Applied Geography 100 (2018) 12–20

Contents lists available at ScienceDirect

Applied Geography

journal homepage: www.elsevier.com/locate/apgeog

The location of retail stores and street centrality in Guangzhou, China

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ARTICLE INFO

Keywords:
Street centrality
Retail location
Points of interest
Multiple centrality assessment model

ABSTRACT

Transportation networks have a profound influence on the location of retail stores, but there has been little research on the relationship between the location of retail stores and street centrality in traditional commercial metropolises. Based on three indices, namely, closeness, betweenness, and straightness, in a multiple centrality assessment (MCA) model, we analyzed the location of various retail stores and street centrality in Guangzhou using points of interest (POI) and street network data. The results show that street centrality in Guangzhou has a large impact on the location of retail stores and that different store types have different centrality orientations: (1) The location of all retail stores correlates most highly with betweenness, followed by closeness and straightness. (2) Shopping malls favor street centrality most, followed by convenience stores, specialty stores, textile and clothing stores, supermarkets, building material stores, and traditional grocery stores. (3) Apart from traditional grocery stores, which are weakly correlated with street centrality, shopping malls and convenience stores value locations with better closeness, while the other retail store types tend to distribute in areas with better betweenness. Our findings can help guide urban planners in designing commercial activity zones and transportation networks.

1. Introduction

Location is critical to the success of retail stores (Scarborough & Zimmerer, 2000; Cheng, Li, & Yu, 2007; Roig-Tierno, Baviera-Puig, Buitrago-Vera, & Mas-Verdu, 2013). Early research discussed retail location mostly based on central place theory, the spatial interaction model, and land value theory (Dawson, 2013, pp. 99–129). However, with the diversification of retail types in urban areas, the location of retail stores has become more complex than in the past. At the same time, accessibility has improved alongside rapid urbanization, and transportation has become a key factor affecting the location of stores. Thus, the impact of transportation on retail location has become a topic of interest for scholars and policymakers.

There is a rich body of literature examining the relationship between retail location and transportation. First, researchers have shown that transportation configurations such as the road grade (Rui et al., 2016), the transportation infrastructure (Erbıyık, Özcan, & Karaboğa, 2012; Nilsson & Smirnov, 2016), and public transportation (Castillo-Manzano & López-Valpuesta, 2009; Cervero & Kang, 2011) can fundamentally affect the distribution of stores. Second, it has been shown that street networks shape the intensity, connectivity, and distribution of economic activities and land use (Hillier, 1996; Liu, Wei, Jiao, & Wang, 2015; Porta et al., 2012). Third, street centrality is a key factor affecting the placement of retail stores, and it has been found that street centrality affects land use and socioeconomic activities (Kang, 2015; Liu et al., 2015; Rui & Ban, 2014). Therefore, the most central neighborhoods (i.e., in areas with high street centrality) tend to be hot spots of economic activity in a region (Liu, Wei, et al., 2015), particularly with regard to retail businesses (Hillier, 1999). Hence, it would be effective to explore the configuration of retail businesses in a metropolis from the perspective of street networks.

Many scholars have studied the relationship between the location of retail stores and street centrality using space syntax and the multiple centrality assessment (MCA) model. Based on graph theory, space syntax maps the street network into connection graphs and measures accessibility by quantifying the degree of topological connection between axes. Scoppa and Peponis (2015) found that street network accessibility had a stronger impact on street-level commercial density than other factors in Buenos Aires, with connectivity being the strongest factor and road width and integration being less significant. Omer and Ran (2015) explored the relationships between retail activity and the street network structure based on integration and choice centrality in

List of abbreviations: MCA, multiple centrality assessment; KDE, kernel density estimation; POI, points of interest; CBD, central business district

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https://doi.org/10.1016/j.apgeog.2018.08.007
Received 27 April 2017; Received in revised form 21 August 2018; Accepted 22 August 2018
0143-6228/

new and traditional Israeli cities. They found that the retail activity in older cities tended to be concentrated in a linear form along the main roads; in contrast, in new cities, it was distributed more equally due to the influence of the "neighborhood unit" concept. The MCA model also maps street networks as nodes with associated links (Crucitti, Latora, & Porta, 2006). However, in contrast to space syntax which regards the actual lengths of roads as scale-free vectors, the MCA model adopts primal networks to measure the metric distance of streets. It defines centrality as a multifaceted concept of being close, being between, and being straight to other places in a geographic system (Porta, Crucitti, & Latora, 2006). This type of model can be used to more effectively evaluate the advantages of urban locations and to quantify their relationship with urban economic activities (Wang, Antipova, & Porta, 2011). Based on this approach, Porta et al. compared retail locations in Bologna (2009) and Barcelona (2012). They found that in Bologna, location was highly correlated with betweenness and closeness whereas in Barcelona, closeness was valued the most, though only slightly more than betweenness and straightness. Cui and Han's (2015) study of retail businesses in Zhengzhou, China, also found that retail businesses tended to be located in areas with high closeness. The studies above focused on the overall impact of various measures related to the centrality of street networks on the location of retail stores. In recent years, some scholars have begun to investigate the relationship between the locations of different types of retail stores and street centrality. Sevtsuk (2011) found that the impact of betweenness on retail stores differed depending on the retail type, with clothing stores showing the most significant correlation with betweenness in Cambridge and Somerville, Massachusetts. Wang, Chen, Xiu, and Zhang (2014) found that there was a significant difference in the correlations between different retail types and street centrality indices, with specialty stores preferring closeness, supermarkets and department stores valuing betweenness, and consumer product stores favoring straightness. Undoubtedly, street centrality has a large influence on the location of retail stores, but the relationship differs by study area. This phenomenon may be related to the measure used to assess centrality, the regional characteristics of the study area, or the selection of the retail sample.

However, few studies have focused on the relationship between the location of retail stores and street centrality in metropolitan areas and traditional commercial cities with a high density of retail stores. Furthermore, many studies obtained data on retail stores through field surveys and government economic censuses consisting of limited samples (Omer & Ran, 2015; Rui et al., 2016; Wang et al., 2014). With the application of spatial data mining technology, big data have created new opportunities for retailing research (Arribas-Bel, 2014; Ruppert, 2013). Points of interest (POI) data are the most popular geo-tag data type and provide a large quantity of information. Compared with traditional census data, POI data can provide spatial and attribute information on individual retail stores, which is of great value for research on the relationship between the location of retail stores and street centrality in metropolises.

This case study examines the relationship between the location of retail stores and street centrality in Guangzhou, China (Fig. 1). With a population of 13.5 million as of 2015, Guangzhou is a large traditional commercial metropolis in China. Guangzhou boasts a well-developed economy and thriving trade and enjoys the reputation of being a "millennium-old trade capital" in China. The city's total retail sales for consumer goods reached 123.95 billion dollars in 2015, ranking third in China. The rapid development of shopping malls, convenience stores, and supermarket chains has created a diverse and highly dense retail distribution pattern. The density of shops in Guangzhou ranks first in the whole country. In addition, Guangzhou has constructed a multilevel street network under the guidance of the transit-oriented development (TOD) model, strengthening the connection between central urban areas and suburbs (Yan, Zhou, & Mao et al., 2006).

In this study, we measured street centrality in Guangzhou based on three indices—namely, closeness, betweenness, and straightness—in the MCA model. Then, the kernel density estimation (KDE) method was used to convert retail store locations according to the retail POI data and street centrality values at nodes in Guangzhou into the same spatial units. Doing so was the basis for a correlation analysis of these units, which intended to examine the relationship between retail store location and street centrality.

2. Data sources and research methods

2.1. Data sources

The data sources included POI data and street network data, which were sourced from Baidu Inc., the largest search engine and the largest web site base in China. POI data are a type of point data describing spatial and attribute information related to geographic entities, including latitude and longitude coordinates, address, name, and category, etc. Such data have the advantage of providing wide coverage, a large volume of information, and high accuracy. In accordance with the Retail Type Categorization of China (GB/T 18106-2004),[1] we selected six categories: shopping malls, supermarkets, convenience stores, specialty stores, traditional grocery stores, and building material stores. In addition, since the textile and clothing industry in Guangzhou has a large number of wholesale and retail clothing markets, we regarded textile and clothing stores as an independent category. A total of 72,269 POI from 7 different retail types in Guangzhou were extracted (Fig. 2). The centerline of main roads was extracted to build the street network. Road intersections and endpoints were extracted as network nodes, and the roads connecting two nodes were specified as links in the street network; we then calculated their lengths. Finally, the street network and POI data were transformed into the same type of coordinates and fitted to the corresponding spatial locations.

2.2. Research methods

2.2.1. Multiple centrality assessment of the street network

We chose three critical measures in the MCA model, namely, closeness, betweenness, and straightness, to evaluate the different characteristics of street centrality. These measures were computed by means of the Urban Network Analysis Toolbox in ArcGIS (Sevtsuk & Mekonnen, 2012).

(1) Closeness (C^C) refers to the inverse of the average distance from a node to all other nodes along the shortest paths in the network. It is a measure of the proximity of a node to all other nodes (Sabidussi, 1966). C^C for node i is defined as follows:

$$C_i^C = \frac{N-1}{\sum_{j=1;j\neq i}^{N} d_{ij}} \quad (1)$$

where i and j denote nodes, N is the number of nodes, and d is the shortest distance between nodes i and j.

(2) Betweenness (C^B) is the frequency of shortest paths between any two nodes passing through a certain node. It is a measure of the volume of traffic flow through that node (Freeman, 1977). C^B for node i is defined as follows:

[1] Based on structural characteristics, the operation mode, the product structure, the service function, location, the business circle, scale, storage facilities, target customers, and whether a business has a fixed operation venue, the Retail Type Categorization (GB/T 18106-2004) of China classifies retail stores into 17 types: traditional grocery stores, convenience stores, discount stores, supermarkets, hypermarkets, warehouse stores, department stores, professional stores, specialty stores, building materials stores, shopping centers, manufacturer stores, TV shopping, mail order, online stores, vending kiosks, and telephone shopping.