Spatial distribution characteristics of Foreign Customs Districts in Kwangtung (Guangdong) Province based on geographic information system (1842–1949)

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Abstract. The Foreign Customs Districts in Kwangtung (Guangdong) Province were spatial areas under the customs business jurisdiction established on the basis of location. Such Districts were under the Commissioner of Chinese Maritime Customs during 1859–1949. Since then, the number of Foreign Customs Districts had grown from two in the late Qing Dynasty to 11 in the Republic of China, which accounted for nearly half of the Chinese Maritime Customs Districts (19). They also gradually developed a vertical spatial pattern system, which was composed of three levels, namely, the head office, sub-offices and barriers. This thesis analyzes the characteristics of the spatial distribution of the Foreign Customs Districts, which are located at the junction of China's land and sea resources by mathematical graph analysis methods, such as kernel density estimation, geographic concentration index, and imbalance index method. The study aims to provide a case study of the spatial structure of the Foreign Customs Districts in the modern Chinese reference.

1. Introduction
During 1859–1949, Foreign Customs was a new type of customs managed and built by the General Commissioner of Customs at the Chinese modern coastal treaty port system. The Foreign Customs Districts of Kwangtung (Guangdong) Province referred to spatial areas under the business jurisdiction of the General Commissioner of Customs established on the basis of location. Such districts played roles in tax collection and tonnage dues. Each district is composed of a series of buildings and stretched across the 4.3 thousand kilometer southern coastline of the modern Kwangtung Province. Modern Foreign Customs inherited the spatial pattern of ancient Chinese customs agencies, and merged with the development of modern and effect contemporary coastal ports in China. Finally, the districts formed a spatial pattern system extending from the coast to the inland. They are important channels for economic, cultural, and scientific exchanges in the modern history of Kwangtung and a physical evidence of the maritime “Silk Road” in Kwangtung Province of the modern times.

The Foreign Customs Districts of Kwangtung Province were distributed at the geographic intersections of the sea and land. The number of districts in Kwangtung reached 11 in 1936, which...
exceeded 50% of the total number of Chinese Maritime Customs Districts. In general, Foreign Customs Districts are composed of three levels, namely, head office, sub-offices, and barriers. For example, the Customs District in Canton is composed of the Canton Customs (head office), 7 sub-offices, and 2 branches. Moreover, the Canton Customs consists of 11 buildings, such as the Canton Customs House, Red House of the Customs, Wave Building, Taxation Department Mansion, staff dormitory, and nursing home. According to partial statistics, the customs district of Kwangtung Province built 87 buildings, out of which 23 remain standing. Furthermore, 12 of the buildings are national cultural heritage conservation units, such as the Canton Customs Houses and Swatow Customs Houses, and 10 are city-level cultural heritage conservation units, such as the Samshui Customs House. Other buildings and surrounding roads, docks, and auxiliary buildings have been covered by modern roads or building systems and thus no longer exist.

The Foreign Customs Districts of Kwangtung Province pertain to the linear cultural heritage formed the previous era, which is a coastal linear landscape with a collection of special cultural resources. It represented an important transportation route for foreign economic and cultural exchanges in Lingnan. Furthermore, it is a typical type of coastal linear cultural heritage in China. Research on the current linear cultural heritage by investigating the spatial distribution characteristics and exploring their role and effect on the allocation of sea and land resources of contemporary Guangdong Province can help promote the overall planning of sea and land elements. In addition, it is beneficial for optimizing spatial structures to maximize their utility.

In the previous era, the administrative regions of Kwangtung Province include the modern Guangdong Province, Hong Kong, Macau, and three cities of the Guangxi Zhuang Autonomous Region, namely, Pakhoi, Fangcheng, and Qinzhou. This area faces the South China Sea to the south and has the longest coastline with numerous islands that twist and turn. It had been a paradise for smuggling. Kwangtung Province is the most difficult area for the Chinese Maritime Customs to manage due to its special geographical location, complex sea and land shape, coexistence of multiple trade systems, and huge trade volume. It is also one of the most complex and important areas for modern customs clearance area in China. Thus, results can provide reference for the exploration of other customs districts in modern China.

The spatial structure of the Foreign Customs Districts in the provinces is an important part of the construction of the customs system under the foreign controlled taxation and tariff system. The Canton, Swatow, Kiungchow, Pakhoi, and Lappa and Kowloon customs were officially operational in 1859, 1860, 1876, 1877, and 1887, respectively. In addition, the Lungchow, Samshui and Wuchow, Kongmoon and Luichow districts were established in 1889, 1897, 1904, and 1936, respectively (Figure 1). However, only two foreign customs were established in Kwangtung in 1860. Finally, they were increased to 11 in 1936. The number of districts accounted for nearly half of the country's 19 foreign customs districts, which in dictates the importance of the foreign customs in modern Kwangtung Province in the Chinese maritime customs system (Figure 2).
In recent years, research on the development, history, economy, management, and taxation of modern Chinese customs has produced numerous literature and theoretical results. From the perspective of research content, the literature mainly focuses on customs development and its history, economy, system, taxation, and maritime affairs. However, theories and methods in sociology, history, and spatial geography are mostly used in terms of methods. Thus, studies that investigate the temporal and spatial pattern of the spatial distribution of customs districts are few. Currently, the research of Wu Songdi, Yang Jingmin, and Yao Yongchao is considered excellent. Thus, to fill the research gap, the current study explores the spatial distribution pattern of the foreign customs in modern Kwangtung Province as the main research object using mathematical graph theory and other research methods to explore the spatial distribution characteristics of the customs districts. In this manner, the study aims to provide an analysis of the port–hinterland perspective for the modernization of Lingnan. In addition, the study aims to provide reference for the protection, utilization, and sustainable development of the customs architectural and cultural heritage.

2. Data sources and research methods

2.1. Data sources

The foreign customs system of modern Chinese customs dates back to 1858 under the “Remediation Clause of Five-port Commerce Articles”. After many adjustments of the foreign customs districts, such as considering native customs and merging of the Likin bureau, the Imperial Maritime Customs Service at the end of the Qing Dynasty was streamlined to a western customs system. The Imperial Maritime Customs Service is a four-level system consisting of the Customs House, sub-offices, maritime customs station, and barriers, where as the western customs system comprised general customs and checkpoints. The systems were adjusted to a vertical and general three-level system in 1936 composed of the head office, sub-offices, and barriers. The traditional Chinese tariff system was dismantled and gradually replaced by the western-style customs system. Therefore, the current study only considers the foreign customs districts in Kwangtung in 1936 as samples.

Kwantung has 11 Foreign Customs Districts, namely, the Canton, Swatow, Kuangchow, Pakhoi, Lappa, Kowloon, Lungchow, Samshui, Kongmoon, Luichow, and Wuchow Customs. Based on the list of Foreign Customs Districts in 1936 in the “Customs records of Guangdong Province” and after consulting relevant historical documents and referring to geographical data from the Postal Route Map.

Figure 2. Comparison of numbers of Customs District.

In 1843, the representative of the Qing government, Qiying, and British Pudingcha signed the "China-UK Five-Port Commerce Charter" in Humen as part of the "Humen Treaty".
of Kwangtung Province in 1914 and the Postal Map of Kwangtung District in 1922, a total of 102 Foreign Customs Districts were selected for the study. The samples include 11 head offices, 83 sub-stations, and 8 barriers (Figure 3).

![Figure 3. Distribution map of foreign customs districts in Kwangtung](image)

2.2. Research methods
The study adopts the spatial point pattern analysis method. Foreign customs districts are represented on the map as point elements, which were analyzed by mathematical graph theories, such as kernel density analysis, geographic concentration index, and imbalance index (Figure 4).

![Figure 4. Flowchart of the research.](image)

2.2.1. Kernel density estimation
Kernel density estimation is a non-parametric estimation method under the spatial point pattern analysis method. It considers the position of sample point \( i(x, y) \) as the center and all locates a circular area for each sample point within as specified range through the kernel density function. This process represents a mathematical function from the center to the boundary from 1 to 0. The closer the

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2 “Postal Route Map of Kwangtung Province, corrected to 31st., October, 1914” https://www.bmarchives.org/items/show/100200165#p=1

3 BMArchives, http://www.bmarchives.org/items/show/100204638.
distance to the center of the sample, the greater the density. In the same manner, the farther the distance from the center, the lesser the density. At the edge of the range, the density will be 0. Calculation is carried in the same manner for each sample point in the area. If the positions of the points overlap, then density is superimposed. The distribution density of each sample in the area can then be obtained as follows.

\[
    f_i(x) = \frac{1}{nh} \sum_{i=1}^{n} \left[ \frac{x - x_i}{h} \right],
\]

Where \( h \) is the bandwidth and \( n \) is the number of points within the bandwidth.

2.2.2. Geographic concentration index

The geographic concentration index is an important indicator that describes the degree of concentration of a geographic element and derived as follows.

\[
    G = 100 \times \sqrt{\sum_{i=1}^{n} \left( \frac{X_i}{T} \right)^2}.
\]

Where \( G \) is the geographic concentration index of foreign customs, \( X_i \) denotes the number of foreign customs in the \( i \)-th administrative regions, \( T \) pertains to the total number of foreign customs in Kwangtung Province in 1936, and \( n \) is the total number of administrative regions in Kwangtung Province. The value of \( G \) ranges between 0 and 100. The larger the \( G \) value, the more concentrated the foreign customs distribution.

2.2.3. Imbalance index method

The imbalance index can be used to measure the degree of equilibrium of the distribution of each foreign customs district in different regions and is generally calculated using the formula of the Lorenz curve equilibrium index. The formula of the imbalance index is presented as follows:

\[
    I = \frac{A - R}{M - R},
\]

where \( A \) is the sum of actual percentages, \( M \) stands for the maximum cumulative number, and \( R \) is the uniform classification cumulative number.

If \( n \) is the number of administrative regions, then the proportion of the number of foreign customs in each region is sorted to the total number of foreign customs descending order. The cumulative percentage of the \( i \)-th place is counted as \( y_i \). The terms of the above formula \( I \) can be then expressed as follows:

\[
    A = \sum_{i=1}^{n} y_i,
\]

\[
    R = \frac{1}{n} \times 100 + \frac{1}{n} \times 2 \times 100 + \cdots + \frac{1}{n} \times n \times 100 = \left( \frac{1}{n} + \frac{1}{n} \times 2 + \cdots + \frac{1}{n} \times n \right) \times 100 = 50(n + 1)
\]

\[
    M = 100n.
\]

Substituting the abovementioned formulas into the original formula, the final imbalance index expression \( S \) is derived as follows:

\[
    S = \frac{\sum_{i=1}^{n} y_i - 50(n + 1)}{100n - 50(n + 1)}.
\]

The imbalance index is \( 0 < S < 1 \). If foreign customs districts are distributed in all regions, then \( S = 0 \). However, if the districts are concentrated in one region, then \( S = 1 \).

2.3. Basic steps

2.3.1. Drawing a base map

This step uses the “2015 China Provincial Administrative Boundary Data—Distribution Map of.
Provinces in China” as the research base map, which is provided by the Resource and Environmental Science Data Centre of the Chinese Academy of Sciences. Then, the boundary of Kwangtung on the base map is drawn according to the position of the administrative map of the Republic of China in 1936. The coordinate system of the base maps is unified and named WGS1984.

### 2.3.2. Building a modern foreign customs database

This process combines historical documents, modern nautical charts, modern Kwangtung administrative maps, and a coordinate picking system to obtain the coordinate values of the samples of the foreign customs districts. It inputs 102 coordinate values into ArcGIS10.2, and avectorized positioning processing was performed.

### 2.3.3. Analysis of mathematical graph theory

The kernel density estimation tool in ArcGIS10.2 software Spatial Analyst was used to analyze the kernel density of the 102 districts to generate a kernel density distribution pattern of foreign customs districts in Kwangtung Province. The study utilized the spatial smoothing method based on the kernel density estimation method in GIS to visually and quantitatively analyze the spatial trend and distribution of discrete point data.

The geographical concentration index is used to describe the degree of centralization of the distribution of the elements of the foreign customs districts.

Lastly, the imbalance index is used to describe the equilibrium state of the distribution of foreign customs elements.

### 3. Spatial distribution characteristics of foreign customs districts in Kwangtung

#### 3.1. Kernel density analysis

The distribution of foreign customs districts in modern Kwangtung displays the highest-level concentrated point of nuclear density in the Pearl River Estuary (Figure 5), where a nearly 50-kernel density was observed, which spread toward the hinterland of the Pearl River.

The second-level strong areas identified are Sawtow and Luichow Customs with kernel densities reaching 12.8 and 22, respectively. The remainder spread west and east along the coastline and formed a response along the coast of Kiungchow with a kernel density of 11.7.

The Canton, Kowloon, and Lappa Customs are concentrated at the Pearl River Estuary, whereas the Samshui and Kongmoon Customs are situated in the hinterland of the Pearl River. Kowloon Customs is the hottest spot with a kernel density of 49, which is much higher than the total of 19 for the Canton and Lappa Customs. In terms of distribution, multiple “hot spots” and independent “cold spots” were observed. The former is located at the Kowloon Customs, whereas the latter is located at the Samshui Customs.

![Figure 5. Kernel density distribution map of foreign customs districts in Kwangtung](image-url)
3.2. Analysis of geographic concentration

A total of nine administrative regions are recognized for Kwangtung Province in 1936, namely, Canton, Qujiang, Gaoyao, Huiyang, Chaoan, Xingning, Maoming, Hepu, and Qiongshan. The total number of administrative regions in the geographical concentration index expression is \( n = 9 \). Although the study selected 102 foreign customs districts, Lungchow and Wuchow Customs were outside the administrative region of Kwangtung. Therefore, six foreign customs districts were excluded from analysis. The total number of foreign customs districts in modern Kwangtung is \( T = 96 \).

The geographical concentration formula to calculate the \( G \) value under uneven distribution can be obtained from Table 1. The table indicates that the geographical concentration index of foreign customs districts in Kwangtung Province in 1936 was \( G = 58.63 \). If the study assumed that 96 foreign customs districts are evenly distributed in each administrative region, then geographical concentration index \( G = 33.33 \). The \( G \) value (33.33) under uniform distribution is smaller than the actual value (\( G = 58.63 \)). This finding indicates that the distribution of foreign customs was highly concentrated in the division of administrative regions in Kwangtung Province in 1936.

| Order | Administrative Regions | Number of Foreign Customs | Total |
|-------|------------------------|---------------------------|-------|
|       |                        | Head Office | Sub-offices | Barriers |
| First District | Canton | 5 | 45 | 3 | 53 |
| Second District | Qujiang | 0 | 0 | 0 | 0 |
| Third District | Gaoyao | 0 | 1 | 3 | 4 |
| Fourth District | Huiyang | 0 | 8 | 0 | 8 |
| Fifth District | Chaoan | 1 | 5 | 0 | 6 |
| Sixth District | Xingning | 0 | 0 | 0 | 0 |
| Seventh District | Maoming | 0 | 5 | 2 | 7 |
| Eighth District | Hepu | 2 | 11 | 0 | 13 |
| Ninth District | Qiongshan | 1 | 4 | 0 | 5 |
| Total | | 9 | 79 | 8 | 96 |

3.3. Analysis of imbalance

According to geographical status, Kwangtung Province is divided into two major regions, namely, coastal and inland. The percentage of the total number of foreign customs districts in each administrative area is calculated to measure the balance of their distribution in the entire province (Table 2). Through the calculation of the imbalance index formula, the study obtained an imbalanced index \( S = 0.68 \), which indicates that foreign customs was unevenly distributed in modern Kwangtung Province (Figure 6). In addition, results show that foreign customs located in coastal areas account for approximately 100% of the total number. This finding is consistent with the degree of geographic concentration.

Figure 6. The Lorentz curve of distribution of foreign customs districts.
Table 2. Total number, proportion, and ranking of foreign customs districts in Kwangtung.

| Geography | Order   | Administrative Regions | Number of Foreign Customs(PCS) | Proportion (%) | Ranking |
|-----------|---------|------------------------|---------------------------------|----------------|---------|
| Coastal   | First District | Canton                | 53                              | 55.2%          | 1       |
|           | Third District | Gaoyao                | 4                               | 4.2%           | 7       |
|           | Fourth District | Huiyang              | 8                               | 8.3%           | 3       |
|           | Fifth District | Chaoan                | 6                               | 6.2%           | 5       |
|           | Seventh District | Maoming           | 7                               | 7.3%           | 4       |
|           | Eighth District | Hepu                  | 13                              | 13.5%          | 2       |
|           | Ninth District | Qiongshan             | 5                               | 5.2%           | 6       |
| Total     |          |                        | 96                              | 100%           |         |
| Inland    | Second District | Qujiang               | 0                               | 0              | 8       |
|           | Sixth District | Xingning              | 0                               | 0              | 8       |
| Total     |          |                        | 0                               | 0              |         |

3.4. Distribution characteristics of construction time

Previous studies have established and administered a total of 11 foreign customs districts in Kwangtung Province from 1859 to 1949. Based on the list of the construction time of the districts, the present study infers that 90.9% of the total of the districts were built during the late Qing Dynasty (Figure 7). As such, the Republic of China has built only 9.1% of the districts. Lastly, more than 50% of the districts were constructed between 1880 and 1900.

Figure 7. Distribution map of foreign customs districts according to time of construction.

4. Conclusion

The thesis analyzes the spatial distribution characteristics of 102 foreign customs districts on the basis of historical documents, modern nautical charts, and geographic information in Kwangtung Province during 1936. Analysis of mathematical graph theories, such as kernel density, imbalance index, and geographic concentration, revealed that the spatial distribution of the modern foreign customs districts in Kwangtung Province was linearly distributed along the Pearl River Estuary to the west and east coasts and formed secondary centers guarding the Pearl River Estuary through the Luichou and Sawtow Customs and along the Pearl River hinterland from the west river to the north.
The characteristics of their spatial distribution reflect the close relationship of the inland with the water system (Figure 8). Relying on the development pattern of Lingnan’s treaty ports, they established a customs district system for taxation, anti-smuggling, and maritime and port affairs. Its external status is similar to the modern transportation, communication, and postal systems.

The conclusions presented by digital map analysis indicate a mutual relationship between material and spiritual culture. The findings enable for the discovery of the peculiarities and complexity of foreign customs in China and provide reference for further studies.

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