represent many growing cities in mountainous regions. The inner-city residential areas in Chongqing, situated immediately adjacent to the CBD, feature streets that not only impact the reach of the CBD but also directly affect the sustainable development of the inner-city environment. This focus highlights the specific urban dynamics of Chongqing, reflecting urban forms common in hillside city environments.

These streets link these urban areas, shaping their functional interplay and overall urban dynamics. Building on this understanding, our study focuses on transitional zones between the CBDs and residential areas in Chongqing. It explores streets with unique environmental characteristics due to their diverse and complex nature [6,7]. This is particularly emphasised in hillside cities like Chongqing, where topographical constraints restrict city centre expansion. The spatial allocation and functional planning of streets in such cities for long-term urban development. Despite increasing academic interest in urban fringe, transitional, and grey spaces, research specifically addressing transitional streets is scarce, primarily due to the lack of a straightforward method for street classification that supports adequate use and sustainable development in constrained urban environments.

This research advances the methodology by treating streets as multifunctional and complex urban spaces, aiming to develop a functional methodological framework for identifying and categorising transitional streets in hillside cities, explicitly focusing on Chongqing's Yuzhong district. This district, covering an area of approximately 23.71 square kilometres, exemplifies the typical challenges faced by hillside urban areas, where limited flat land significantly influences street development and functional distribution. The vertical dimension and elevation differences of Chongqing's hillside urban landscape directly influence the transportation patterns for pedestrians and vehicles, both motorised and non-motorised. The city's pronounced topographical fluctuations restrict accessibility and connectivity between different urban areas, necessitating street designs closely adhering to the natural terrain and frequently incorporating stairs. In this context, the primary modes of transportation include walking, motorcycles, and other motor vehicles, while the use of non-motorised vehicles such as bicycles is considerably constrained. The methodologies and insights derived from studying transitional streets in Chongqing can provide valuable guidelines for urban development initiatives in cities with similar topographical contexts. This research facilitates the efficient utilisation of street space in hillside cities and sets a pioneering direction for the targeted development of transitional street functions. Building on existing research in street classification, this study integrates Point of Interest (PoI) data to explore urban functional zoning methods, explicitly examining the functional categorisation of transitional streets between the CBD and residential areas in the Yuzhong district of Chongqing, within the context of hillside urban settings.

The core questions addressed in this study are:

- What are the main types of streets based on social life functions in the existing street typology?
- How can PoI data be effectively utilised to rapidly identify and visualise the functional spatial distribution of transitional streets?
- What unique functional characteristics do transitional streets exhibit between the CBD and the residential areas in hillside cities of China?

The structure of this study includes a detailed background that explains main terminologies, describes the methods and techniques employed, synthesises the analysis and discusses the significant findings and conclusions. This approach facilitates the efficient use of street space in hillside cities and sets a pioneering direction for the targeted development of transitional street functions.

2. Background of the Study

2.1. Street Typology

Street typology plays a pivotal role in urban transportation policy and street design guidelines, reflecting the transition from a vehicle-centric single-dimensional system to a complex multi-dimensional classification system that acknowledges various modes of transportation and urban functionalities [8–10]. This shift aims to overcome the limitations of traditional one-dimensional road classification systems, such as overly narrow categorisations, insufficient consideration of street space vitality, and lack of careful consideration for different modes of transportation [11–13]. Consequently, modern street research adopts

an integrated multi-dimensional classification system, focusing on transportation functions and considering place characteristics and other multidimensional aspects [10,14].

This study adopted three criteria for selecting urban street design guidelines to ensure a profound understanding of urban street classification methods and safeguard the precision and applicability of existing categorisation practices. Firstly, only guidelines published in the last decade were considered to ensure the modernity and relevance of the information. Secondly, the focus of the research was on the division of streets within urban areas to ensure the specificity and practicality of the findings. Lastly, the chosen criteria for classification were primarily based on the functionality of the streets, with a particular emphasis on the pedestrian environment as a primary factor.

Based on these standards, this study meticulously analysed street design guidelines from nine cities, as detailed in Table 1. The analysis revealed that despite the varying factors and focuses considered in street classification across different cities, there is a shared fundamental principle of determining street functions based on the land use or commercial activities adjacent to the streets. This approach enhances the practicality and efficacy of street design and facilitates a deeper understanding and refinement of methods for classifying streets within urban interiors.

Table 1. Summary of urban street design guidelines.

Location	Year	Name of Guidelines	Street Classification
Global Designing Cities Initiative	2024	Global Street Design Guide [15]	Pedestrian-Only Streets, Laneways and Alleys, Parklets, Pedestrian Plazas, Commercial Shared Streets, Residential Shared Streets, Residential Streets, Neighborhood Main Streets, Central One-Way Streets, Central Two-Way Streets, Transit Streets, Large Streets with Transit, Grand Streets, Elevated Structure Improvements, Elevated Structure Removal, Streets to Streams, Temporary Street Closures, Post-Industrial Revitalization, Waterfront and Parkside Streets, Historic Streets and Streets in Informal Areas.
San Francisco	2015	The San Francisco Better Streets Plan [16]	Commercial, Residential, Industrial/Mixed-use and Special.
Oklahoma	2020	Planokc Development Guide [17]	Major and Minor Arterials, Major & Minor Connectors, Neighborhood, Main Street, Industrial and Downtown.
Washington D.C.	2024	Union Market Streetscape Design Guidelines [18]	Urban Thoroughfare, Zipper, Market, Connector, Pedestrian-Focused Street, Alleys, Gateway and Threshold.
Alexandria	2022	Alexandria Complete Streets Design Guidelines [19]	Commercial Connector, Main Street, Mixed-Use Boulevard, Neighborhood Connector, Neighborhood Residential, Parkways, Industrial, Shared Street
Kuala Lumpur	2015	Urban Design Guidelines for Central Kuala Lumpur [20]	Main Shopping Streets, Character Streets, City Boulevards, Shared Spaces, Market Streets, Lanes and Alleys, City-wide Connectors, Local Connector and Residential Streets.
Chengdu	2022	Chengdu Street Integration Design Guidelines for Building a Park City [21]	Living Street, Commercial Street, Landscape Street, Traffic-type Street, Industrial Street and Specific-type Street.
Shanghai	2016	Shanghai Street Design Guidelines [22]	Commercial Street, Life Service Street, Landscape Street, Traffic Street and Integrated Street.
Beijing	2020	Urban design guidelines for street renewal management in Beijing [23]	Traffic Leading Category, Life Service Category, Comprehensive Service Category, Stable Passing Category (Landscape Leisure Category, Residential Category, other categories) and Characteristic Category.

In synthesising and analysing these guidelines, it became clear that street functions typically focus on several main areas, such as transportation, commercial activities, and residential needs, which reflect the diverse functionalities necessary for urban life [9]. Some guidelines further detail these categories, including transportation, environmental, and economic aspects, highlighting the streets' role in shaping cities' economic and social landscape.

The adjacent land use and facade features are significant factors in the multidimensional street classification system for identifying the street design types [24]. Adjacent land use refers to the land next to the streets, whose attributes, such as the type of use and development density, define the pedestrian traffic and activity demand on the streets [25,26]. However, it is the facade business, meaning the interface of the plots facing the street, that has a more direct and immediate influence on the vibrancy and behaviour patterns of the street. It can be categorised into main types: commercial, landscape, life services, and transportation [12,27]. This underscores the urgency of considering these features in street design.

Upon integrating and analysing nine street design guidelines [15–23], it has been found that street functional classifications generally focus on several main areas to accommodate the diverse needs and objectives of different cities. From the usage perspective, streets are primarily categorised into transportation, commercial, residential, industrial and recreational types, emphasising the diversity of basic needs and functionalities within urban life. Based on this, some guidelines further refine these categories to include aspects of transportation, environment, and economy.

In terms of transportation functions, guidelines such as those of the Global Designing Cities Initiative [15] and Oklahoma [17] categorise streets by analysing adjacent road traffic volumes and infrastructure, classifying them into types such as central one-way streets, central two-way streets, transit streets, large streets with transit, grand streets, elevated structure improvements, elevated structure removal, major and minor connectors, etc. Environmentally, the Global Designing Cities Initiative [15] and Kuala Lumpur's guidelines [20] provide detailed provisions for landscape integration, such as streets to streams, waterfront and parkside streets, and city boulevards, directing future urban planners to focus on the sustainability of green environments and their integration with natural landscapes. Economically, most guidelines emphasise economic functions, with those from Alexandria [19], Kuala Lumpur [20], Chengdu [21], Shanghai [22] and San Francisco [16] covering types like commercial and shopping streets, which facilitate the development of future economic activities and enhance the internal economic sustainability of cities.

The classification of street functions reflects, to some extent, the development direction of a city. Considering comprehensively, this study focuses more on the inclusiveness and comprehensiveness of transitional streets to ensure that these streets effectively coordinate socio-economic activities between CBDs and residential areas, balancing the urban environment. Given the 2022 update of Chengdu's street design guidelines [21], which cover commercial, landscape, life services and transportation types, and considering the geographical and lifestyle similarities between Chengdu and Chongqing, this study selects Chengdu's guidelines [21] as the primary reference. This choice has high timeliness and relevance and meets the actual needs of urban development in China.

2.2. Point of Interest Data

As a spatial information resource, PoI data have been extensively collected and accumulated by major map service providers with the advancement of internet technologies. This research utilises PoI data to delineate the classification of transitional streets precisely, identifying and segmenting their functional characteristics. PoI data encompass many Point-like geographical entities, such as schools, banks, businesses, restaurants, and supermarkets [28–30]. These data capture the spatial and attribute information of these entities, including names, addresses, coordinates, types, and evaluations, characterised by detailed information coverage, large data volumes, and the convenience of quantitative analysis. These attributes not only make PoI data easily accessible and broad in coverage but also rich in socio-economic property information, providing a new perspective for urban research [31].

Currently, PoI data are widely applied in areas such as urban functional area classification [32], architectural type identification [33], urban land use monitoring [34], commercial

retail site selection and public service facility needs analysis [35]. Urban functional area studies typically employ PoI data as the primary source, identifying urban functional zones by analysing PoI spatial distribution features. For instance, Hu et al. [36] successfully identified functional zones in the Guangzhou Economic and Technological Development Area by analysing PoI frequency density indices and functional type ratios. Luo et al. [37] categorised urban spatial functions by combining PoI density and the K-star algorithm. Although extensive research on urban functional area classification is based on PoI data, studies on street function classification are relatively scarce. Identifying urban functional areas typically involves segmenting the city into smaller units using grids or neighbourhood boundaries and then reclassifying PoI data within these units. Then, the density and frequency indices of each PoI type in each unit are determined using predetermined thresholds to determine the functional area types of each unit. This study posits that this method can theoretically be applied to street function classification, as public spaces that host extensive resident activities are supported by sufficient PoI data for conducting the necessary density analysis.

3. Materials and Methods

3.1. Study Area

The study area is the Yuzhong District of Chongqing, China, covering an area of 23.71 square kilometres with a total population of 578,000. The CBD of Yuzhong District, known as Jiefangbei CBD, represents the core of Chongqing's mother city, serving as the economic and cultural centre and the oldest urban district of Chongqing. This study focuses on the transitional streets between Jiefangbei CBD and the inner-city residential areas. Figure 1 presents a detailed view of the research area within Chongqing's Yuzhong District based on base-map data from the Baidu map. The delineated area highlighted in red represents the focused study region, covering approximately 3.14 square kilometres, showcasing the urban form of our research.

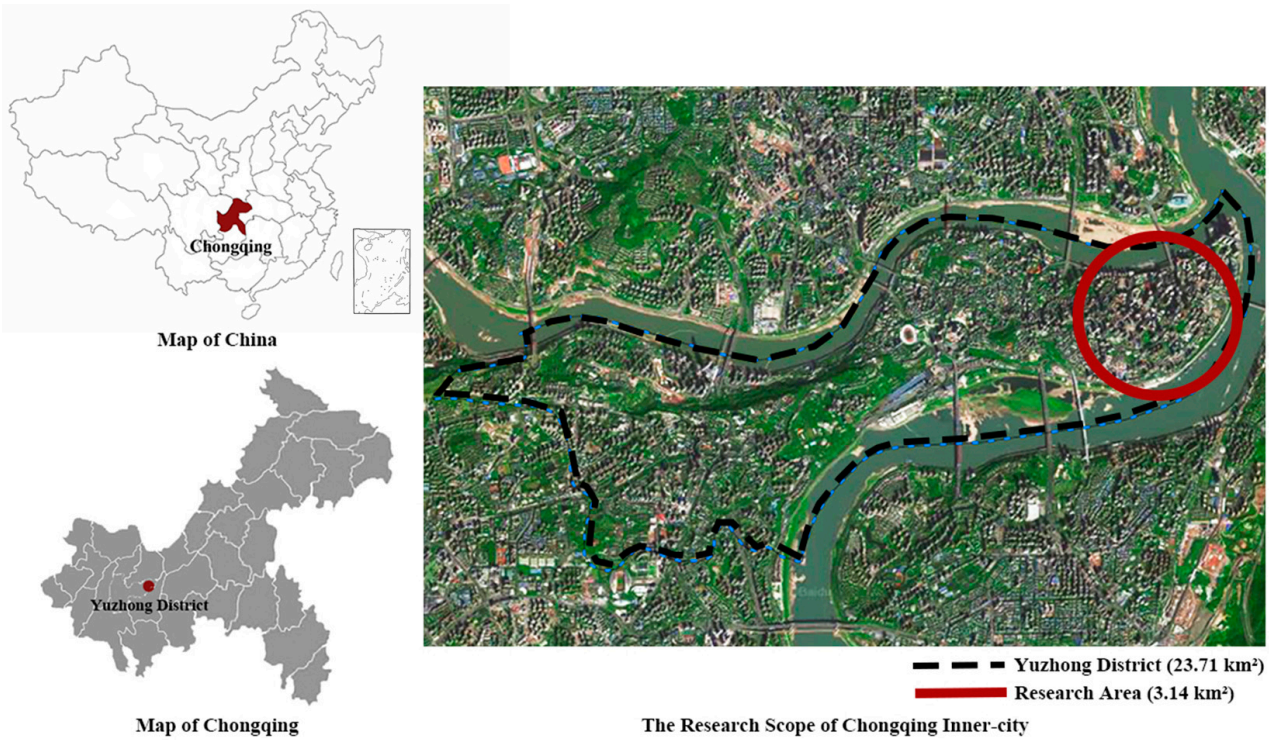


Figure 1. Research Scope of Transitional Streets Between Jiefangbei CBD and the Inner-city Residential Areas. Source: [38].

The urban topography of this study is primarily characterised by hilly terrain, as illustrated in Figure 2. Specifically, the study area, the Jiefangbei district of Chongqing's Yuzhong district, exhibits pronounced hilly landscape features. The elevation map reveals substantial variations within the area, ranging from a low of 144 m to a high of 320 m. This significant relief indicates pronounced topographical undulations consistent with the geographic characteristics of hillside urban environments targeted in this research.

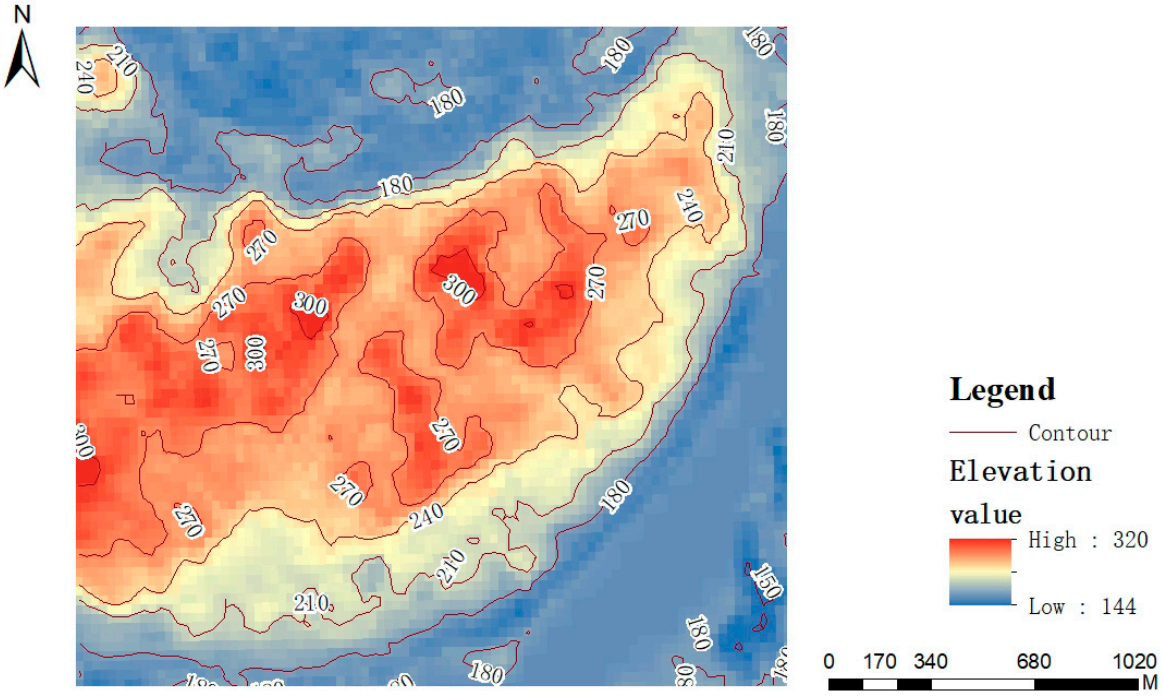


Figure 2. The Elevation Map of the Research Area. Source: (Author, 2024).

3.2. Identification of Framework for Streets' Functional Classification

In establishing the framework for identifying the functional types of inner-city transitional streets, a method based on PoI data is employed for detailed functional classification. The process consists of several main steps, as shown in Figure 3. Data preprocessing begins with the collected PoI data, which are reclassified into different functional types and mapped to corresponding urban street functional categories, forming a functionally classified PoI dataset. Using road network data, transitional streets between the CBD and residential areas are extracted. A 20-m buffer zone is established around these streets to facilitate the subsequent selection of PoI data. For defining the research boundary, maps and road network buffer data are used to delineate the study area and exclude PoIs outside this boundary. In data analysis, this study extracted PoI data to classify urban functional areas within the road network buffer zone. Prior research on urban functional area classification has commonly employed a 250 × 250 m grid to segment the study area [36]. However, given the relatively small area in this study, multiple trials were conducted, and we opted to divide the research area into a 200 × 200 m grid, using this as the basic unit of analysis. This division scale not only ensures an adequate number of PoI samples within each analysis unit but also better conforms to the spatial scale of the study area, thereby enhancing the accuracy and validity of the research. Furthermore, the frequency density index (Fi) and ratio index (Ci) of each PoI type are computed to assess the functional characteristics of each grid. Areas with an index of zero are excluded, and those with a ratio index greater than or equal to 50% are identified as single-function zones, while those below 50% are considered mixed-function zones. Function classification and validation follow, where the process forms a classifier for the functional types of transitional streets, distinguishing and identifying the functional categories of urban spaces. A visualisation

map of the transitional street functional zones is constructed, and comparative analysis is for data validation, ensuring the accuracy of the classification. Finally, the integration of street function type data and street classification information is conducted to summarise and categorise the types of transitional streets.

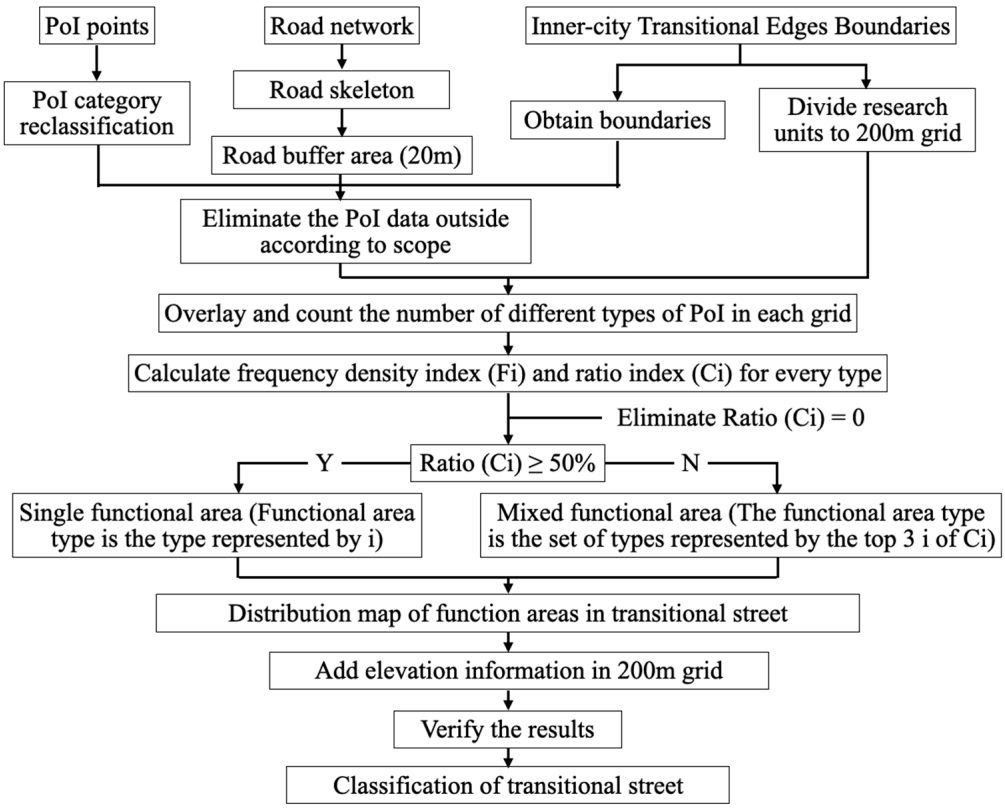


Figure 3. The flow chart of Transitional Street Functional Identification Based on PoI Data. Source: (Author, 2024).

3.3. Data and Pre-Processing

The PoI data used were obtained via the internet before September 2023 from Baidu PoI. This data set includes each Point's name, address, and classification information. The initial step was data preprocessing to ensure the quality of the PoI data, which mainly involved data cleaning and organisation. Data cleaning encompassed removing duplicate entries, Points with low-quality or missing information, and those with unclear functional orientation. Subsequently, road network data between the CBD and the inner-city residential areas were extracted using Tianditu's mapping service, delineating the transitional streets. Following this, PoI Points within the study area were selected based on the buffer zone of the extracted road network, as shown in Figures 4 and 5.

Data preprocessing obtained 2130 Baidu PoI data points across 14 primary and 93 secondary classification categories. Referring to the Chengdu city street design guidelines of 2022 and adhering to the universality and consistency principles of PoI classification from 2010, the PoI data were categorised into six types: life service, commercial, tourism (landscape), industrial, traffic, and specific types (shopping, waterfront, alleyway). Given that the specific type in this study area was predominantly shopping-related, this category was directly used for classification. This study classified PoIs related to food and beverage, financial institutions, science and education, automotive services, business residential, life services, leisure and entertainment, healthcare, and fitness as life service types. PoIs related to corporate enterprises and hotel accommodations were classified as commercial, those related to tourism attractions as tourism, and those associated with transportation facilities as traffic type. PoIs related to shopping activities were classified as shopping streets. No

industrial-type PoIs existed in the transitional area between the CBD and residential areas. Hence, the industrial type was excluded from subsequent classifications. Financial institution PoIs, explicitly referring to banks and ATMs, and automotive-related PoIs, specifically referring to vehicle maintenance and care, were categorised as life service types. This paper re-categorized the 14 primary types of PoI into five categories, as shown in Table 2.

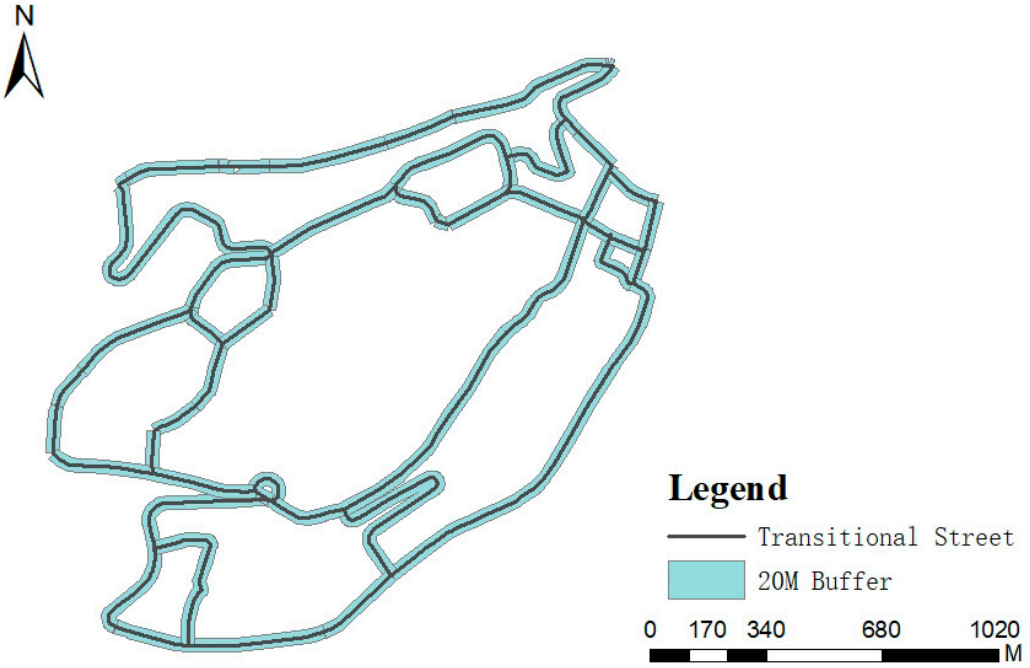


Figure 4. Transitional Street Network. Source: (Author, 2024).

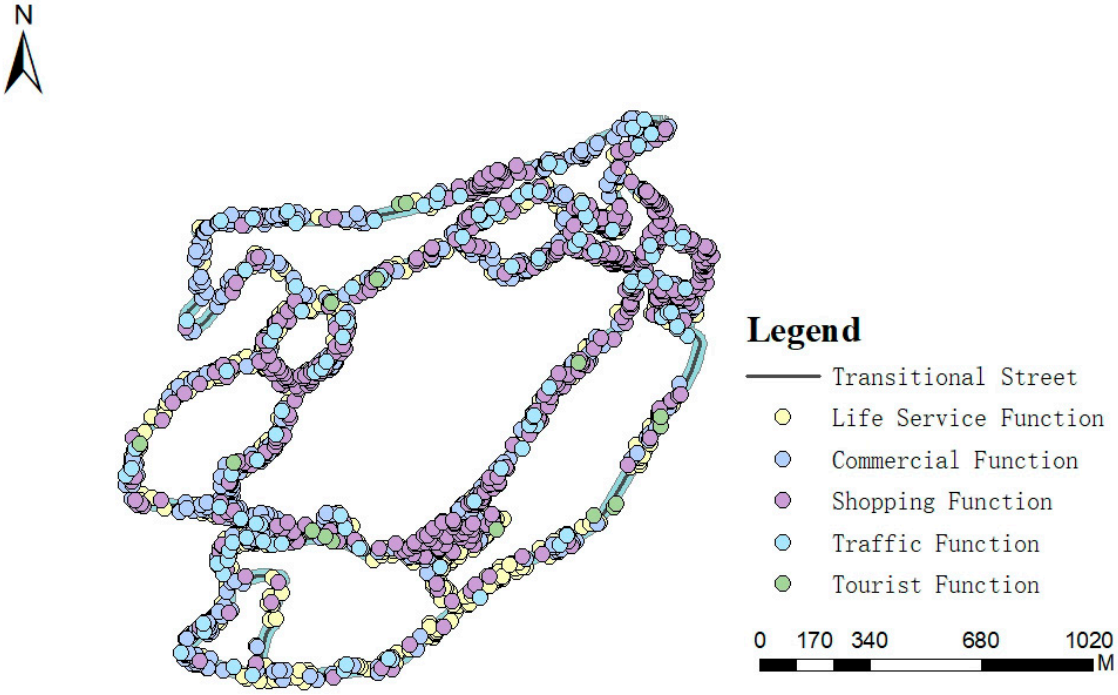


Figure 5. Distribution of PoI data in Transitional Streets. Source: (Author, 2024).

Table 2. PoI Classification of Functional Integration.

Function Type	PoI Category
Life service	food and beverage, financial institutions, science and education, automotive services, business residential, life services, leisure and entertainment, healthcare, fitness
Commercial	corporate enterprises, hotel accommodations
Tourism	tourism
Traffic	transportation facilities
Shopping	shopping

To determine the primary function of each 200-m grid unit, two indices were constructed: Frequency Index (F_i) and Ratio Index (C_i) to assess the street function type. The formulas for these indices are as follows:

$$F_i = \frac{n_i}{N_i} \ (i = 1, 2, \ldots, 5) \tag{1}$$

$$C_i = \frac{F_i}{\sum_{i=1}^{5} F_i} \times 100\% (i = 1, 2, \ldots, 5) \tag{2}$$

The formula, i represents the type of PoI, n_i denotes the number of PoIs of the category i in the grid unit, N_i is the total number of PoIs of category i, F_i is the frequency density of type i PoI within the grid unit, and C_i represents the proportion of the frequency density of category i PoI within the grid unit.

After calculating F_i and C_i for each grid unit, function discriminant analysis can be conducted. If the C_i of a particular type in a grid unit is greater than 50%, the unit is a single-function zone, and its type corresponds to the type i with the highest C_i. When all C_i values are less than 50%, the unit is regarded as a mixed-function zone, and its type is determined by the top three C_i types. If a grid unit does not include any PoIs, meaning that C_i has no value, then this unit is considered a no-data area.

4. Analysis and Synthesis

4.1. Results of Transitional Streets' Functional Areas

In studying the functional areas of transitional streets between the CBD and residential areas in Chongqing's Yuzhong District, it was observed that the area predominantly comprises single-function zones, accounting for 62.9% of the total study area. Mixed-function zones make up 32.3%, and no-data areas account for 4.8%. This outcome, illustrated in Figures 6–8, demonstrates a high proportion of single-function zones within the 200-m grid division, indicating a concentrated and compact distribution of similar type PoIs.

In the mixed-function zone analysis, see Figure 9, areas comprised of transportation, life services, and shopping types held the highest proportion at 30%, demonstrating the integrative and complementary nature of these functions in urban living. The combination of commercial, life services, transportation, and shopping types accounted for 20%, further validating the commonality of multiple-function integration and coexistence on transitional streets.

By overlaying contour lines, slope aspects, and gradients within a grid, the relationship between the layout of transitional streets and the terrain undulations in a hillside urban environment can be observed, as shown in Figures 10–12. The maps clearly illustrate significant topographical changes within the study area, particularly between the CBD and the inner-city residential areas. This spatial analysis reveals a pronounced downhill trend from the CBD to the residential areas, highlighting the role of transitional streets in connecting these two functional zones. In hillside cities, transitional streets exhibit unique characteristics as they must accommodate steep slopes while maintaining traffic flow and pedestrian access. The configuration of these streets is designed to adapt to the complex spatial dynamics introduced by rugged terrain, including effectively managing elevation changes to minimize impacts on transportation and mobility.

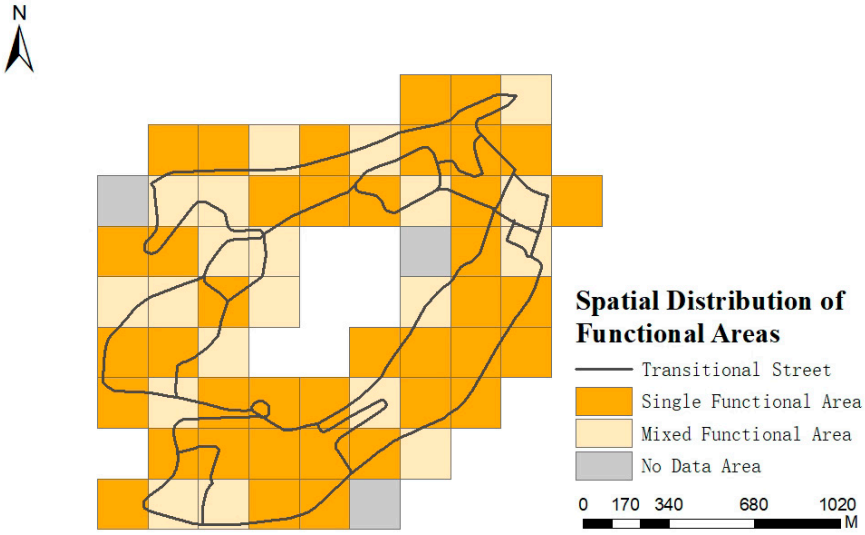


Figure 6. Transitional Street Distribution of Single/Mixed Functional Areas in Inner-city of Chongqing. Source: (Author, 2024).

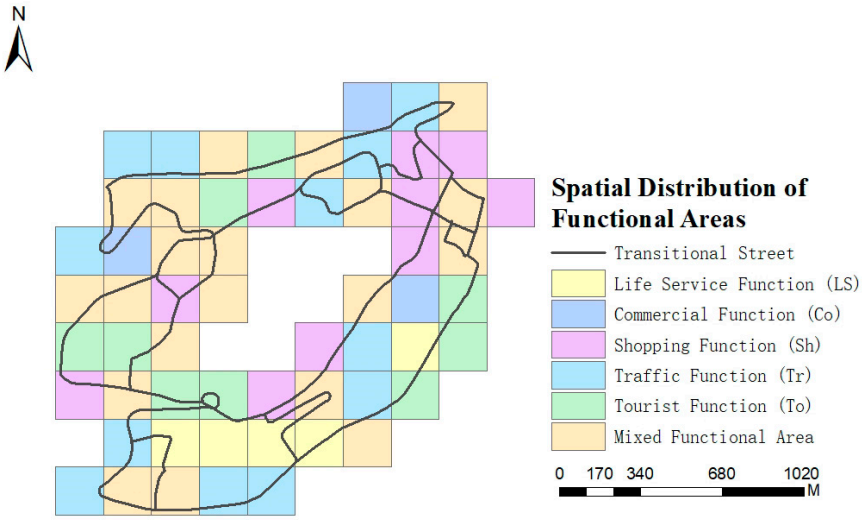


Figure 7. Transitional Street Distribution of Single Functional Areas in Inner-city of Chongqing (Subsequent figures will utilize same abbreviations as described above). Source: (Author, 2024).

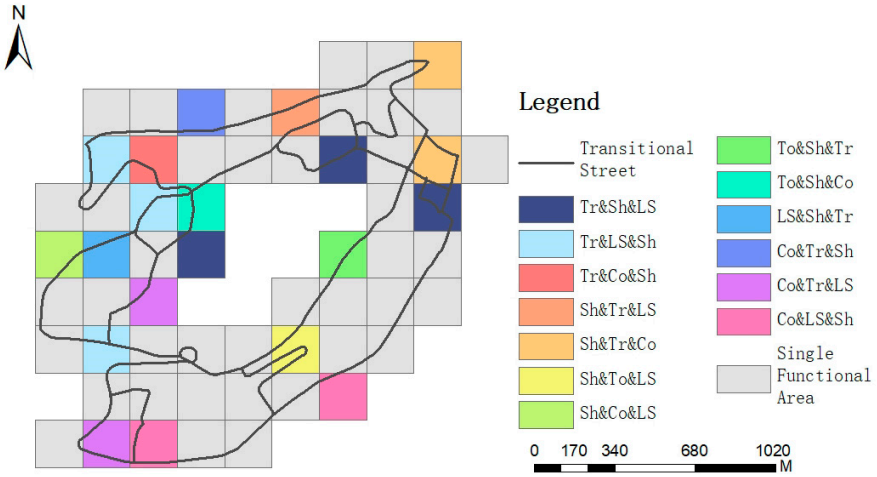


Figure 8. Transitional Street Distribution of Mixed Functional Areas in Inner-city of Chongqing. Source: (Author, 2024).

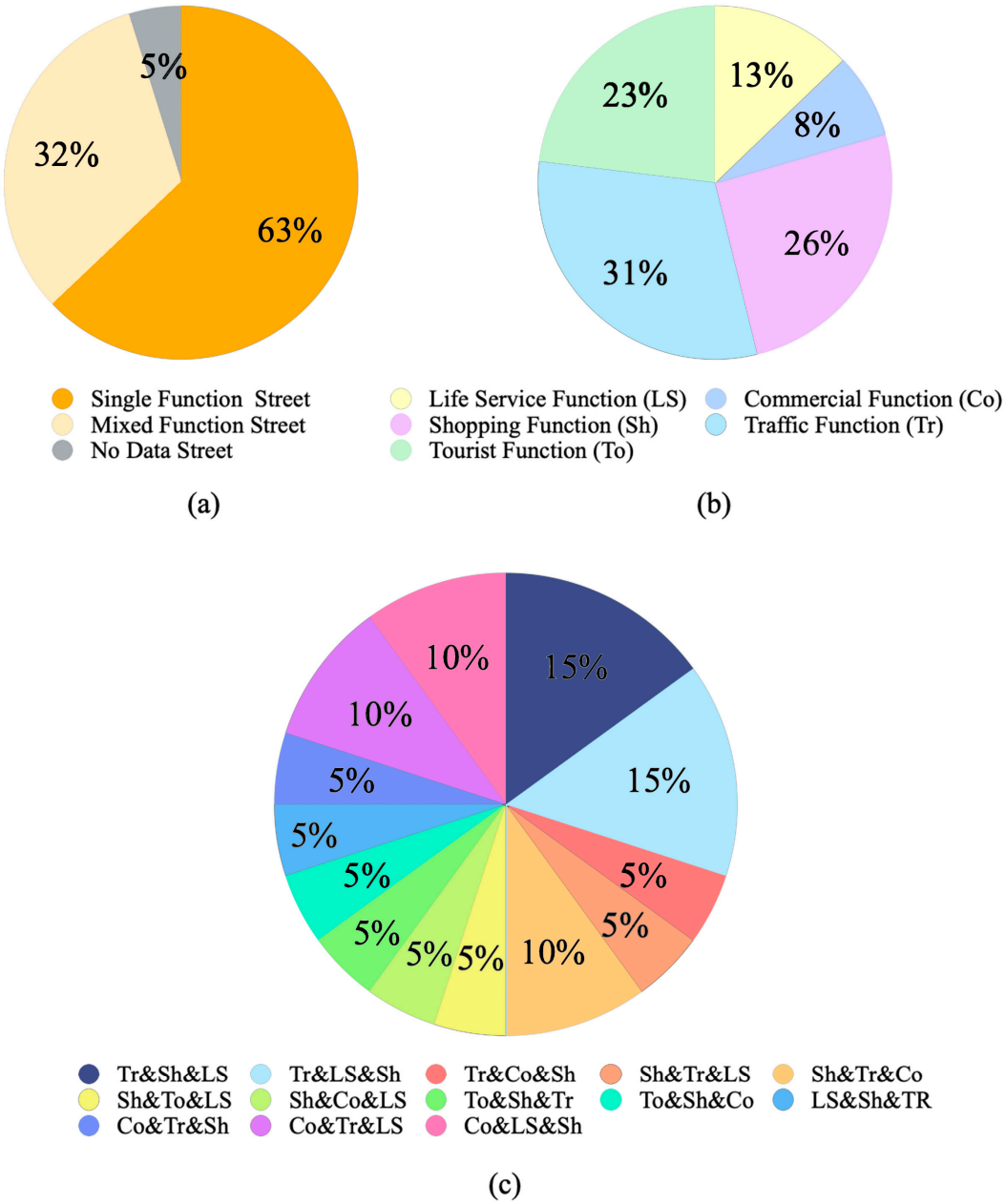


Figure 9. Proportion of All Types: (**a**) Proportion of Function Type Street (**b**) Proportion of Single Functional Streets. (**c**) Proportion of Mixed Functional Streets. Source: (Author, 2024).

In past urban planning designs, the functionality of these streets has been significantly influenced by their topographical context. They are designed to maximise connectivity, ensuring that movement between different city areas remains as smooth as possible despite the challenging terrain. The terrain analysis underscores the importance and necessity of transitional streets in hillside urban settings. These streets support city infrastructure and enhance urban life quality by improving accessibility and integrating diverse urban spaces, thus forming a cohesive urban environment.

Regarding spatial distribution, mixed-function zones primarily oriented towards transportation were concentrated in the northwestern part of the study area. In contrast, commercial-centric mixed-function zones were more prevalent in the southwestern part. This distribution pattern is related to the geographical and socio-economic connections between the city centre and residential areas. The widespread distribution of transportation zones may align with their role as urban transit hubs, and the concentration of shopping

and scenic areas may be associated with the geographical locations of commercial activities and tourism attractions.

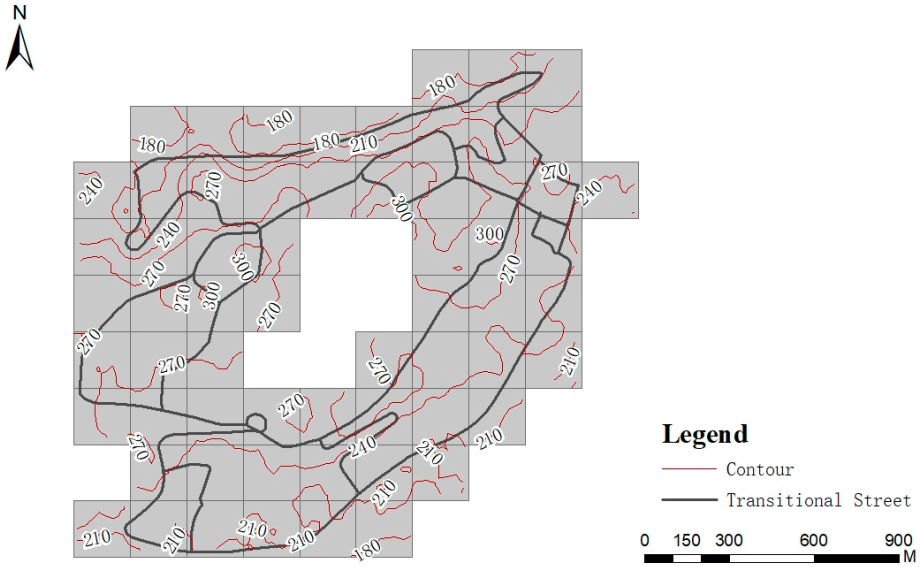


Figure 10. Transitional Street Elevation in 200 m Grid. Source: (Author, 2024).

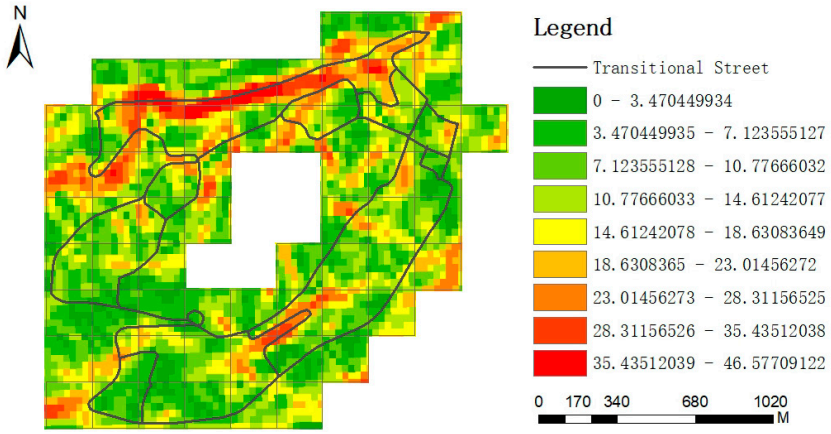


Figure 11. Transitional Street Slope in 200 m Grid. Source: (Author, 2024).

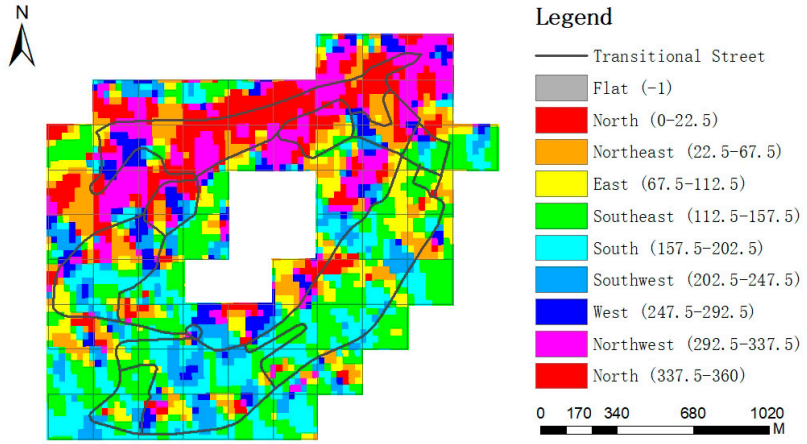


Figure 12. Transitional Street Aspect in 200 m Grid. Source: (Author, 2024).

4.2. Verifying the Results

A field comparative analysis strategy was adopted to validate the feasibility of this study's transitional street functional zoning identification method. One grid unit from each of the six functional zone types was selected as a sample, distributed across different functional areas between the CBD and the inner-city residential zones of Chongqing's Yuzhong District. A thorough validation analysis compared each sample unit's satellite images and street view from Baidu Maps with the functional identification results based on PoI data.

A primary challenge in the validation analysis was the high overlap and mixing of life services, commercial and shopping areas. These areas often exhibit vigorous functional mixing in real life, where commercial activities may be closely adjacent to life services or shopping facilities. Additionally, even in primarily tourism areas, PoIs with commercial, life services, transportation and shopping features may exist, posing a challenge for classification.

The verification results for each type of area demonstrated:

Commercial areas: As illustrated in Figure 13, Beiqu Road is a prominent commercial space, a transitional street near the residential area, predominantly consisting of companies. The automatic PoI recognition result is consistent with the actual situation.

(a) **(b)** **(c)**

Figure 13. Commercial Areas (**a**) PoI Grid, (**b**) Transitional Street Plan, (**c**) Baidu Street Map. Source: (**a**) (Author, 2024), (**b**) [39], (**c**) [38].

Life services areas: As shown in Figure 14, Kaixuan Road, which is mainly adjacent to residential areas, consists of schools, convenience facilities and a few transportation facilities. The PoI automatic recognition result aligns with reality.

(a) **(b)** **(c)**

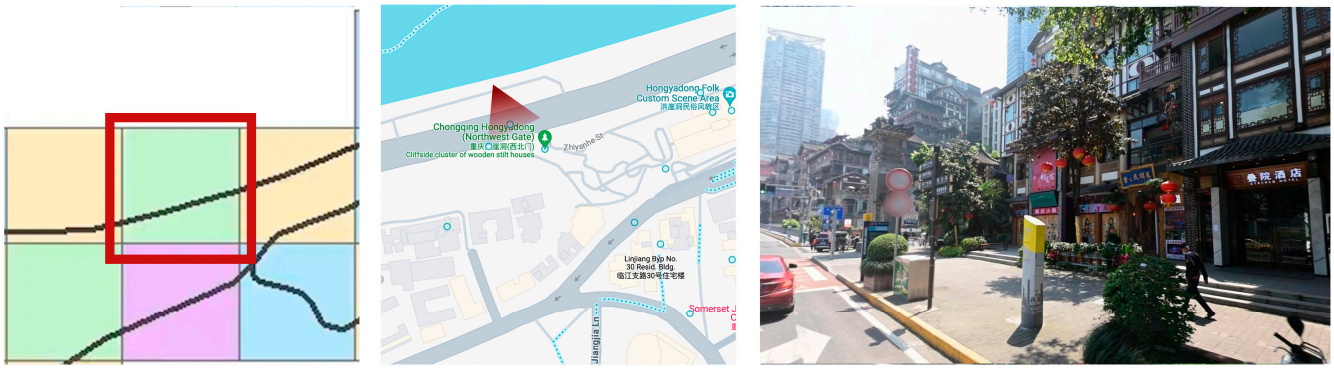
Figure 14. Life Services Areas: (**a**) PoI Grid, (**b**) Transitional Street Plan, (**c**) Baidu Street Map. Source: (**a**) (Author, 2024), (**b**) [39], and (**c**) [38].

Traffic areas: Depicted in Figure 15, Linjiang Branch Road includes bus stations and light rail stations. Despite the presence of shopping malls and small businesses, transportation functions dominate, making the area primarily used for transit. The PoI automatic recognition result matches the actual conditions.

(a) **(b)** **(c)**

Figure 15. Traffic Areas: (**a**) PoI Grid, (**b**) Transitional Street Plan, (**c**) Baidu Street Map. Source: (**a**) (Author, 2024), (**b**) [39], and (**c**) [38].

Tourism areas: As shown in Figure 16, the area near Hongyadong, a typical urban tourism area, also involves other similar regions like Shiba Ti and Bai Xiang Ju. Streets near these tourism areas exhibit scenic street characteristics, hence the PoI automatic recognition result corresponds with the real situation.



(a) **(b)** **(c)**

Figure 16. Tourism Areas: (**a**) PoI Grid, (**b**) Transitional Street Plan, (**c**) Baidu Street Map. Source: (**a**) (Author, 2024), (**b**) [39], and (**c**) [38].

Shopping areas: As illustrated in Figure 17, part of Minsheng Road is characterised by shopping malls and street-front shops, consistent with the PoI automatic recognition and actual situation.

Mixed-function areas: In Figure 18, Datong Road has a complex functionality, amalgamating banks, bus stations, and commercial facilities. It has an even distribution and no clear street-type orientation, fitting the mixed-function street characteristic. The PoI automatic recognition result agrees with the actual situation.

Overall, through field comparative analysis, this study's method for identifying functional zones of transitional streets has demonstrated high feasibility and accuracy, affirming that the classification based on PoI data can effectively reflect the actual functional layout of urban streets.

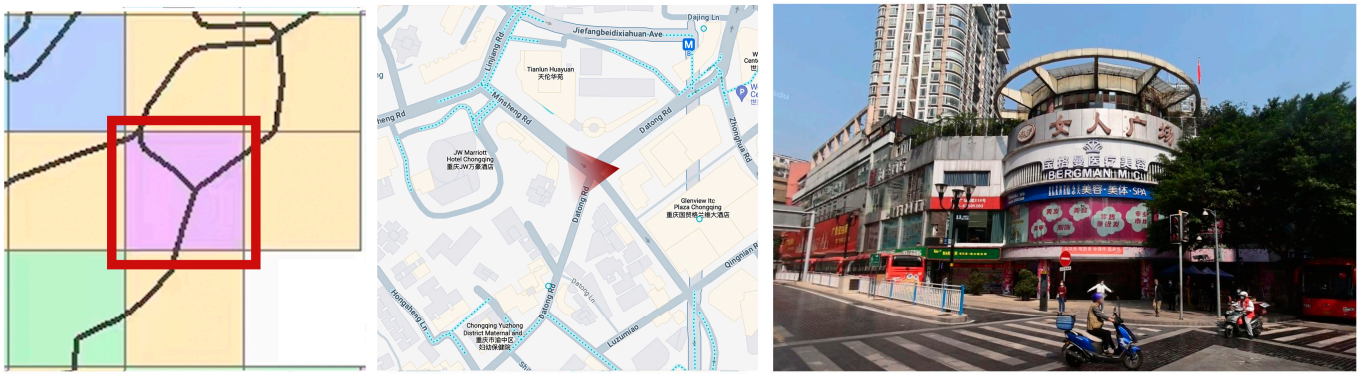


Figure 17. Shopping Areas: (**a**) PoI Grid, (**b**) Transitional Street Plan, (**c**) Baidu Street Map. Source: (**a**) (Author, 2024), (**b**) [39], and (**c**) [38].

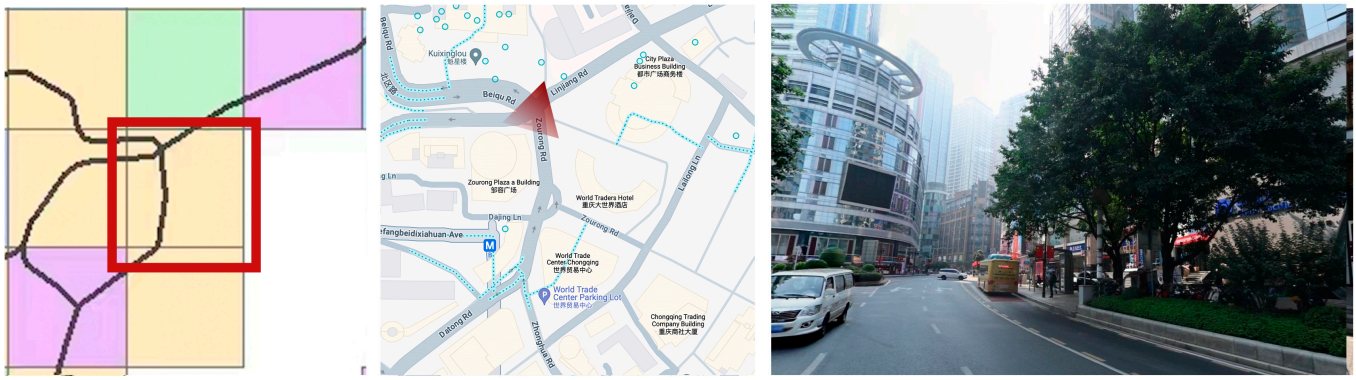


Figure 18. Mixed-function Areas (**a**) PoI Grid, (**b**) Transitional Street Plan, (**c**) Baidu Street Map. Source: (**a**) (Author, 2024), (**b**) [39], and (**c**) [38].

5. Classification of Transitional Street

The classification of transitional streets, a significant component of urban public space, has been guided partly by the street design guidelines of cities like Chengdu. However, discrepancies with actual conditions necessitate a tailored approach. Hence, based on the characteristics of transitional streets and findings from this study, these streets are divided into eight functional categories as follows. See Table 3:

Table 3. Comparison between Transitional Street Classification and Street Design Guideline Classification.

Transitional Streets Classification	Classification Rationale	Main Characteristics	Street Design Guidelines Classification
Commercial Streets	These streets are predominantly characterized by commercial functions, featuring a concentration of commercial office buildings and activities.	Commercial PoI are densely clustered, particularly near the CBD, while displaying a dispersed trend in transitional areas.	Commercial Street, Commercial Connector, Commercial Shared Streets
Residential Service Streets	These streets are located near residential areas and concentrate amenities related to residential services, such as schools and hospitals.	The distribution of service points is dense, facilitating the daily convenience of residents.	Residential Shared Streets, Residential Streets, Neighborhood Main Streets, Neighborhood Residential, Living Street

Table 3. *Cont.*

Transitional Streets Classification	Classification Rationale	Main Characteristics	Street Design Guidelines Classification
Heavily Traffic Streets	These streets are designed and strategically positioned to optimize urban traffic flow, often equipped with a variety of transportation facilities.	Transportation functions are evenly distributed, connecting the city centre with peripheral areas.	Central One-Way Streets, Central Two-Way Streets, Major and Minor Arterials, Traffic-type Street, Transit Streets, Large Streets with Transit
Shopping Streets	The streets prominently feature shopping-related commercial activities that radiate outward from the CBD.	Shopping points are concentrated and closely linked to urban economic development.	Market, Main Shopping Street, Market Streets
Touristic Streets	These streets are situated near or include major tourist attractions, possessing unique appeal.	They are typically integrated with scenic green spaces, offering significant visual and cultural attractions.	Historic Streets, Touristic Streets, Waterfront and Parkside Streets
Landscape Streets	These streets make extensive use of urban green spaces and plazas, emphasizing beautification and recreational functions.	They incorporate leisure and entertainment spaces, typically featuring walkways and rest areas.	Streets to Streams, Landscape Street, Parkways, City Boulevards
Mixed-Use Streets	These streets do not have a single dominant function, but instead integrate multiple functions including residential, commercial, and entertainment.	They are functionally diverse and utilize mixed-use spaces, fostering a variety of activities within the area.	Parklets, Pedestrian Plazas, Industrial/Mixed-use, Mixed-Use Boulevard, Integrated Street
Unclassified Areas	These areas are unclassified due to insufficient data on PoI, making it challenging to assign them specific functions.	The data is sparse, and the functional features are not clearly defined.	Alleys, Pedestrian-only streets, Laneways and Alleys, Elevated Structure Improvements, Elevated structure Removal, Streets in Informal Areas, Other categories not clearly falling into the above classifications

In comparing various street types within urban street design guidelines, the classification of transitional streets significantly illustrates the characteristics of urban centre areas. These streets primarily serve the area between the CBD and inner-city residential zones, supporting functions related to social life services, encompassing commercial and residential services, transportation, shopping, tourism, and landscape aspects. Moreover, a notable radial distribution pattern, diminishing from the CBD outward, is also apparent.

In contrast to conventional streets, transitional streets in inner-city areas do not include industrial streets, elevated structure improvement streets, or parkways. Specifically, the absence of industrial streets correlates with the gradual disappearance of industrial zones due to advancing urbanisation, resulting in their absence in inner-city areas. Elevated structure improvement streets refer to streets that are integrated with or include elevated infrastructures such as overpasses, flyovers, or elevated walkways. These types of streets are considered in urban planning when addressing significant topographical variations, especially in hillside or mountainous cities like Chongqing. However, they are relatively uncommon within city centre areas due to spatial constraints and their construction and maintenance complexity. This study excludes them from the classification of transitional streets because they do not typically intersect with the core areas between the CBD and residential zones. As for parkways, despite some streets being in well-landscaped areas, the saturated development within the urban centre does not afford the necessary green environments, thus excluding these types of streets. Additionally, other specific street types such as service lanes and alleys that do not align with the functionalities typically associated with transitional streets have been deliberately omitted from the final classification. These adjustments and selections reflect the unique positioning and functional focus of transitional streets within the urban structure.

This study explores the functional characteristics of transitional streets in urban centre areas and their impact on the urban spatial structure. By referencing the other city street design guidelines and comparing them with empirical field data, the roles and functions of transitional streets within the urban framework have been clarified. The classification results reveal the functional attributes and distribution trends of various types of streets and provide a scientific basis for further urban planning, particularly in optimising urban functional layouts and designs. In this study, the optimisation process specifically relates to classifying transitional streets to inform urban design decisions that support more effective use of space in the context of Chongqing's unique geographic and urban challenges. By categorising streets based on their functional characteristics and the needs of the area, urban planners can design more suitable and effective layouts that align with the specific demands and constraints of hillside urban environments.

Specifically, the categorisation of commercial and shopping streets underscores the CBD's role in driving the economic activities of surrounding areas, which directly implies formulating urban economic policies and optimising commercial spaces. While conventional street design guidelines often categorise shopping streets under commercial streets, special streets, or pedestrian streets, this study advocates for considering shopping streets as a distinct category based on detailed functional analysis and PoI data classification. This refined categorisation aids in a more precise understanding of how the CBD influences the economic landscape of adjacent areas through its commercial activities. Special streets, as defined in the guidelines from Chengdu, cover a range of types, including commercial pedestrian streets, waterfront pedestrian paths, and alleys. Pedestrian streets, designated for pedestrian use and leisure, typically feature a combination of shopping and daily living amenities and are often integrated with shopping streets, which can blur the distinctions between these categories. Commercial streets primarily comprise service-oriented PoIs like corporate offices and hotel accommodations, which generally have less capacity to attract and manage foot traffic than shopping streets. This is due to commercial streets primarily facilitating non-retail business activities. In contrast, shopping streets focus explicitly on retail and consumer services, a distinction to the significant growth trend in urban shopping activities. shopping streets, typically surrounding the CBD area, distinctly signify the CBD's role in stimulating economic activities in adjacent regions. Independent classification and study of this category can provide more accurate data support and a basis for decision-making in urban economic policy formulation and commercial space optimisation. For instance, understanding the distribution and functional characteristics of shopping streets can assist urban planners in designing more effective commercial promotion areas, optimising consumer experiences involves refining the urban environment to improve satisfaction, convenience, and engagement for shoppers and visitors. Economic growth can be fostered through these strategies by creating vibrant commercial hubs that attract investment, increase employment opportunities, and boost the local economy.

The rational planning of residential service streets and landscape streets provides residents with functional and environmentally suitable living conditions and establishes a smooth transition between the CBD and residential areas. This spatial and functional transition helps balance the intense commercial activities of the CBD with the tranquil living needs of residential areas. Residential service streets mainly focus on providing facilities that cover various aspects of daily life, including food and beverage, financial institutions, science and education, automotive services, business residential, life services, leisure and entertainment, healthcare, and fitness. The centralised layout of these features makes the residential areas convenient and efficient, enhancing residents' life satisfaction and quality. In urban planning, the strategic layout of these service facilities plays a significant role in enhancing the attractiveness and comfort of residential areas. It is an essential factor in improving the sustainable development capabilities of urban residential zones.

The category of landscape streets exemplifies the integration of green and recreational spaces within the city, especially during rapid urbanisation processes where green spaces are often insufficient in inner-city areas. Transitioning typical large-scale green street

types like parkways and city boulevards into landscape streets suitable for densely packed urban centres can effectively utilise limited spatial resources to provide residents with the green recreational areas they need. This improves the city's microclimate and enhances its aesthetic appeal and residents' wellbeing. The design and maintenance of landscape streets should emphasise their role in the urban ecosystem.

Furthermore, the independent categorisation of heavily trafficked streets highlights their central role in the urban transportation system. This classification underscores their pivotal position in the urban traffic network by thoroughly analysing the public transport points on transitional streets, particularly rail transit stations and bus stops. As the primary connection between the exterior and the city centre, heavily trafficked streets accommodate substantial pedestrian traffic and serve as significant congregation areas. Traditional street classification guidelines often divide traffic streets based on vehicle routes. Still, this study refines the function of transitional streets through PoI data, focusing more on the street's transportation functions and the throughput and capacity of public transportation facilities. This approach allows urban planners to understand and design city traffic flows more precisely, optimising the configuration of transportation networks, especially regarding public transportation facilities' layout and adjustments. Recognising heavily trafficked streets as an independent category forms a component of future strategy to enhance urban transportation systems. This approach addresses these areas' unique demands and challenges, facilitating the development of targeted solutions that improve traffic management and promote sustainability. This strategic emphasis aims to achieve more accessible and convenient urban transport networks suitable for the development and functionality of metropolitan areas like Chongqing. This strategic classification emphasises the need to optimise efficient traffic flows in urban planning, which is an indispensable component of city development.

The specialised classification of touristic streets plays a role in urban planning and management, especially in tourist cities like Chongqing. This street type emphasises the strategic deployment of tourist resources and highlights the integration of urban landscapes and cultural characteristics, thus enhancing the city's touristic appeal and cultural image. Analysing PoI data between CBDs and residential areas identifies significant tourist attractions within these transitional zones. These attractions not only boost the city's economic growth but also bring additional pressure on its social functions, particularly during busy holiday periods when crowds are dense. Therefore, the design and management of touristic streets require planning to handle the pedestrian and traffic demands during peak times. This strategy ensures that various aspects of urban design and functionality are carefully considered, helping to prevent potential disruptions and enhancing the implemented solutions' efficiency and effectiveness. For example, when designing touristic streets or integrating new transportation systems, comprehensive planning helps meet current needs and anticipate future growth, thus supporting sustainable urban development. Moreover, the particular categorisation of touristic streets can be an independent consideration for future urban planning, especially in emerging tourist cities or cities developing their tourism sector. Especially relevant in cities like Chongqing, which is rapidly developing its tourism sector, the strategic planning of touristic streets is essential. Chongqing, known for its unique landscape and cultural heritage, is increasingly recognised as an emerging tourist destination. This growth in tourism highlights the importance of integrating carefully planned touristic streets that enhance visitor experiences and support the city's economic expansion in the tourism industry. By thoughtfully designing these streets, cities can better showcase their cultural and historical attributes while enhancing their attractiveness as tourist destinations.

Mixed-use streets play a special role in urban transition areas, as their unique attribute of functional diversity allows them to simultaneously meet commercial, residential, and service needs within the same area, thereby enhancing the coherence and diversity of the urban layout. These streets serve as transition zones between CBDs and residential areas and optimise the layout and functionality of city areas to ensure that available space is

used effectively, increasing land use efficiency and facilitating functional diversity. In urban planning, establishing mixed-use streets is one of the main strategies for meeting modern urban development needs. Integrating multiple functions promotes economic vitality within the area and improves residents' quality of life. Similar street types like pedestrian plazas and mixed-use boulevards have precise functions and design standards. However, transitional streets exhibit a higher degree of functional mixing due to their unique location and functions, emphasising the necessity of multi-functional integration.

Unclassified area streets present unique challenges and opportunities in urban planning and design. These streets, often difficult to categorise into specific functional types due to geographic location or insufficient data, play a main role in enhancing urban connectivity and accessibility. Similar to alleys, pedestrian-only streets, laneways and alleys, and streets in informal areas in street design guidelines, the formation of these streets is often related to the topography of hillside cities. For example, in hillside cities with complex terrain, certain streets may not be developed for specific commercial or residential functions due to their location on steep slopes where construction is challenging. These streets, often situated in areas with significant elevation changes, cannot support traditional urban development on their flanks. Despite these limitations, they are indispensable for ensuring connectivity within the city, serving as links within the urban transportation network and addressing the connective demands of hillside urban settings.

This section successfully categorises and describes the transitional streets with different functions between the CBD and residential areas of Chongqing, providing an empirical basis for effective planning of urban public spaces. The study of these street categories fills the gap in the existing literature on the functional classification of urban transition area streets, offering new insights into changes in urban spatial structures. Through the functional classification of transitional streets, the research not only reveals their role in urban structures but also highlights the distribution trends and functional characteristics of different types of streets in the city, providing a scientific basis for future urban planning and development, especially in optimising urban functional layouts and designs. These insights help to understand how urban spaces can adapt to rapid social and economic changes and how street planning can respond to these changes, holding significant theoretical and practical significance.

6. Discussion

The primary finding of this study is the development of a method to precisely identify and classify the functions of transitional streets in urban spaces, using street typology as the core analytical tool. Compared to the existing literature, the purpose of this study is the first to propose and validate a detailed classification of the diverse functions of transitional streets. Previous studies have predominantly focused on pedestrian environments and economic vitality but have often overlooked the impact of street function classification on urban planning and design [12,27,40]. Our method introduces a comprehensive framework for the classification of street functions. By recognising the dominant functions among various streets, our approach aids planners and policymakers in creating more effective and sustainable urban environments.

This study addresses the initial three questions mentioned in the introduction. First, based on existing socio-spatial street typologies and PoI data analysis, single-function, mixed-function and non-functional streets were identified within the study area. This categorisation was refined into eight functional types: commercial, residential services, traffic, shopping, touristic, landscape, mixed-use streets and unclassified areas.

Then, considering the unique layout characteristics of inner-city transitional streets, the study utilised ArcGIS 10.2 to delineate these streets with a 200-m grid buffer system. The method involved frequency density analysis within these zones, integrating internet map data to map the functional distribution of PoI within transitional streets.

Finally, the typological study of inner-city transitional streets emphasised their unique functional features and developmental potential within the urban fabric. As components

of the inner-city public space, their functional typology classification facilitates viewing transitional margins as multidimensional urban spaces, harmonising the social functions between CBDs and inner districts, thus expanding the CBD's influence and fostering economic vitality in the surrounding areas.

The main innovation of this study lies in developing a novel classification method for transitional street types, which optimises urban space utilisation by identifying the functional types of transitional streets. Our model provides greater precision and adaptability in recognising complex urban functions than traditional land use classifications. This new classification method challenges the conventional single-function division. It offers a more dynamic and diverse perspective on understanding urban transitional areas. It reveals the significant potential of transitional streets in urban spatial planning and socio-economic development, thereby opening new opportunities for research and application.

Mainly, this study underscores the role of transitional streets in urban public spaces by classifying their functions, which enhances the harmony of social functions between CBDs and internal areas. This classification expands the influence of CBDs and boosts economic vitality in surrounding regions. In the specific context of the study area, transitional streets near residential zones should promote the development of life service facilities such as schools, medical centres, and financial services to meet residents' daily needs and improve their quality of life. Similarly, transitional streets near commercial centres should focus on developing business, transportation, and shopping facilities to enhance accessibility and attractiveness.

Furthermore, this study offers another perspective on stock planning and development by addressing the issue of land scarcity in hillside cities. It integrates a detailed street typology classification that accounts for the multifunctional nature of transitional streets, enabling urban planners to utilise limited urban land and enhance functional diversity more effectively, promoting broader urban economic growth and social welfare.

In terms of applicability, the method developed in this study is suited for use in hillside urban environments of various scales. It is designed to enhance urban planning strategies by providing a detailed classification of street types, effectively allocating urban resources and infrastructure development. This applicability is due to cities facing similar geographical constraints as those in the study, where traditional planning methods may fail to address the challenges of varied topographies. The development of this classification method was relatively time-consuming despite the small scale of the research, primarily due to the need for repeated validation and trials to select and build an appropriate classification method. However, future research using this method will be more convenient and time saving than current classification approaches, and it can be scaled up to more significant sites. This is mainly due to the easy accessibility of online big data and the multiple benefits of using a PoI data-based classification tool. This method helps precisely map street functions and offers immense value to urban planners aiming to enhance urban landscape efficiency and sustainability. The ability to customise this method according to different urban environments makes it a versatile tool for urban planning departments. An integrated analysis of PoI frequency density and functional type distribution has established a complex hybridity of street functions, providing a robust decision-support framework for urban development.

This PoI-based street function classification method, accessible and methodologically sound, enables the construction of precise classification models, creating an intelligent mapping between PoI features and street functions. Given the diversity of PoI data distribution and urban transitional street spatial patterns, this method offers a customisable street typology classification reference for urban planning departments, which can be particularly effective in resource-constrained settings such as hillside cities.

7. Conclusions

This study underscores the importance of identifying and classifying the functional areas of transitional streets to enhance urban planning and design decisions. Utilising a

novel methodology that integrates PoI data with urban street information, this research has successfully delineated and analysed transitional streets within the CBD of Chongqing's Yuzhong district through a precise 200 × 200 m grid system and frequency density analysis. The findings confirm that PoI data provides a robust mechanism for accurately identifying transitional streets, contributing to urban spatial planning and socioeconomic development.

The methodological innovation of this study lies in its ability to categorise transitional streets into distinct functional types, which enhances urban design by providing detailed street typology information for infrastructure development and urban regeneration. This classification substantially enriches the study of urban internal streets by providing nuanced insights into the distribution of urban functions. It offers detailed and practical information, enhancing urban design by identifying areas for infrastructure development and urban renewal. Furthermore, the method aids urban planners in crafting policies that target specific functional enhancements, such as improving access to services in residential areas or enhancing commercial activities in business districts.

In subsequent studies, this study lays a strong foundation for future research to explore urban transitional areas' socio-economic impacts. Researchers are encouraged to utilise the developed classification method to investigate how transitional street functions evolve under different urban contexts and their specific impacts on urban development. This could include examining the influence of these functions on economic resilience and integrating additional data sources like mobile phone signals and taxi trajectories to understand temporal variations in street functionality.

Furthermore, applying this classification method in hillside cities presents a unique opportunity to address the challenges of topographical constraints, enhancing urban resilience and infrastructure planning. Future studies could also expand on this work by developing predictive models for urban planning, offering valuable tools for city planners to anticipate and effectively respond to changes.

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