

Article

Coupling of Pawnshop Building Distribution and Urban Spatial Structure in Macau via GIS and Space Syntax Analysis

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Abstract

Pawnshop buildings are places where pawn transactions are conducted. They are usually composed of a front shop and a back building, and their shape resembles a fortress. As a typical gambling city, pawnshops in Macau appeared as early as the Qing Dynasty. By the late Qing Dynasty (1644–1912) and early Republic of China (1912–1949), they had become a common market. They reached their peak during the Anti-Japanese War and were an important financial institution for the people to solve their urgent needs. Today, many pawnshop buildings have become architectural heritage sites and are distributed around the buffer zone of the World Heritage Site. Their location is consistent with the evolution of urban space and the development of gambling and tourism industries. However, existing research lacks systematic research based on spatial quantification technology and it has yet to be determined whether there is a spatial alignment relationship between pawnshop location and urban spatial structure. This paper takes the whole of Macau as the research area and combines DepthmapX space syntax, GIS analysis, and historical data comparison of pawnshop buildings to explore the path dependence characteristics of pawnshop building location and the service radius law in urban space. The study found that the location of pawnshop buildings in Macau has evolved through three stages: initially relying on traditional market spaces, then gathering around casino areas during a stable phase, and finally becoming closely tied to the core areas of gambling venues in the prosperous stage. It shows a path dependence that is continuously strengthened on nodes with low traffic resistance. The service radius of pawnshop buildings exhibits an unbalanced characteristic, with a dense core area and a blank peripheral area, forming a multi-level system of a 200 m core service circle, a 400 m extended service circle, and an 800 m radiation service circle. This study proposes pathways for the adaptive reuse and activation of traditional pawnbroking architectural heritage. For instance, by drawing on the operational model of the Tak Seng On Pawnshop, the integration of cultural exhibition and livelihood services can be realized, thereby providing practical references for the adaptive reuse and conservation of heritage assets. This study offers dual theoretical and practical support for the conservation of pawnbroking architectural heritage in Macau, the site selection and planning of modern pawnbroking establishments, and the optimization of the city's urban spatial structure. Meanwhile, it enriches the research system on the spatial alignment between the peripheral financial industry and urban space.

Keywords: pawnshop architecture; pawnshop site selection; pawnshop premises; space syntax; urban spatial structure



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1. Introduction

1.1. Research Background

As a world-renowned tourist and gambling city, Macau's pawnshops existed as early as the Qing Dynasty, and by the late Qing Dynasty (1644–1912) and early Republic of China (1912–1949), they had become a thriving industry [1,2]. As a transshipment port in the Pearl River Estuary, Macau has developed a thriving pawn market since the Qing Dynasty, relying on the inner harbor trade economic circle. Traditional pawnshops, through their dual functions of poverty relief and safekeeping of valuables, provided crucial financial support for the adjustment of urban and rural economies [3]. During the Anti-Japanese War, the influx of refugees from the mainland and Hong Kong led to a surge in Macau's population, and pawnshops became an important vehicle for alleviating people's livelihood difficulties, even giving rise to century-old brands such as Tak Seng On Pawnshop, forming a vivid physical testament to Macau's financial history [4]. As a product of the collision between Lingnan architectural tradition and European architectural style, Macau's traditional pawnshop buildings, with their unique structure of multi-story towers with enclosed warehouses, have become a material carrier of the fusion of Chinese and European cultures. Their concentrated distribution areas, such as Avenida de Almeida Ribeiro and Rua de Cinco de Outubro, remain the core carriers of Macau's urban fabric and commercial memory to this day [5,6]. From the industry's heyday in the late Qing Dynasty to its modern transformation, the location of pawnshop buildings has always been deeply tied to Macau's economic structure, urban pattern, and cultural characteristics. The evolution of these buildings serves as a distinctive case study for comprehending Macau's urban development. With the passage of time, many of Macau's pawnshop buildings have become architectural heritage. For example, the existing Tak Seng On Pawnshop is the best-preserved example (Figure 1). It opened in 1917 (the sixth year of the Republic of China), and has now been transformed into an exhibition hall for the pawnshop industry [7]. The pawnbroking industry, as one of the oldest peripheral financial sectors in human history, with its core feature of short-term financing services based on movable property pledge, has become an important supplement to the mainstream financial system, playing a unique role in capital flow, goods circulation, and social emergency response [8]. This function of rescuing people from crises and providing relief is imbued with even deeper historical value and regional characteristics in Macau, a special region that combines Lingnan cultural roots with Portuguese rule.

Today, with the gaming industry becoming a pillar of Macau's economy, pawnshops have transformed from serving the public to being dependent on casinos, leading to profound changes in their site selection logic. However, the historical inertia of traditional site selection continues. This intertwined traditional and modern site selection characteristic not only highlights the ongoing impact of pawnshops on Macau's regional development but also provides a unique perspective for exploring their spatial evolution.

1.2. Problem Statement and Objectives

This study focuses on the architecture of pawnshops in Macau, examining two core issues: path dependence in site selection and service radius. The aim is to achieve the following three objectives:

First, to systematically trace the historical evolution of pawnshop site selection in Macau, revealing its path dependence on characteristics and formation mechanisms. By integrating historical maps and spatial data, the study clarifies the site selection patterns during the traditional trade period, the transitional period, and the modern gaming period, identifying key triggering factors for path dependence.



Figure 1. Tak Seng On Pawnshop in Avenida de Almeida Ribeiro. The Chinese characters shown in the photo are either the name of a pawnshop sign or a shop. They have no specific meaning. (Image source: taken by the authors).

Second, to quantitatively analyze the spatiotemporal evolution of the service radius of Macau pawnshops and its influencing factors. Using case studies of traditional pawnshops (such as Tak Seng On) and modern pawnshops, spatial analysis methods are employed to calculate the service radius range in different periods, exploring the correlation between service radius and site location, target audience (public needs, gambler needs), and transportation conditions. Transportation conditions exert a direct influence on the customer acquisition efficiency of pawnbroking establishments. Nodes with low traffic resistance can reduce customers' travel costs and enhance transaction frequency; in addition, traffic flow is positively correlated with population density, which determines the scale of potential demand for pawnbroking services.

Third, to provide theoretical support and practical reference for the heritage protection and sustainable development of Macau's pawn industry. By revealing the positive significance and potential constraints of the dependence on past site selection, the study proposes pathways for the revitalization and utilization of traditional pawnshop architectural heritage. Finally, based on suggestions for optimizing service radius, the study provides data support for the selection of modern pawnshops, contributing to the simultaneous enhancement of the industry's cultural and economic value.

This study presents the following innovations: Theoretically, it uncovers the path-dependent mechanism underlying the cooperation between the peripheral financial industry (pawnbroking) and urban spatial structure and enriches interdisciplinary research on urban heritage and space syntax. Methodologically, it integrates space syntax, GIS kernel density analysis and buffer analysis to establish a quantitative system of three-tier service radii at 200, 400 and 800 m. Empirically, it clarifies the three-stage evolutionary law of pawnbroking in Macau from its dependence on traditional markets to its integration with the gaming core, thus filling the research gap in the spatial quantification of pawnbroking in Macau.

2. Literature Review

2.1. Heritage Transformation of Pawnshop Buildings

In the field of historical architectural heritage, some scholars have begun to explore and study pawnshop architecture. Some scholars examine the Tak Seng On Building in Macau, originally a large pawnshop built in 1917, focusing on its history, architectural features, and transformation into a pawnshop museum [9]. They detail the building's facade features, including its waterwashed stone finish, ground floor columns, and the design of the main entrance with sliding doors, iron security bars, and colored frosted glass. Yung et al. examines eight case studies of shophouse revitalization in Hong Kong, which includes the location of the Woo Cheong Pawn Shop on Johnston Road [10]. They analyze architectural type and development, especially noting that the Woo Cheong Pawn Shop shophouses were built in the form of the verandah shophouse and were acquired by the Urban Renewal Authority (URA) in 2003 for a redevelopment project. They discuss the social, environmental, economic, and political considerations contributing to the adaptive reuse and conservation of shophouses within urban renewal projects. Lee focused on the pawnshop case in Guangzhou. He details the architecture of the former Dongping Pawnshop's storage building, noting that it was a fortified multi-story tower built during the Qing Dynasty, and he describes the remaining storage building as following the same architectural style as the proper pawnshop [11]. They also note that the commercial component of the residential development includes renovated ground-floor shops for retail, and the first and second floors were converted into a high-class British-style restaurant [12].

Ung [1] examines pawnshops, including the Tak Seng On Pawnshop, in the context of Macau's Avenida de Almeida Ribeiro, noting their concentration in this commercial area during the 1930s. Lang also focused on this restoration case, highlighting the Pawnshop Building restoration as a pioneering adaptive reuse project that established it as a key landmark on Macau's heritage trail and spurred conservation efforts for other commercial structures [13]. Wouters et al. discusses construction details, innovations, and developments of techniques in 19th-century fireproof buildings, with the Pawnshop Building in Brussels serving as one of the three representative case studies [14]. They focus on the structural elements and materials of the Pawnshop Building, noting the use of wrought iron girders, cast iron beams, and a brick barrel vault floor, and highlighting the building's exceptional encasing of iron for fire protection. Dmytryk et al., from the perspective of industrial building renovation, discuss the former pawnshop building in Odessa, originally constructed in 1904–1905 and later converted into a sewing factory in 1930 [15]. They note that the renovated pawnshop building currently functions as a multifunctional organization, housing various small stores, cafes, sports clubs, and other retail and service outlets.

2.2. Chinese Pawnshops and Pawn Industry

The development of the pawn industry in China exhibits clear phased characteristics. Its origins can be traced back to the temple economy of the Southern Dynasties. During the Tang and Song Dynasties, it gradually separated from temples to become an independent industry. It reached its peak during the Ming and Qing Dynasties, forming an industry structure dominated by pawnbrokers from Shanxi and Huizhou [8]. Affected by social unrest in the late Qing Dynasty and early Republic of China, the pawn industry, although maintaining a certain scale, showed signs of decline and even disappeared after the founding of the People's Republic of China. The establishment of the first modern pawnshop in Chengdu in 1987 marked the industry's revival. Subsequently, it underwent a development stage of regulation by the People's Bank of China (1996–2003) and joint regulation by the Ministry of Commerce and the Ministry of Public Security, with the

legal system gradually improving [16]. The development trajectory of the pawn industry in Macau follows the overall pattern of China's pawn industry while also exhibiting distinct regional characteristics. During the Qing Dynasty, relying on its maritime trade advantages, Macau's pawnshops gradually took shape and formed a three-tiered system of "pawning, mortgage, and trust". During the War of Resistance against Japan, it reached its peak due to population influx, becoming an important force in regulating the regional economy. After the 1970s and 80s, traditional pawnshops gradually disappeared due to the impact of modern banking. In 1961, based on the suggestion of the Macau authorities, the Portuguese Overseas Department approved the formal opening of the gaming industry in Macau. Pawnshops gradually transformed into businesses serving gamblers, and the existing institutions are mainly pawnshops [4]. This transformation has both continued the industry's financial attributes and deeply embedded itself in Macau's unique industrial ecosystem, forming a development path that is different from that of Chinese mainland [5,6].

Some scholars argue that policy regulation is the core external factor influencing the development of the pawn industry. The regulatory system of China's modern pawn industry has evolved from vague to clear. The promulgation of the *Pawn Management Measures* in 2005 clarified the corporate legal status of pawnshops, stipulated the core business scope, such as movable property pledge and property rights pledge, and set entry conditions, such as registered capital and security facilities [16]. The shift in regulatory bodies from the People's Bank of China to the Ministry of Commerce and the Ministry of Public Security reflects a more profound understanding of the dual characteristics of the pawn industry—its financial attributes and its role in public security management [17]. Macau's pawn industry has a unique set of rules. The *Macau Pawnshop Regulations of 1903* laid the legal foundation for the industry's development, but no specific regulations were formulated after the handover. Currently, it mainly operates based on general commercial laws and regulatory practices [5,6]. This policy flexibility, while promoting the industry's adaptation to the gaming economy, has also resulted in regulatory gaps and potential risks [17].

2.3. Functions and Modern Uses of Pawnshop Buildings

Therefore, pawnshops in China have developed distinct local characteristics over a long period: functionally, they combine financing, safekeeping, and unredeemed sales, serving a shift from the traditional poor to small- and medium-sized enterprises and individuals with emergency needs. Their business structure is primarily based on movable property pledges, gradually expanding to real estate mortgages and property rights pledges [16]. Regionally, they are densely distributed in the east and sparsely distributed in the west, concentrated in economically developed large cities and commercial districts [3]. Macau pawnshops, due to differences in their industrial environment, have developed unique characteristics: traditional pawnshops use a separate pawn building and warehouse, emphasizing theft- and moisture-proof architectural design. Modern pawnshops are primarily "pawn" shops, offering short-term loans with high interest rates, primarily serving gamblers' short-term cash flow needs, and commonly engaging in the secondary sale of luxury goods [4]. Brand-name watches account for over 50% of pawned items, with high-end watches like Rolex reaching up to 70% of their market value and an unredeemed rate exceeding 80%. Therefore, the sale of secondhand luxury goods has become an important supplement to profits. This combination of historical heritage and modern industry distinguishes it from pawnshops in Chinese mainland and creates a significant difference from similar businesses outside of China.

Conversely, international pawnshop architecture exhibits diversified, large-scale, and standardized development characteristics, with significant regional differences. In the United States, the pawn industry, as an important component of the consumer credit market, functions as both a bank for the poor and an emergency financing facility for the middle class. Its clients cover low-income groups, the middle class, and even the wealthy with their emergency needs. While the average loan amount is low, interest rates are generally high, and the industry is relatively dispersed due to state-specific interest rate restrictions [18]. The British pawn industry experienced a decline due to its well-developed social welfare system and robust consumer credit system. Traditionally, its clients were primarily the working class, and collateral was mostly everyday items. However, with market demand, it gradually shifted its focus to high-value collateral [18]. The *Pawnbroker Ordinance (Pfandleiherverordnung (PfandlV))* (Verordnung über den Geschäftsbetrieb der gewerblichen Pfandleiher) in Germany strictly regulate the pawn industry [19], allowing profits only through loan interest and storage fees. The pawn industry cannot rely on the sale of forfeited items. Its business focuses on high-end watches, precious metals, and other valuables, and it has high entry barriers, requiring professional appraisal personnel and sufficient insurance. Japan's pawn industry has gone through cycles of being run by private companies, being run by both the government and private companies, and then being run by private companies again. It reached its peak after the Meiji Restoration. Modern pawnbroking is centered on chain pawnbroking services for everyday items. On the other hand, standardized regulations and localized services characterize Singapore and Malaysia [16].

2.4. Site Selection for Pawnshop Buildings

Despite the fragmented nature of existing research on pawnshop site selection, it has produced several key findings. From a macro-regional perspective, pawnshop architecture in China exhibits a significant economic dependence, with the eastern coastal areas and large cities becoming concentrated areas due to high demand for funds and convenient pawnbroking, while rural and county-level markets suffer from insufficient coverage [3]. Regional economic development levels and the gap in financial services strongly correlate with this distribution pattern [16].

Site selection studies in specific regions like Macau reveal that the spatial layout of traditional pawnshops exhibits clear trade orientation and commercial agglomeration. Zha's doctoral dissertation points out that Macau's traditional pawnshops are concentrated in core commercial areas such as Avenida de Almeida Ribeiro and Rua de Cinco de Outubro [6]. These are closely linked to the Inner Harbour trade economic zone, a distribution that facilitates customer acquisition and the transportation and circulation of pawned goods. Simultaneously, pawnshop site selection must adapt to Macau's high-density urban space and humid climate, often relying on the arcade-style commercial street fabric and employing relatively enclosed tower-like structures. Wen, using Macau's pawn industry as an example, proposes that as the core industry in the region shifted from trade to gambling, pawnshop site selection showed a casino-dependent characteristic, gradually clustering in areas with high casino density, such as Avenida da Amizade, forming a spatial symbiotic relationship between gambling and pawning [4]. This transformation reflects both the direct impact of changes in service targets on site selection and the industry's adaptive adjustment to the regional industrial structure.

Overall, existing research has identified key factors influencing pawnshop site selection, including economic level, industrial structure, and commercial agglomeration. However, there is insufficient attention paid to the historical aspects of site selection evolution and a lack of systematic analysis of the path dependence mechanisms in the transformation

of Macau's pawnshops from a trade-oriented model to one dependent on casinos. Furthermore, quantitative research on the relationship between site selection and service radius is scarce, failing to reveal the interaction between the two. This constitutes the two core research questions of the present study: (1) What are the path-dependent characteristics and formative mechanisms of the site selection of pawnshop buildings in Macau? (2) What are the spatiotemporal evolution rules, influencing factors and supply–demand matching status of the service radius of pawnshops in Macau?

3. Study Area and Methods

3.1. Study Area

The spatial scope of this study covers the entire Macau Special Administrative Region (SAR). Located on the southeastern coast of Chinese mainland, on the western bank of the Pearl River Delta [20], downstream of the Xijiang River, Macau is adjacent to Guangdong Province, 60 km from Hong Kong, and 145 km from Guangzhou. The land portion of Macau comprises two sections: the Border Gate section (Posto Fronteiriço das Portas do Cerco) and the Ap Cung River section (Canal dos Patos). The sea portion consists of six sections: the Inner Harbour section, the Cotai Channel section, the southern waters of Macau, the eastern waters of Macau, the artificial islands section, and the northern waters of Macau. Its coordinates range from 113°31′41.4″ E to 113°37′48.5″ E and from 22°04′36.0″ N to 22°13′01.3″ N. As of June 2024, the total land area of Macau has expanded to 33.3 km², with a sea area of 85 km² [21]. The area is divided into 7 parishes (Freguesia) (Figure 2) [22], which include the Freguesia de Nossa Senhora de Fátima, Freguesia de Santo António, Freguesia de São Lázaro, Freguesia da Sé, and Freguesia de São Lourenço on the Macau Peninsula, along with the Freguesia de Nossa Senhora do Carmo on Taipa Island, the Freguesia de São Francisco Xavier on Coloane Island, and one area without parish division, the Cotai Reclamation Area. The Portuguese and Traditional Chinese translations of the place names involved in this study are shown in Appendix A.

Based on key policy milestones in the development of Macau's pawn industry, this study divides it into three periods of urban spatial development and evolution [5,6]. The distribution characteristics of pawnshops in each period are as follows:

(1) Initial Stage (before 1961): Macau's pawn industry mainly focused on traditional public services, with a relatively small number of pawnshops, primarily concentrated in the old city areas of the Macau Peninsula, such as the Freguesia da Sé and Freguesia de São Lourenço, serving mainly local residents.

(2) Stable Stage (1961–2002): In 1961, the Portuguese Overseas Department approved the official opening of the gaming industry in Macau. The pawn industry gradually integrated with the demand for gaming and tourism, and the number of pawnshops steadily increased, expanding its distribution to commercial districts of the Macau Peninsula and the old town of Taipa.

(3) Prosperous Stage (2002–present): In 2002, the Macau SAR government implemented the policy of opening up gaming rights, leading to the rapid development of the gaming and tourism industry. The pawn industry experienced explosive growth, spreading to emerging areas such as the new casino clusters in Cotai and the area around the Taipa Ferry Terminal.

All three phases of this study take the Macau Special Administrative Region as the research subject. Owing to coastal reclamation projects, the geographical scope of the prosperous stage encompasses the newly reclaimed coastal areas, and this spatial change reflects the authentic historical process of urban spatial evolution in Macau.

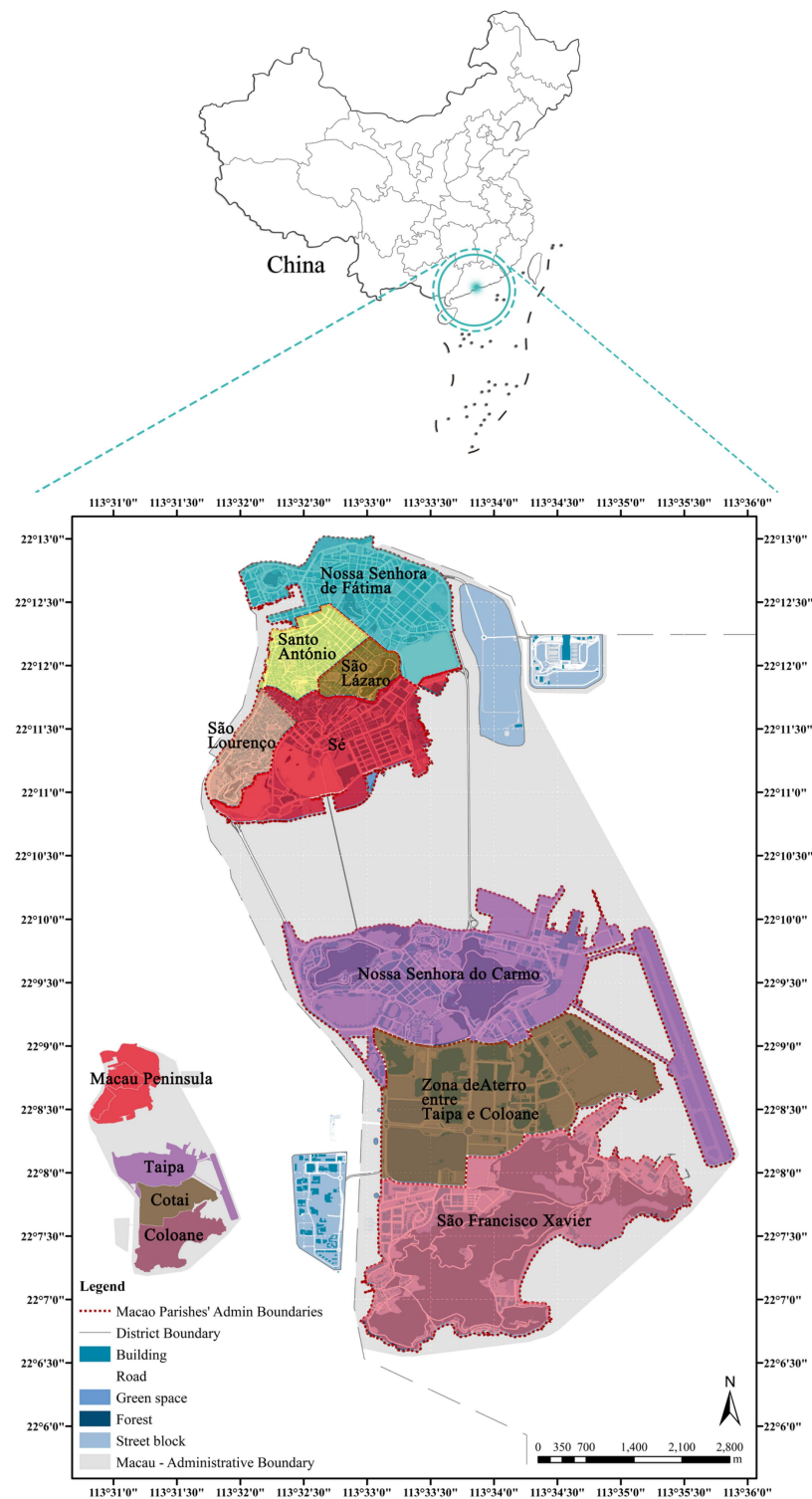


Figure 2. Geographical boundaries and parish divisions of the study area.

3.2. Analytical Methods

3.2.1. Space Syntax

To ensure the cross-period comparability of space syntax metrics across the three developmental stages of Macau's pawnshop industry, this study first conducted standardized restoration and 0–1 normalization processing on the road network data of each period. The initial and stable stages relied on historical maps of Macau for road network restoration, while the prosperous stage adopted current road network data. The unified restoration and normalization steps for historical road network data are as follows:

(1) Cartographic mapping and historical map analysis

Historical maps of Macau in the initial (before 1961) and stable (1961–2002) stages were imported into CAD software (version 2024) for digitization. The main spatial elements of the maps were identified, including typical urban street blocks, core commercial roads, and landmark-based traffic nodes. Considering the differences in drawing styles and scale expressions of historical maps, adaptive adjustments were made for the subsequent spatial correction to match the spatial characteristics of Macau's high-density urban fabric.

(2) Reference point setting and scale unification

Typical and immovable geographic landmarks in Macau were selected as the fixed reference points to ensure the accurate splicing of historical road network data. Based on the modern surveying and mapping data of Macau and historical cadastral records, the actual length of Macau's core commercial roads was used to determine the unified scale of historical maps, and the road network was calibrated with the WGS84 coordinate system to realize the spatial alignment of multi-period data.

(3) Image correction and georeferencing

The geometric correction tools in CAD were used to rotate, stretch and scale the digitized historical map images, aligning the selected reference points with the determined geographic coordinates of Macau. This step corrected the deviations of historical maps in direction and proportion, ensuring that the restored road network was consistent with the actual geographic spatial pattern of Macau in the corresponding period.

(4) Road network digitization and width processing

The polyline tool in CAD was used to draw the center lines of streets and roads based on the direction and distribution of road networks on historical maps. Combined with the historical records of Macau's street width (the average width of traditional alleys is about 5 m, and core commercial roads are about 15–20 m), the road width of different grades was standardized and set, matching the road width classification standard of the prosperous stage to avoid the impact of road grade differences on space syntax calculation.

(5) Distance relationship balance

In view of the possible scale distortion of historical maps, the modern open street map of Macau was used as the reference to check the distance between core landmarks in the restored historical road network. Local-scale adjustment (stretching or compression) was carried out for the distorted areas, ensuring that the distance between key nodes conformed to the actual measurement standard of the corresponding period while retaining the historical authenticity of the original road network structure as much as possible.

(6) Data verification and unification

The restored historical road network data was compared with the historical literature and urban planning records of Macau in the corresponding period to verify the rationality of the road network connection and node setting. The inconsistent road segments were revised to ensure the integrity and accuracy of the multi-period road network data.

(7) The 0–1 normalization of space syntax metrics

After the completion of multi-period road network data restoration and unification, the integration and segment angular connectivity of each period were calculated by DepthmapX software (version 0.8). To eliminate the numerical deviation caused by the expansion of Macau's urban space (e.g., reclamation) and the increase in road network scale

in different periods, the 0–1 normalization method was adopted to process the two metrics. The calculation formula is $X_{norm} = (X - X_{min}) / (X_{max} - X_{min})$, where X_{norm} is the normalized value, X is the original value of the metric, X_{min} and X_{max} are the minimum and maximum values of the metric in the corresponding period, respectively. This processing converts the space syntax metrics of all periods into a unified value range of [0, 1], realizing the scientific and effective cross-period comparison of the metrics.

Space syntax is a core method for analyzing the relationship between urban spatial morphology and pedestrian agglomeration. It reveals the correlation between spatial accessibility and usage frequency by quantifying the topological structure of road networks [23]. This study uses DepthmapX software (version 0.8) for analysis, selecting two core indicators: integration and segment angular connectivity, and combining them with the spatial correlation analysis of pawnshop building distribution in different periods.

(1) Integration

Integration is a core indicator of space syntax, reflecting the average accessibility of a road node to all other nodes in the region. The global integration analysis covers the entire area, with a radius set to $R = n$ [24]. Areas with high global integration are usually urban core transportation corridors, which undertake the function of cross-regional passenger flow distribution. This study imports road network data from various periods. The road networks in the initial and stable periods are restored based on historical maps, while the current data is used in the prosperous period to generate a heat map of the spatial distribution of global integration. Then, the layer showing pawnshop building locations for the corresponding period is superimposed with the integration heat map to observe the distribution of pawnshop building locations and global integration and to determine whether their agglomeration has a trend.

(2) Angular Connection Value

Traditional connection values only count the number of physical connections between road nodes, ignoring the impact of road orientation on pedestrian flow. By introducing the idea of “angular cost,” angular connection values measure how easy it is to get from one node to its neighbors. This better reflects the mountainous terrain and winding roads of Macau [25]. A higher angular connection value indicates a gentler angle between the node and its surrounding nodes, less resistance, and higher efficiency in pedestrian flow. An angular topology model of the road network was constructed in DepthmapX (0.8 version), the angular connection values of each node were calculated, and a spatial distribution map was generated. The spatial coupling relationship between pawnshop locations and nodes with high angular connection values was compared at different times to analyze the dependence of selecting pawnshop locations on nodes with low passage resistance.

3.2.2. GIS Analysis

ArcGIS 10.8 software was used to quantify the spatial clustering patterns and service area characteristics of pawnshops through kernel density analysis and buffer analysis. Combined with POI data from casinos and commercial centers, the correlation between their location selection and consumption scenarios was revealed.

(1) Kernel Density Analysis

Kernel density analysis visually presents the clustering centers and diffusion trends of elements by calculating the density distribution of spatial point elements. Based on the urban scale of Macau, where the average street width is approximately 5 m, a search radius of 300 m was set to generate a kernel density map of pawnshop buildings during the prosperous period, identifying and comparing the core clustering areas and spatial transfer trajectories of pawnshops in different periods. This search radius was determined by three

key considerations: first, it aligns with the 5 min walking range (about 300 m) in Macau's ultra-high-density urban fabric, matching the immediate service demand of pawnshops for gamblers and local residents; second, a 300 m radius can accurately identify the agglomeration centers of pawnshops without over-smoothing the spatial clustering characteristics; third, it is consistent with the radiation scope of casinos and commercial centers in Macau, which is the core service target of modern pawnshops, thus ensuring the rationality of spatial correlation analysis between pawnshops and core consumption scenarios. The number of pawnshops in each parish was counted, and a parish distribution chart was created to analyze regional differences. Simultaneously, the kernel density map of pawnshop buildings was overlaid with the POI distribution of casinos and commercial centers to quantify the spatial correlation strength between pawnshops and core consumption scenarios.

(2) Buffer Analysis

Buffer analysis defines the service area by generating circular buffer zones centered on point elements and judges the demand matching degree by combining the number of commercial facilities and residential areas within the zones. Based on the characteristics of pedestrian traffic in Macau, three levels of buffer zones were established: a core service zone of 200 m, an extended service zone of 400 m, and a radiation service zone of 800 m. The hierarchical buffer radius was formulated by combining Macau's urban spatial characteristics and the service attributes of pawnshops, with reference to the research on commercial service radius in similar high-density cities such as Hong Kong and Singapore: (1) the 200 m core service circle is the immediate walking range for gamblers to obtain emergency financial services, covering the dense business areas around casinos and commercial centers with the highest foot traffic; (2) the 400 m extended service circle expands to the surrounding residential and commercial mixed areas, meeting the emergency pawn needs of local residents and small merchants, and matching the scale of a single street block in Macau; (3) the 800 m radiation service circle basically covers the core functional area of a single freguesia in Macau, reflecting the maximum radiation scope of pawnshops under pedestrian traffic dominance, and can effectively identify the service gap of pawnshops in peripheral areas. This multi-level service range system was constructed, and the number of POIs (Points of Interest) in commercial centers and residential areas within each buffer zone was counted. The demand matching degree between the number of commercial facilities, residential areas, and pawnshops was calculated.

3.3. Research Process

The research roadmap for this study is shown in Figure 3. We followed a progressive logical framework of "literature foundation-spatial analysis-results interpretation-summary and induction". First, through a systematic literature review and integration, we traced the historical evolution of pawnshop architecture in Macau, policy changes, differences in characteristics between domestic and international pawnshops, and existing research findings on site selection, laying a theoretical foundation for subsequent empirical analysis. Second, starting with spatial distribution characteristics, we used quantitative methods such as spatial accessibility analysis (integration, angular connectivity value) and spatial distribution characteristic analysis (kernel density estimation, buffer analysis) to accurately characterize the spatial pattern and morphological features of pawnshop architecture in Macau. Based on this, we further conducted in-depth analysis and discussion of the results, focusing on core issues such as the path dependence continuation dilemma, spatial imbalance of service radius, and policy site selection norms. Finally, by summarizing and inducing, we formed research conclusions, clarified research limitations, and looked forward to future research directions, thus constructing a complete research loop from theoretical review to empirical verification and mechanism explanation.

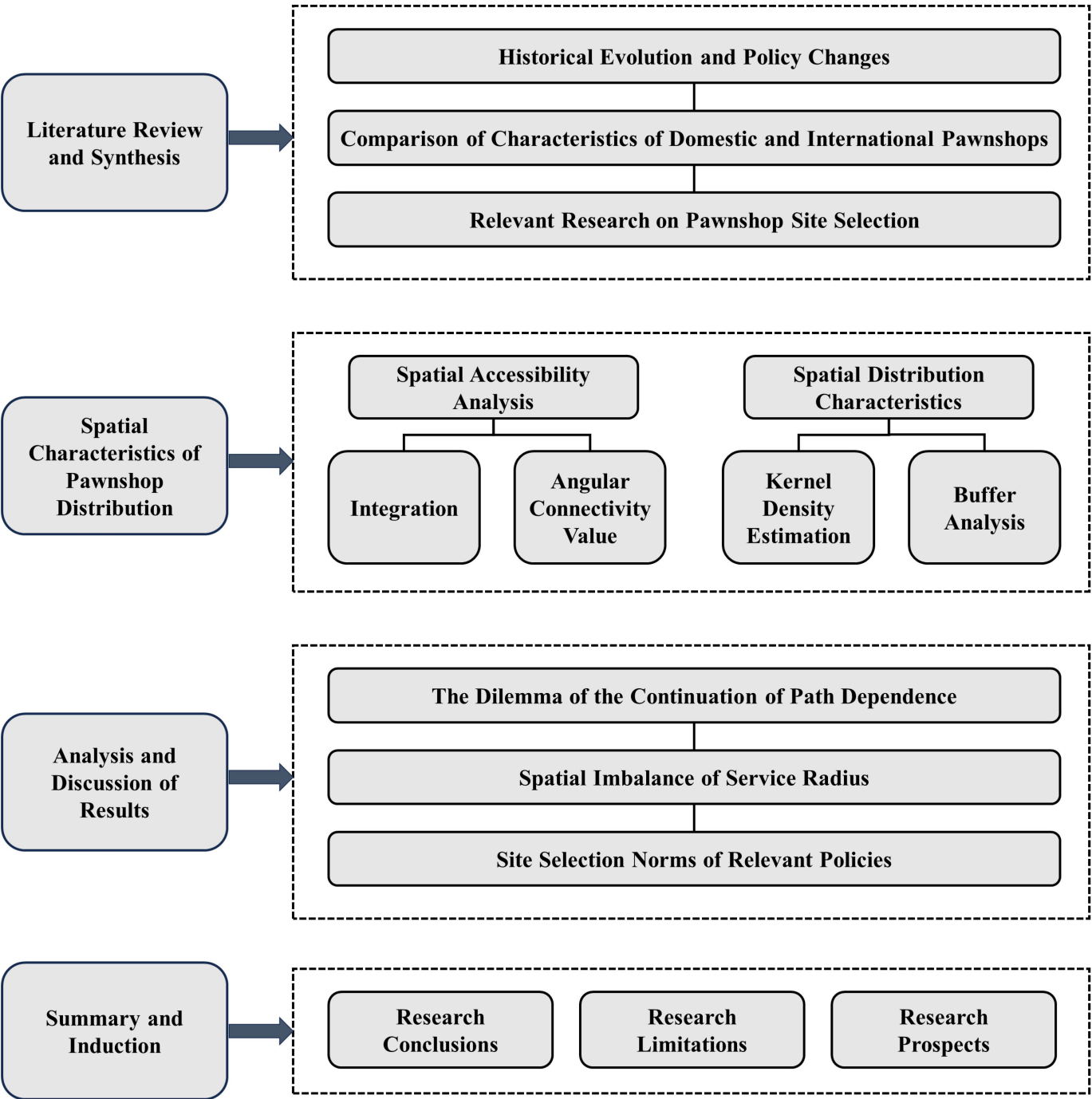


Figure 3. Research process in this study.

3.4. Data Sources and Processing

3.4.1. Data Sources

Basic data on pawnshop buildings comes from the *Macau Statistical Yearbook* published by the Statistics and Census Service of Macau, including attribute information such as pawnshop names and registered addresses. Parish boundary data originates from the *Macau Freguesia Division Standards* officially published by the Municipal Affairs Bureau of Macau (IACM). The base map of the study area uses high-resolution remote sensing imagery from Google Earth (<https://earth.google.com/web/>, accessed on 16 December 2025) in the second quarter of 2024. Casino and commercial center POI data was crawled from open platform APIs such as AMaps (<https://www.amap.com/>, accessed on 16 December 2025), and Baidu Maps (<https://map.baidu.com/@12646005,2515705,13z>,

accessed on 16 December 2025) using Python (version 3.14.3). The short update cycle and high timeliness of data from online platforms, along with the inclusion of core information such as the name, coordinates, and type attributes of geographic entities, necessitated the manual verification of duplicate, canceled, and erroneous points to ensure high-quality basic data support for the research. The processed location data of Macau pawnshop buildings is in the Supplementary Materials.

3.4.2. Data Processing Methods

To adapt to the needs of space syntax and ArcGIS analysis, the data was standardized. Through address matching and name comparison, records of canceled, closed, and duplicate pawnshops were removed. All spatial data was uniformly converted to the WGS84 coordinate system to eliminate coordinate deviations from different data sources, ensuring the accuracy of spatial overlay analysis. Commercial center POIs were normalized according to business type, merging similar business types such as “shopping malls,” “commercial complexes,” and “department stores” to provide a unified standard for service radius analysis.

All spatial analysis layers in this study were standardized and unified to the WGS84 geographic coordinate system (EPSG: 4326) to ensure the accuracy of spatial overlay and calculation. The key analysis layers used for KDE and buffer analysis include: (1) Pawnshop point layer: including attribute information such as name, registered address, and establishment period, with duplicate and canceled records removed; (2) Casino and commercial center POI layer: classified by business type (casino, shopping mall, retail store), with non-core POIs filtered out; (3) Macau freguesia boundary layer: official vector data from the Municipal Affairs Bureau of Macau; (4) Road network layer: restored historical road network (for initial/stable stages) and current road network (for prosperous stage), with unified grade classification. All layers were processed in ArcGIS 10.8 and DepthmapX (version 0.8), and the analysis workflow is consistent with the research process shown in Figure 3.

3.4.3. Differentiated Analysis Strategy by Period

During the initial stage (before 1961) and the stable stage (1961–2002), due to the scarcity of POI data, a combination of “space syntax + qualitative statistics” was adopted. Spatial morphology dependence characteristics were analyzed through integration degree and angular connectivity values, supplemented by historical documents and statistical data to provide industry background interpretation. During the boom period (2002 to present), a comprehensive approach of “space syntax + POI-GIS” was adopted. Based on topological analysis, the quantitative analysis of kernel density and buffer zones was strengthened to reveal the spatial coupling and service radius adaptability of pawnshops, casinos, and commercial centers.

4. Results

4.1. Space Syntax Calculation Results

4.1.1. Integration Analysis

The global integration level was low in the initial stage: the average value was only 198.735, and the highest value was 278.23. The overall spatial connectivity and accessibility were weak, and the red areas with high integration were scattered. Pawnshop buildings dispersed in a point-like pattern during this period, primarily concentrated in areas such as San Kio District, Rua de Cinco de Outubro, and Travessa do Auto Novo. Judging from the color tone of Figure 4, these areas are mostly yellow and green, indicating medium integration, but they are not the high-integration core areas shown in Figure 4. This char-

acteristic matches the stage of urban development at that time. Before 1961, the casino industry had not yet been scaled up, and pawnshop buildings, as traditional living facilities, were attached to the layout of streets and alleys where residents gathered and did not show a tendency to cluster in high-integration areas. They were a scattered layout tied to daily life.

During the stable period, the global integration level improved compared to the initial stage, averaging 402.351 and reaching a peak of 621.566. Urban spatial network connectivity strengthened, and the highly integrated red and orange areas began to concentrate in the core areas. Although Figure 5 does not show specific pawnshop locations, historical information indicates that 90% of pawnshops during this period were located near casinos. The Casino Macau Palace (Floating Casino in Inner Harbour), Kam Pek Casino (Golden Casino in City Center Avenue), and Casino Lisboa (Nam Van) at that time correspond precisely to the high and relatively high integration of core areas in Figure 5. Therefore, it can be inferred that during this period, pawnshop architecture departed from the traditional scattered layout of urban areas and began to cluster in highly integrated casino functional areas, demonstrating a clear trend of dependence on highly integrated core functional areas.

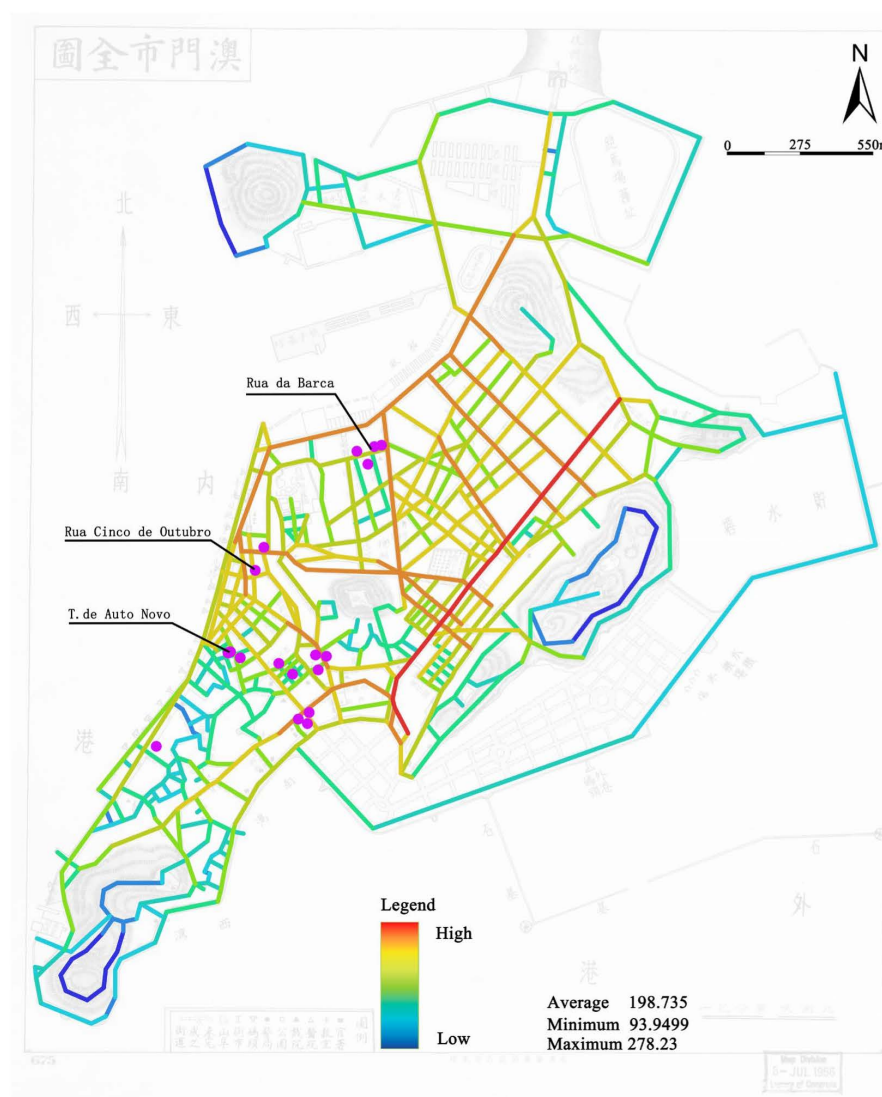


Figure 4. The global integration of Macau and the distribution of pawnshop buildings in the initial stage. The background map references historical maps of Macau, and the relevant Chinese text displays major city landmarks or reference locations at that time.

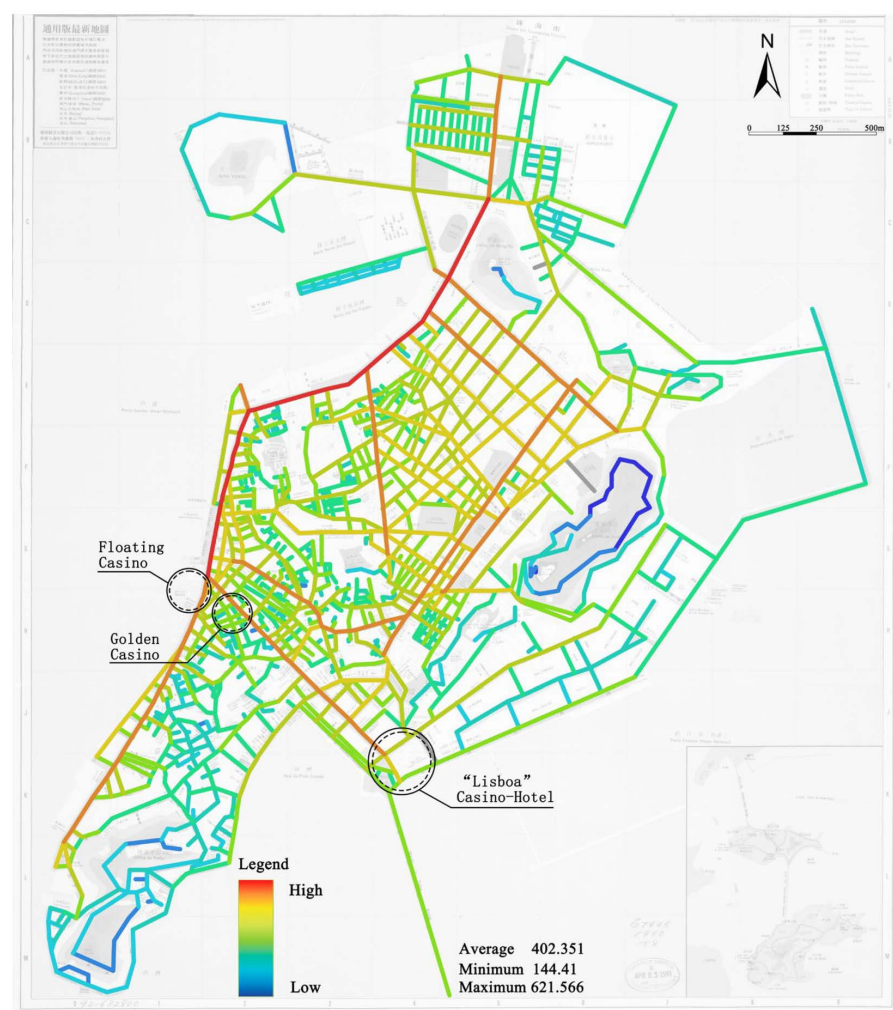


Figure 5. The global integration of Macau and the distribution of pawnshop buildings in a stable stage. The background map references historical maps of Macau, and the relevant Chinese text displays major city landmarks or reference locations at that time.

During the prosperous development period, the global integration score surged, averaging 3017.88 and peaking at 4412.60, reflecting a high-dimensional stage in the connectivity and accessibility of Macau's urban space. The highly integrated red areas formed a dense core network. Pawnshop buildings from this period are marked with diamond-shaped points, concentrated in the highly integrated red areas and surrounding zones shown in Figure 6, such as the densely populated area A in the upper part and the central core area B. These areas are precisely the main distribution zones of contemporary casinos, and the pawnshop building locations overlap with the highly integrated areas. The data indicates that the clustering trend of pawnshops during the boom period was highly strengthened, completely bound to the highly integrated core functional area layout. This design reflects the deep coupling between the city's core space and the gaming-related industries, with a very clear spatial orientation for the clustering.

From a global integration perspective, the values gradually increased across the three periods, reflecting the continuous enhancement of connectivity and accessibility of Macau's urban space. Highly integrated areas evolved from scattered localized zones into a dense core network. In the beginning, pawnshop buildings were spread out and connected to traditional market areas in a way that was not too obvious. There was no clear clustering trend. During the stable period, they moved away from the traditional layout and toward attaching to highly integrated casino areas, which started a trend of cluster-

ing. During the prosperous period, a complete integration with highly integrated core functional areas occurred, resulting in a strengthened clustering trend. Overall, the distribution of pawnbroking establishments has maintained a positive correlation with street integration degree. The spatial alignment degree between pawnshop distribution and street integration degree shows a gradient change, with a relatively weak alignment in the initial phase, a moderate alignment in the stable phase, and a particularly close alignment in the prosperous phase. Amid the increasing complexity of Macau's urban spatial structure, this correlation intensity fluctuates slightly, yet the core underlying logic of the relationship remains unaltered. This evolution reflects both Macau's functional transformation from a traditional market city to a gaming hub city and the shift in the layout logic of pawnshop buildings from serving the public to a highly integrated space attached to core industries.

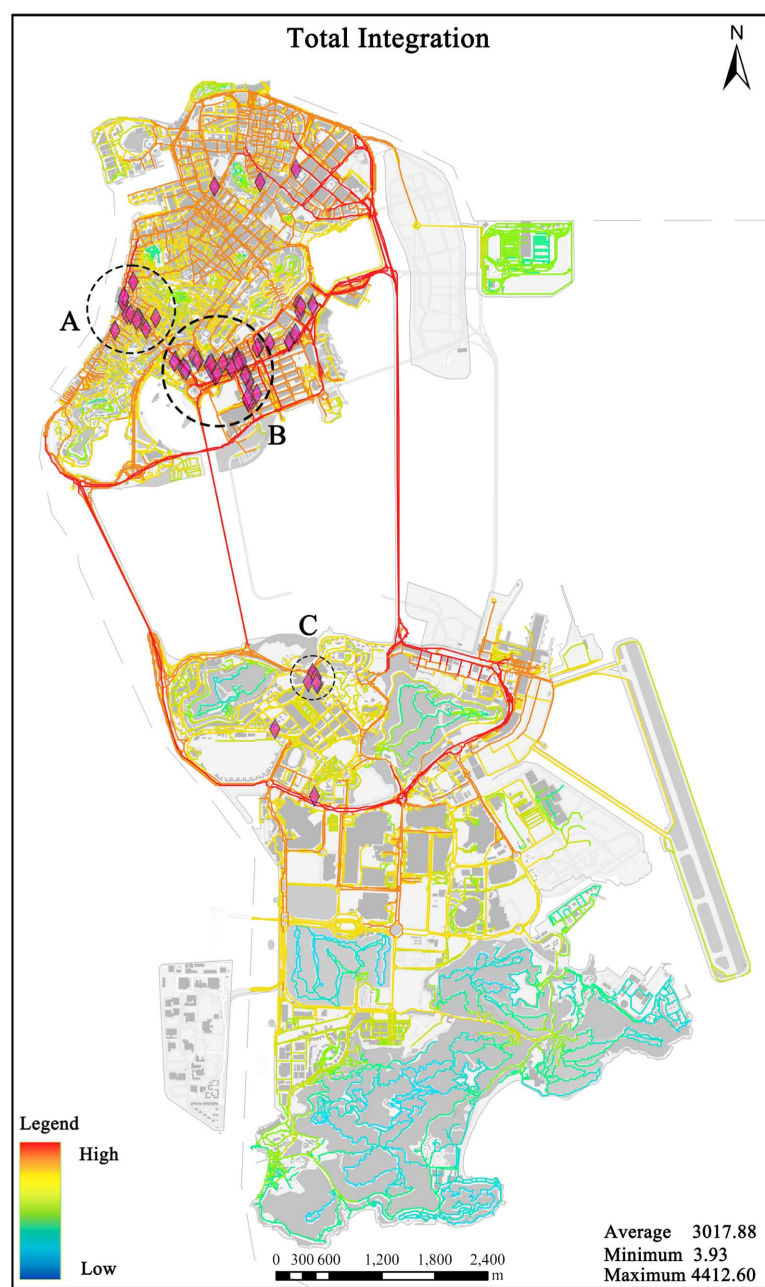


Figure 6. The global integration of Macau and the distribution of pawnshop buildings in prosperous development stage.

4.1.2. Connectivity Value Analysis

In their early stages, pawnshops in Macau were mainly scattered throughout traditional districts such as San Kio District, Rua de Cinco de Outubro, and Travessa do Auto Novo. As shown in Figure 7, these areas, predominantly yellow-green in color gradation, represent medium-to-high connectivity value nodes. These were densely populated traditional commercial and residential areas in Macau at the time, with low traffic resistance. During this period, the gaming industry was not yet large-scale, and pawnshop buildings were not deeply integrated with casinos. Instead, they relied on the high-connectivity nodes formed by traditional streets and alleys. These areas were the core circulation routes for citizens' daily activities, and low traffic resistance ensured customer accessibility. In terms of spatial coupling, the pawnshop locations and the high-angle connectivity value nodes of traditional commercial districts were distributed. Each pawnshop was embedded in a convenient area of its street; its dependence on traditional low-resistance nodes for daily life did not form a centralized spatial connection but rather adapt to the daily traffic needs of each district through a dispersed layout.

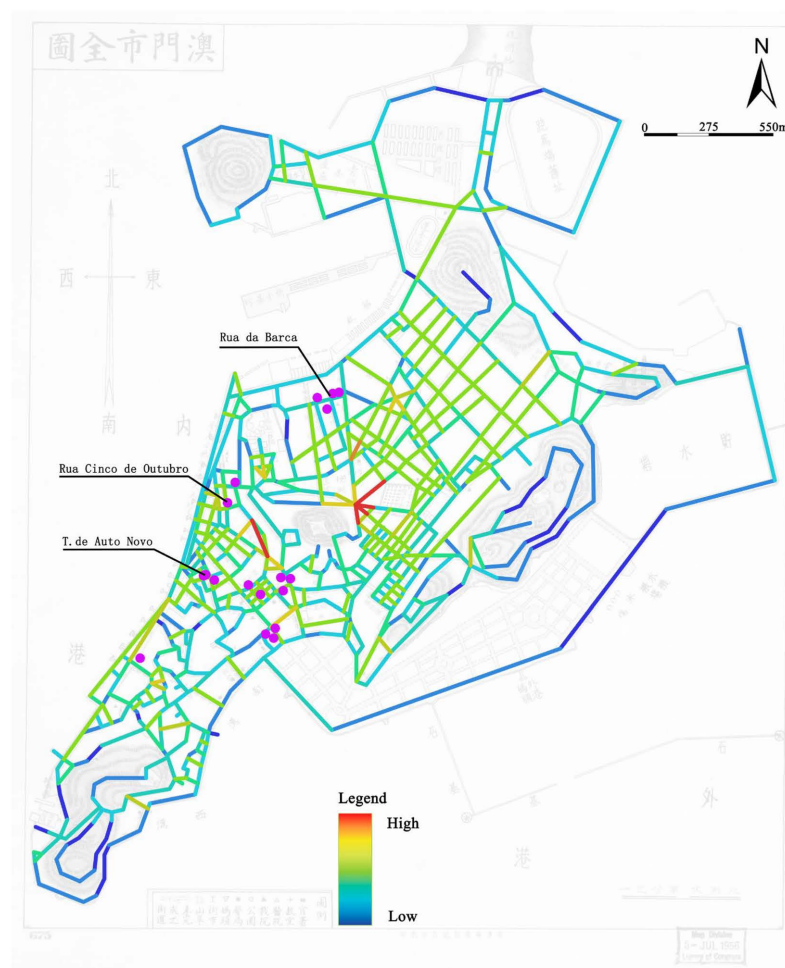


Figure 7. Initial phase of Macau's angular connection values and pawnshop building distribution points. The background map references historical maps of Macau, and the relevant Chinese text displays major city landmarks or reference locations at that time.

During the stable period, as shown in Figure 8, areas where casinos were located, such as Nam Van, exhibited high-connectivity values (red and yellow), indicating they were high-connectivity nodes in the city's traffic flow at the time, with lower traffic resistance than other areas. After the legalization of gambling in this phase, casinos be-

came the core of urban traffic flow. Pawnshops shifted their locations to high-connectivity nodes surrounding casinos. The high density of people at casinos, along with the low traffic resistance of these nodes, meets gamblers' temporary financial needs and reduces arrival costs for customers due to the nodes' high connectivity. Pawnshop buildings and the high-connectivity nodes, where casinos were located, formed a bound relationship in terms of spatial coupling. The dependence upgraded to relying on casino traffic and high-connectivity, low-resistance nodes. Spatial concentration increased compared to the initial stage, forming a layout logic centered around the core traffic carrier.

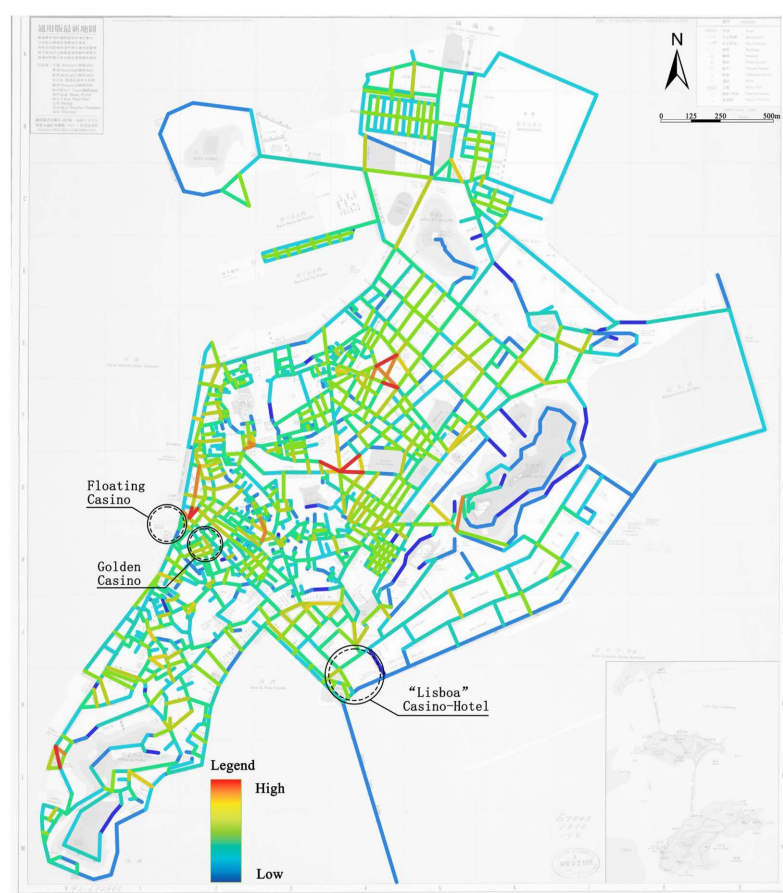


Figure 8. Stable phase of Macau's angular connection values and pawnshop building distribution points. The background map references historical maps of Macau, and the relevant Chinese text displays major city landmarks or reference locations at that time.

As shown in Figure 9 from the prosperous period, the diamond-shaped points representing the locations of pawnshop buildings are concentrated in the high-angle connectivity areas of green and yellow tones, such as areas A and B. These areas are the core of modern Macau's commerce, gaming, and transportation, including the newly expanded casino clusters. High-angle connectivity nodes indicate better connectivity and accessibility of the road network, with low traffic resistance throughout the day. During this stage, the gaming industry expanded on a large scale, further optimizing the urban road network, resulting in denser and more concentrated high-connectivity nodes. In terms of spatial coupling, pawnshop locations are highly concentratedly matched with modern high-integration nodes, covering both the high-traffic demand of the casino clusters and leveraging the low-resistance characteristics of the modern road network to achieve rapid arrival of customers from across regions. The degree of dependence deepens into a deep binding with modern high-connectivity, low-resistance nodes, with the tightness and

concentration of spatial association reaching their peak and the layout entirely revolving around the low-resistance traffic nodes in the city's core.

This reveals that the spatial alignment relationship between the site selection of pawnshop buildings and high-angle connectivity nodes in the three periods evolves from dispersed adaptation to bound association and then to highly concentrated matching, with a continuously increasing dependence on low-traffic-resistance nodes. In the initial stage, it relied on traditional residential low-resistance nodes with dispersed coupling and loose association, adapting only to daily street-level traffic. In the stable stage, it relied on casinos and highly connected low-resistance nodes, with coupling shifting from dispersed to concentrated, and bound to a single traffic carrier. In the prosperous stage, it relied on modern, highly integrated low-resistance nodes, with highly concentrated coupling and tight association, that adapted to large-scale comprehensive traffic. The underlying logic is that the core functions of the city have shifted from traditional life to gambling traffic and then to modern comprehensive services, and the attributes of low-traffic-resistance nodes have upgraded accordingly. As a dependent business, the dependence of pawnshop buildings on low-resistance nodes in their site selection has continuously strengthened with the iteration of the city's core traffic carriers.

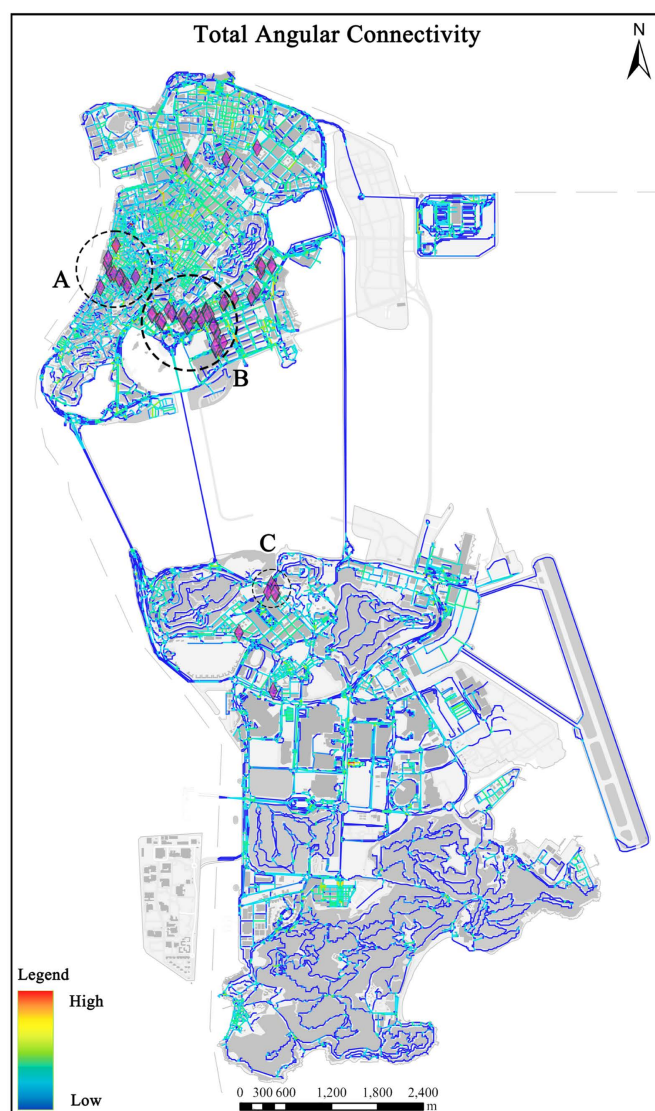


Figure 9. Prosperous phase of Macau's angular connection values and pawnshop building distribution points.

4.2. GIS Analysis Results

4.2.1. Kernel Density Analysis

In its early stages, the gaming industry had not yet become dominant. The city's economy was mainly based on traditional commerce, handicrafts, and daily services for residents. The layout of pawnshops was tailored to local living needs. In Macau's narrow alleyways, which averaged 5 m wide, pawnshops were scattered and embedded in densely populated residential areas and commercial streets, serving the daily small-amount pawning needs of residents, such as clothing and small appliances. At this time, the agglomeration did not have obvious industrial dependence; it only formed small, scattered clusters around traditional living spaces, without forming large-scale agglomeration areas. The spatial distribution was characterized by its integration within the urban landscape. The core area highly overlapped with the city's traditional living network, and no independent pawnshop building clusters appeared.

Following the legalization of gambling in 1961, a stable period saw the core clusters of pawnshops relocate to the vicinity of casinos. It was determined that 90% of pawnshops were located within a 300 m radius of Casino Macau Palace (Floating Casino in Inner Harbour), Kam Pek Casino (Golden Casino in City Center Avenue), and Casino Lisboa (Nam Van), covering approximately six 50 m wide blocks. During this phase, gambling became a pillar industry, and the temporary, large-amount pawning needs of gamblers, such as jewelry and watches, replaced local daily needs, becoming the core customer base of pawnshops. Spatially, pawnshop buildings moved from traditional street blocks to the streets and alleys surrounding casinos, forming casino-dependent clusters based on casino foot traffic. Small clusters of pawnshops formed within 300 m of each casino. However, because casinos were located as single points, each cluster was relatively independent and not contiguous. The relocation trajectory reflects the single-point clustering characteristics oriented towards the gambling industry, with the core area almost entirely tied to the spatial layout of the early casinos.

As shown in Figure 10 of kernel density, the core clustering of pawnshop buildings during the prosperous period exhibited a “dual-core contiguous clustering” characteristic. High kernel density was concentrated in the traditional casino cluster area of Nam Van-Zona de Aterros do Porto Exterior (Z.A.P.E) on the peninsula and the new gaming complex cluster area in Cotai, both forming contiguous high-density areas within a 300 m radius. After the opening of gaming operating licenses in 2002, the gaming industry upgraded to large-scale complexes. For example, the Venetian and Galaxy in Cotai saw a surge in foot traffic and spending power. Pawnshops were embedded in the commercial road network consisting of 50 m wide blocks surrounding these complexes, not only relying on the casinos but also supporting the commercial clusters. In terms of spatial transfer trajectory, the area expanded from single casino perimeters during the stable period to a dual-core cluster of traditional casino clusters and new gaming complex clusters. The contiguous layout of these complexes created a large-scale cluster, which led to pawnshops in traditional market areas largely withdrawing from the core area, reflecting a clustering pattern that is oriented towards gaming complexes.

Figure 11 illustrates the polarization and high concentration of pawnshops in Macau. Looking at the distribution, Freguesia da Sé dominates with 71 pawnshops, making it the area with the highest density of pawnshops in Macau. The Freguesia de Nossa Senhora de Fátima and the Freguesia de Santo António each have only two pawnshops. Freguesia de São Lourenço has 6, and Freguesia de Nossa Senhora do Carmo has 10. These numbers are lower than those in Freguesia da Sé, and Freguesia de São Lázaro and Freguesia de São Francisco Xavier have zero pawnshops. This difference stems from the divergence in the functional positioning of pawnshops. Freguesia da Sé is Macau's traditional

commercial core area, where the superimposed commercial centers (POIs) in Figure 12 are highly concentrated. The dense shops and office buildings generate foot traffic and commercial demand. Local merchants' temporary cash flow needs and tourists' urgent need for liquid assets provide a stable customer base for pawnshops. In contrast, areas like Freguesia de Nossa Senhora de Fátima are more residential, with lower commercial activity. Freguesia de São Lázaro and Freguesia de São Francisco Xavier primarily serve cultural and leisure functions, lacking the high-frequency financial needs required to support pawnshops; therefore, pawnshops are extremely rare or even nonexistent there.

Furthermore, the density of pawnshop buildings exhibits a close spatial alignment with the POIs of casinos and commercial centers (Figure 12). Freguesia da Sé is both a commercial hub and one of the areas with the highest concentration of casino facilities in Macau. The high mobility of people brought by casinos, such as tourists and gamblers, often creates temporary cash flow needs. The dense commercial activity also increases the demand for emergency cash by merchants and consumers, continuously activating the demand for pawnshops in Freguesia da Sé, thus increasing the density of pawnshops. Quantitatively, the distribution of pawnshop buildings in Freguesia da Sé overlaps with the areas covered by casinos and commercial centers by over 80%. The casino and commercial center POIs of Freguesia de Nossa Senhora de Fátima and Freguesia de Santo António are less than 10% of those in Freguesia da Sé, and the number of pawnshops there is only about 3%. Although Freguesia de Nossa Senhora do Carmo has a small number of commercial facilities, it lacks the support of large-scale casinos, and the number of pawnshop buildings is only 14% of that in Freguesia da Sé. This data confirms the emergency financial service nature of pawnshops. Their survival is highly dependent on the flow of people and the demand for capital turnover in core consumption scenarios. The denser the consumption scenarios, the higher the spatial concentration and scale of pawnshops.

4.2.2. Buffer Zone Analysis

The 200 m radius represents the core service radius of pawnshops, focusing on the densest concentrations of immediate consumption and commercial foot traffic. There are a total of 91 pawnshops in Macau (Figure 13, Table 1). This radius encompasses 32 commercial centers and 779 residential areas, averaging approximately 0.35 commercial centers and 8.56 residential areas per pawnshop. Spatially, the 200 m radius of the 71 pawnshops in Freguesia da Sé concentrates the vast majority of the 32 commercial centers, demonstrating a high degree of integration between pawnshops and commercial facilities in the core commercial area. The foot traffic in the commercial centers provides strong transaction demand for pawnshops, which in turn supplement the service types available in the core area. However, the relatively small number of residential areas within this radius indicates that the pawnshop customer base is primarily commercial foot traffic, supplemented by permanent residents, aligning with the core commercial positioning of Freguesia da Sé. In contrast, in non-core areas, such as the 200 m radius of the two pawnshops in Freguesia de Nossa Senhora de Fátima, there is almost no commercial center coverage, indicating a supply–demand imbalance due to insufficient commercial facilities.

The 400 m radius represents the secondary service radius of the pawnshops, incorporating more resources as the coverage expands. Within this radius, the number of commercial centers has increased to 34 and residential areas to 1627. The matching rate of commercial centers is 5.7% higher than the 200 m radius, and the matching rate of residential areas has doubled. The addition of only two commercial centers indicates that new commercial facilities are still concentrated within the 200–400 m range of the Freguesia da Sé pawnshops, and the commercial facilities for pawnshops in non-core areas have not improved. The substantial increase in the number of residential areas signifies that the pawnshops'

customer base has expanded from purely commercial foot traffic to surrounding residents. For example, the residential coverage within the 400 m radius of pawnshops like Freguesia de Nossa Senhora de Fátima and Freguesia de São Lourenço strengthens their residential service attributes. However, the 400 m radius of the Freguesia da Sé pawnshops remains primarily commercial, while non-core areas exhibit a supply–demand structure with ample residential space but weak commercial facilities.

Table 1. Comparison of demand matching degree within different radii of Macau during its prosperity period.

Radius Range	Number of Commercial Centers	Number of Residential Areas	Commercial Center—Pawnshop Ratio	Residential Area—Pawnshop Ratio
200 m	32	779	0.35	8.56
400 m	34	1627	0.37	17.88
800 m	37	3227	0.41	35.46

Source: Statistics compiled by the authors.

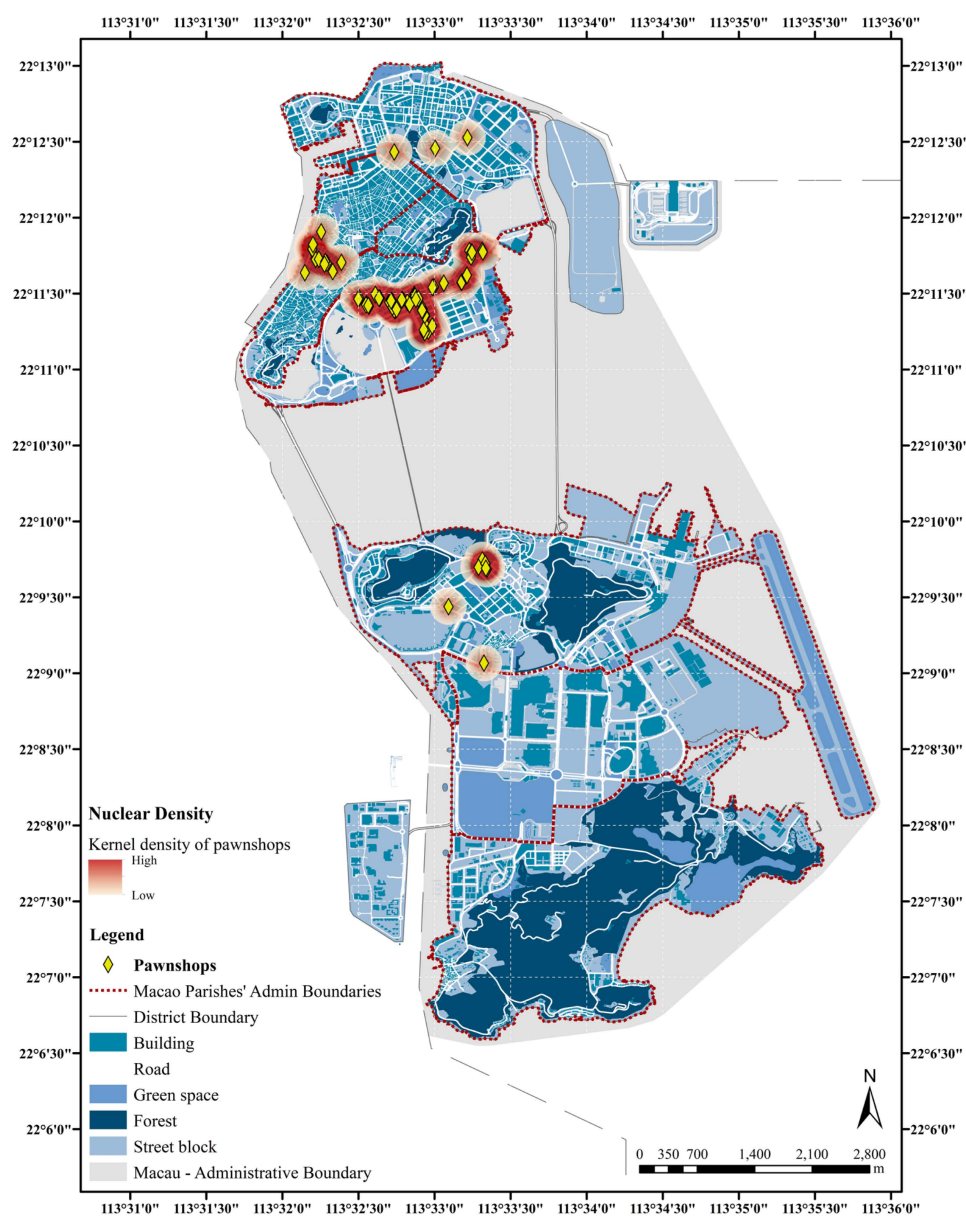


Figure 10. Kernel density analysis of pawnshop buildings in Macau during its prosperous period.

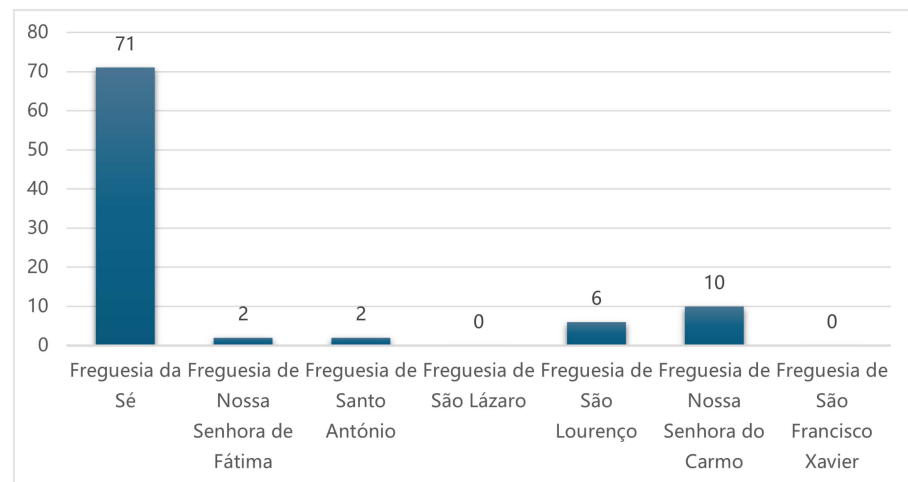


Figure 11. Statistics on the number of pawnshops.

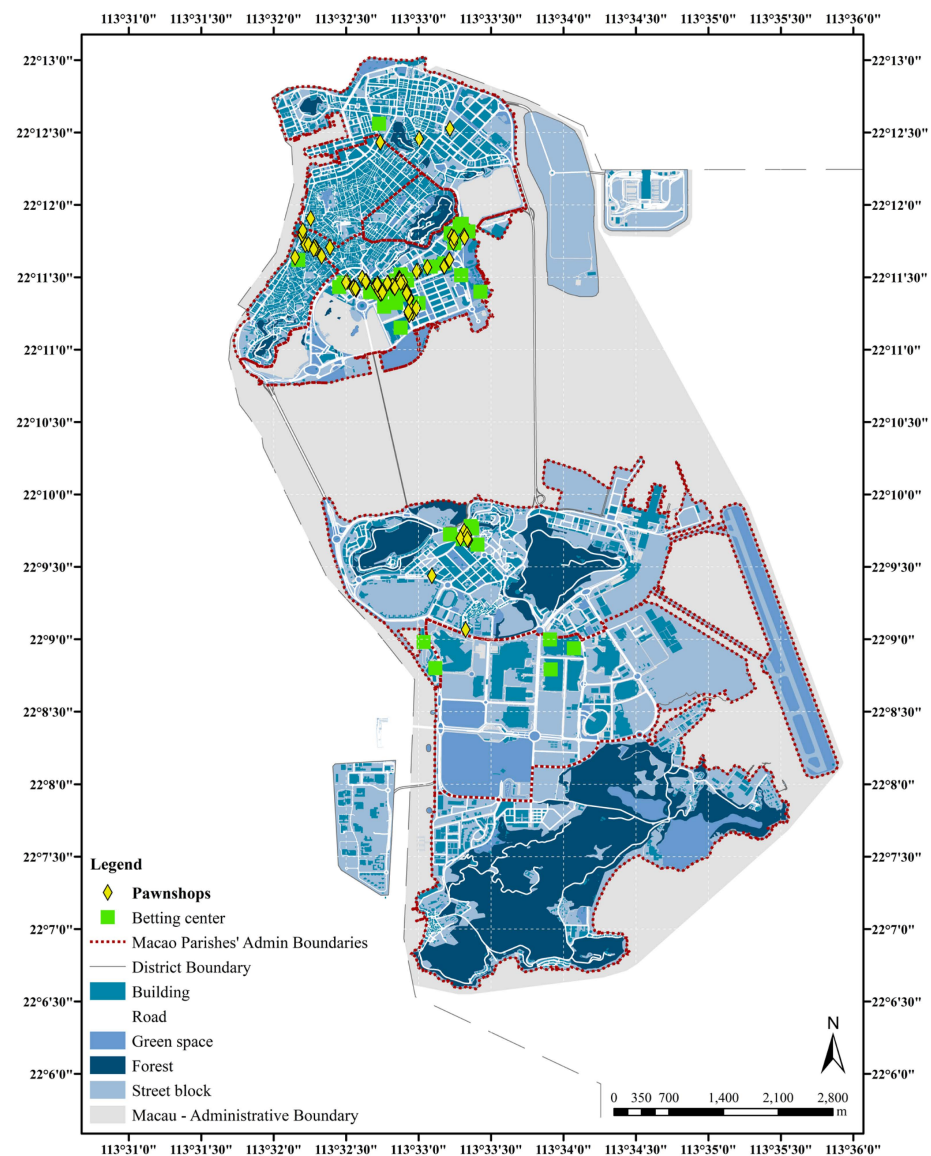


Figure 12. During the prosperous development period, the density of pawnshops in Macau overlapped with the distribution of points of interest (POIs) in casinos and commercial centers.

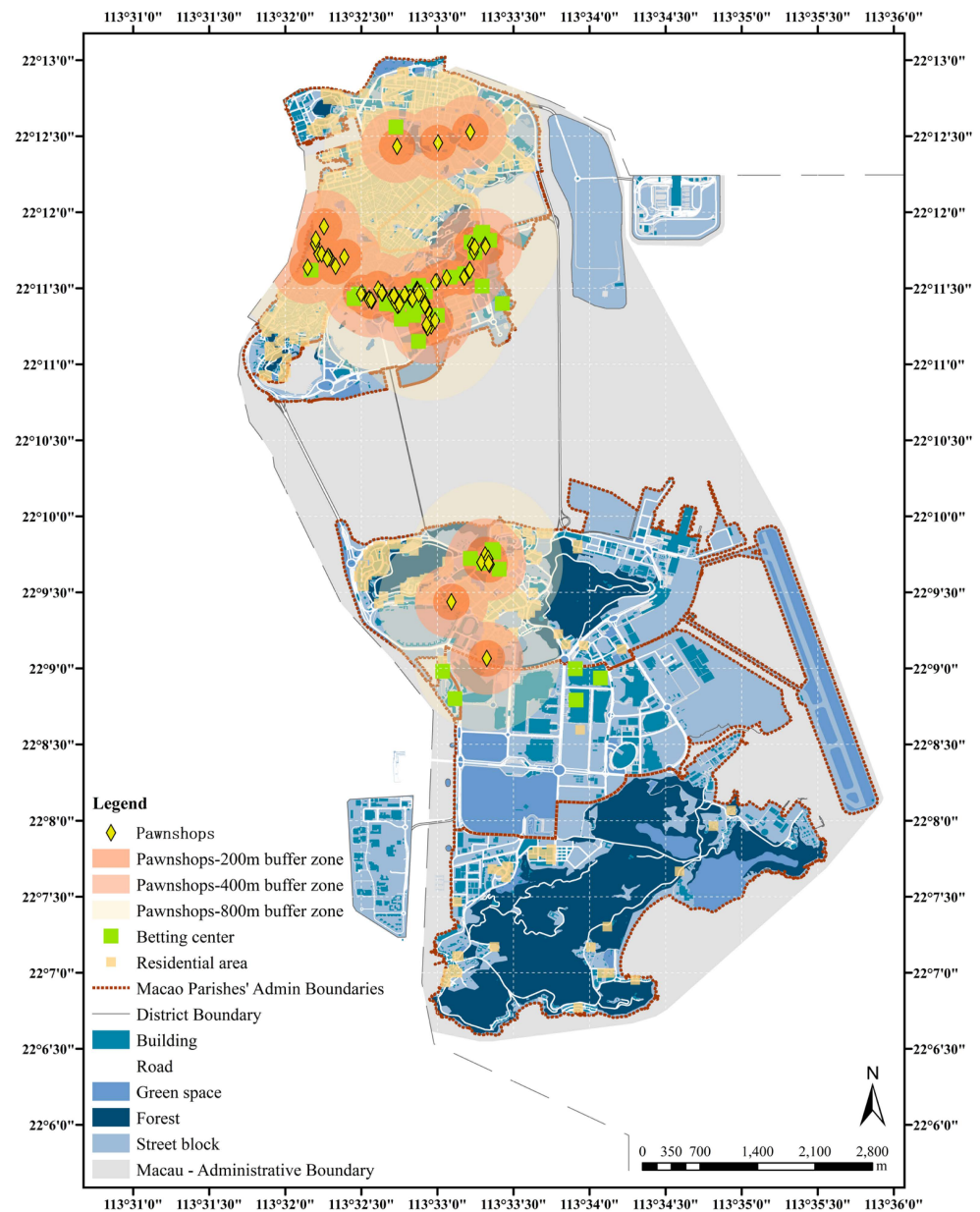


Figure 13. During the prosperous period, the three-tiered buffer zones of Macau's pawnshops overlapped with the POI distribution of commercial centers and residential areas.

The 800 m radius represents the maximum service radius of pawnshops, essentially covering the main functional spaces of the area. Within this radius, there are 37 commercial centers (92.5% of all pawnshops in Macau) and 3227 residential areas (96.7% of all residential areas in Macau). The matching rate of commercial centers is 10.8% higher than that of the 400 m radius, and the matching rate of residential areas is more than double that of the 400 m radius. At this point, most commercial and residential resources are covered, and the 800 m radius of pawnshops in non-core areas supplements the commercial facilities, achieving dual coverage of both commercial and residential areas. However, the Freguesia da Sé pawnshop still exhibits a high concentration of commercial businesses and a low proportion of residential businesses. Furthermore, the Freguesia de São Lázaro and Freguesia de São Francisco Xavier, with zero pawnshops, lack coverage of commercial and residential needs within their 800 m radius, resulting in service gaps.

5. Discussion

5.1. The Persistent Dilemma of Path Dependence

The research conclusions reflect the coupling effectiveness from a dual-dimensional perspective: (1) From the perspective of distribution characteristics, the spatial shift of pawnbroking establishments from traditional commercial blocks to the gaming core area in Macau verifies the transformation of the city's urban functions from a trading port to a gaming and tourism city. Kernel density analysis reveals that the spatial overlap between pawnbroking establishments, casinos and commercial centers exceeds 80%, which reflects the supporting role of urban space in underpinning core industries. (2) From the perspective of service radius, the matching degree between the three-tier service radius system and urban population density as well as commercial vitality—evidenced by the coverage of 32 commercial centers within a 200 m radius in the core area—embodies the dynamic balance between supply and demand in urban space, whereas service gaps in peripheral areas reveal the issue of functional lag amid urban spatial expansion.

The space syntax analysis above reveals that the location selection of pawnshops in Macau has undergone a path evolution from traditional suburban affiliation to clustering around casinos and then to deep integration with the core gaming area. This path dependence presents a double-edged sword effect in the current industry development. On the one hand, during prosperous periods, the overlap between pawnshops and highly integrated gaming core areas exceeded 80%, forming a stable symbiotic model of gambling and pawnshops. According to data from *Macau Economic Yearbook 2024*, the average monthly transaction volume of pawnshops around casinos was 3–5 times higher than that in non-core areas, confirming the economic rationality of path dependence. On the other hand, this dependence leads to a weak ability to withstand risks in the industry. During the fluctuation of Macau's gaming revenue in 2023, some pawnshops in the Cotai casino cluster closed down due to a decline in customer traffic, exposing the structural risks of relying on a single industry (Figure 14). Data from the Statistics and Census Service of the Government of Macau Special Administrative Region shows that Macau's total retail sales in 2024 fell by 14.9% year over year to MOP 71.99 billion. Among the major retail sectors, sales of watches and jewelry, leather goods, and department stores decreased by 25.3%, 22.6%, and 18.6% year over year, respectively. The data indicates that the decline in young gamblers and changing consumption habits have led to a customer gap for pawnshops around traditional casinos, while older pawnshops in traditional districts like Avenida de Almeida Ribeiro have maintained a stable customer base due to their preservation of essential services. Future site selection needs to break free from path-dependent limitations. While continuing the layout of the core gaming area, it is crucial to leverage traditional commercial nodes along historical pathways to revitalize businesses that combine public services with cultural displays, such as the revitalization model of the Tak Seng On Pawnshop Museum, thus achieving a creative transformation from path-dependent practices.

5.2. Spatial Imbalance of Service Radius

The preceding GIS buffer zone analysis revealed an imbalance in the service radius of pawnshops in Macau: an over-density core area and a lack of coverage in peripheral areas. A 200 m core service circle concentrates 90% of the 32 commercial centers, while areas like the North District and Coloane lack pawnshop coverage within an 800 m radius. Following the liberalization of Macau's gaming industry, the space surrounding casinos underwent dramatic restructuring, particularly in core areas like the old casino district from Rua de Pequim to Avenida da Amizade and the new gaming complex clusters in Cotai. The original everyday services for residents, such as grocery stores, tailor shops, and restaurants serving diverse cuisines, were gradually replaced by pawnshops and currency

exchange points catering to gamblers, creating a strong spatial link between casinos and pawnshops [26].

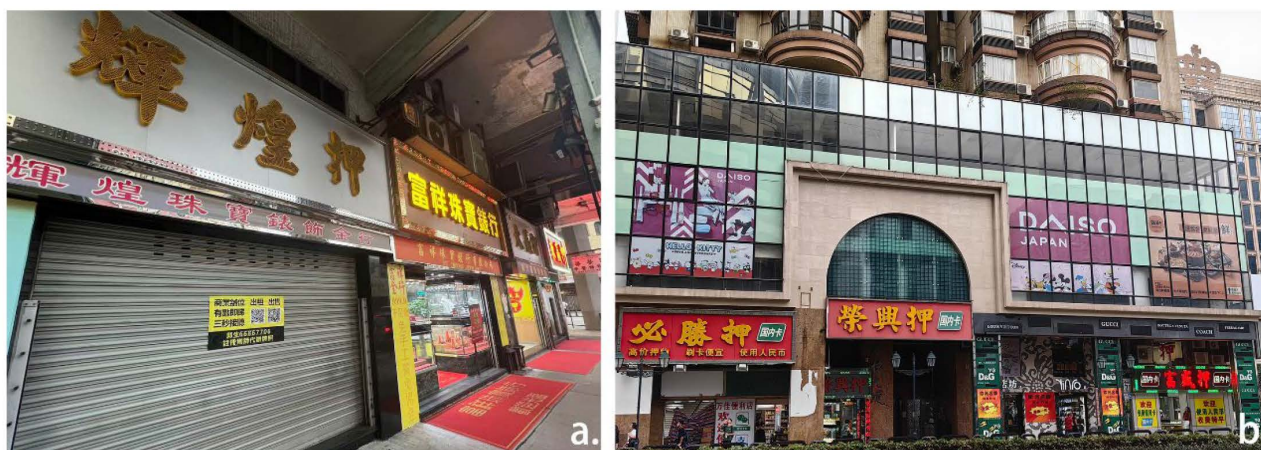


Figure 14. Some stagnant modern pawnshops. (a) The current state of pawnshops across the street from the Inner Harbour casinos, some of which have been closed down, been transferred, or are being rented out. (b) The pawnshop business in traditional tourist districts attached to residential areas. The Chinese characters shown in the photo are either the name of a pawnshop sign or a shop. They have no specific meaning.

The current inadequacy of the service radius stems from both the casino-oriented site selection logic and a lack of synchronization with urban spatial expansion. While the population of emerging residential areas like the Cotai reclamation area has increased by 37%, the pawnshop layout has lagged behind. Simultaneously, the service radius coverage gap in peripheral residential areas continues to widen, directly related to the city's shift towards a tourist-oriented model. Zandonai mentioned that 64% of tourists to Macau come from Chinese mainland, and casinos and surrounding services are entirely designed around the needs of tourists, while the service needs of traditional residential areas such as the North District and Coloane are seriously neglected. Referring to international experience, pawnshops in Germany are laid out with a density standard of “50,000 people/shop” [18]. The reasonable service radius of the current 91 pawnshops in Macau should cover all seven Freguesias in Macau.

In the future, a three-level service radius system needs to be built: (1) the core gaming area should retain a high-density layout of 200 m to meet the needs of instantaneous funds; (2) new residential areas should add community-type pawnshops with a 400 m extended service circle to cover the emergency needs of residents; (3) the historical city should integrate traditional pawnshop resources with an 800 m radiation circle to take into account cultural tourism consumption and people's livelihood services. At the same time, through digital means such as mobile assessment points and online appointments, the service gaps in peripheral areas can be filled to balance accessibility and layout density.

5.3. Site Selection Guidelines Based on Relevant Policies

The literature review above points out that Macau's pawnshop industry lacks specific regulations and relies on general commercial laws for oversight. This policy gap has led to multiple problems in the site selection process. Some pawnshops are illegally located on the ground floor of residential areas, causing complaints due to noise and safety issues; some pawnshops in Cotai do not meet security standards but are adjacent to casinos, posing a money-laundering risk. Macau should now issue relevant regulations for the pawnshop industry as soon as possible, clarifying requirements such as safe distances and business-type restrictions for site selection. Based on the spatial alignment characteristics

analyzed above, future site selection needs to establish a dual standard of policy compliance and risk control. First, it should strictly adhere to the provisions of the proposed regulations to avoid policy risks. Second, referencing the spatial coupling pattern of a “pawnshop–casino–commercial center” in core areas, and prioritizing high-angle connecting nodes, such as the area around the Taipa Ferry Terminal, while ensuring compliance, will guarantee passenger accessibility and reduce security risks. Simultaneously, drawing on Singapore’s integrated model of pawnshop industry regulatory registration and regional planning [16], a pre-assessment mechanism for pawnshop site selection should be established, incorporating service radius coverage and compliance into the admission criteria to achieve a standardized layout.

6. Conclusions

The value of this study lies primarily in its theoretical and practical dimensions. Theoretically, through quantitative analysis using space syntax and GIS, it systematically traces the evolution of pawnshop architecture in Macau from its traditional trading era to its modern gaming era. It reveals the formation mechanism of path dependence and the spatiotemporal evolution of service radius, filling a gap in existing research on spatial quantitative analysis in this field, enriching research findings on spatial alignment relationship between peripheral financial industries and urban spatial structure, and providing a methodological reference for spatial research on similar characteristic financial industries. Practically, the study clarifies the revitalization potential of traditional pawnshop architectural heritage, providing direction for the integration of its cultural and economic values. The quantitative service radius data and layout optimization suggestions can provide a scientific basis for the site selection planning of modern pawnshops; the proposed normative ideas addressing policy and regulatory gaps can also support industry risk prevention and orderly development.

However, this study still has some limitations. In terms of data, the lack of POI data during the initial and stable periods prevented unified quantitative analysis across all periods. Some conclusions rely on historical documents and qualitative inferences, which to some extent affected the depth and accuracy of the analysis. This study adopts a dynamically evolving whole-region research scope. While this approach aligns more closely with the actual process of urban development, it also entails a limitation in that the research scopes across different phases are not fully comparable. Angular integration value is employed as a proxy indicator for traffic flow in this study. Though it can reflect potential traffic demand, it cannot fully replace actual traffic flow data. Future research may integrate on-site monitoring data to further validate the findings derived from the research model. From a research perspective, while focusing on spatial location characteristics, there is insufficient exploration of the deep interaction between non-spatial factors, such as economic cycle fluctuations and changes in consumer demographics and location evolution. The analysis of service radius is primarily based on static spatial data, with insufficient consideration given to dynamic changes brought about by urban spatial expansion and transportation network optimization.

Future research can be expanded in several ways. At the data level, multi-source data such as archival documents and industry surveys can be integrated to compensate for the shortcomings of insufficient early data and improve the continuity and completeness of the research. In terms of research dimensions, further integration of economic operation data and socio-demographic information can deepen the analysis of the interaction mechanism between non-spatial factors and location evolution, enriching the research with diverse perspectives. At the application level, in conjunction with Macau’s urban master plan, optimization schemes for pawnshop layouts in different areas can be refined to address

the imbalance in service radius. Simultaneously, the impact of digital transformation on the service radius and location logic of pawnshops can be considered, providing more comprehensive support for the industry to achieve sustainable development in the context of cultural heritage preservation and economic adaptation.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/buildings16040858/s1>, GIS Location Data of Pawnshop Buildings in Macau.

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Appendix A. Chinese Translation of Macau's Place Names and Architectural Names

Tak Seng On Pawnshop—德成按
Avenida de Almeida Ribeiro—亞美打利庇盧大馬路/新馬路
Rua de Cinco de Outubro—十月初五日街/泗街
Woo Cheong Pawn Shop—和昌大押
pawning, mortgage, and trust—當/按/押
Avenida da Amizade—友誼大馬路
Freguesia de Nossa Senhora de Fátima—花地瑪堂區
Freguesia de Santo António—花王堂區
Freguesia de São Lázaro—望德堂區
Freguesia da Sé—大堂區
Freguesia de São Lourenço—風順堂區
Freguesia de Nossa Senhora do Carmo—嘉模堂區
Freguesia de São Francisco Xavier—聖方濟各堂區
San Kio District—新橋
Travessa do Auto Novo—清平直街
Rua de Pequim—北京街

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