Design of Commercial Format Layout in Digital Urban Block Based on Space Syntax and Correlation Analysis

Jiabei Wang[1], Shuge Su[2]

[1]Southeast University, Jiangsu/China · 614240624@qq.com; [2]Southeast University, Jiangsu/China

Abstract: Realizing the ideal of digital urban design needs to be based on data-based empirical research, and the working method of applying research results to design. In this paper, we take the urban renewal project of Gaochun Old Street Historical Commercial Street in Nanjing, which was built in the Song Dynasty, as an example. It describes how to comprehensively utilize the results of spatial syntax modelling and commercial business density correlation calculations, and spatially analyse these data in the deepening stage of the urban block-scale design scheme. The conclusions are also applied to auxiliary design work such as base potential assessment, scheme comparison and optimization. (1) The high value areas of integration, penetration and connectivity parameters of the road network in commercial neighbourhoods are clarified, and the cluster clustering phenomenon of commercial business distribution is found. (2) The differences in the calculation results of the three algorithms under the same road network structure were compared. (3) Each type of correlation characteristics of the two were calculated to see if they are significantly positively correlated. Among them, the integration degree and selectivity of the road network were significantly positively correlated with the density of commercial buildings of shopping, accommodation and catering types, but the correlation with the density of commercial buildings of living types was weak. (4) Based on the degree of dependence of each commercial type on the road network, new renewal and protection strategies are proposed for the current spatial characteristics and commercial layout of urban block, in order to promote the synergistic development of business and tourism.

Keywords: Historic conservation district, road network structure, commercial businesses, space syntax, spatial scale

1 Introduction

Facing new opportunities and challenges, major cities around the world are actively carrying out innovative urban planning and construction practices. With this background, how to better apply the results of multi-source data analyses to spatial design has become a hot topic in digital landscape. It is a consensus that historical and cultural districts should be comprehensively developed with commercial, transportation, residential and recreational functions in order to improve the vitality of the city. However, the mixing ratio of various functions and how to rationally distribute various facilities is one of the focuses of future development which requires a rational platform for all parties to play (YANG 2012).

Many scholars have studied the correlation between road network patterns and commercial format layout of buildings from the 20th century onwards. For example, the Athens Charter of 1933 clearly states that ‘streets need to be functionally classified, and streets should be divided into major traffic routes, residential roads, commercial roads, and industrial roads, etc., according to different functions. In recent years, Fu Kun analysed the difference between the dense areas of commercial layout in the road network system of square, radial, circular and other plane shapes (FU 2011). Professor Sheng Qiang's team conducted an empirical study and digital design of commercial space profitability and customer flow, and showed that spatial structure evaluation is the basis of business allocation (SHENG et al. 2018).

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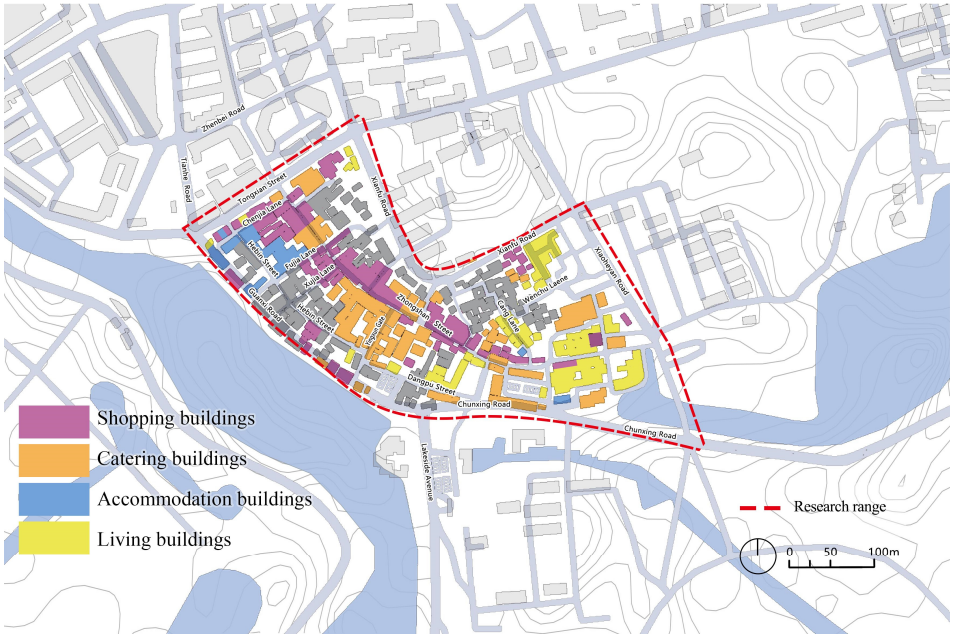

Fig. 1: Schematic layout of the Gaochun Old Street block. Shows the road network structure of the historic conservation district, and labels the layout of shopping, dining, lodging, living, and building business of local residents.

The realization of digital urban design needs to be based on data-based empirical research and the application of research results to the design methodology. We chose to use a block in China as an example, the Gaochun Old Street (Figure 1), a historic conservation district located in Nanjing, Jiangsu Province, as the study site. It is one of the "Ten Famous Historic Conservation Districts of China", with its preserved ancient commercial buildings in the Ming and Qing dynasty styles. Gaochun Old Street was built in the Song Dynasty and has been in existence for more than 900 years. It is the main commercial street of Chunxi Old Town, which is formed by the spontaneous gathering of merchants. The road network is complex in form, with clear primary and secondary, using Gaochun Old Street as a case study site is representative. The road data comes from Open Streetmap platform, and due to the edge effect, the data range is larger than the site range (JIANG et al. 2002). The POI (Point of Interest) data comes from the Gaode Map API open platform (as of November 2024). Covering a total of 7 service commercial formats, including shopping, catering, living, healthcare, sports and leisure, accommodation, finance and insurance. Based on the definition of China's National Economic Industry Classification Standard (G/BT 4754-2011), the four commercial formats of living, healthcare, sports and leisure, and finance and insurance, which are fewer in number and have similar functions, are merged into the living services category. The data were captured by the data acquisition tool and imported into ArcGIS 10.8. Combined with the field survey, the data were pre-processed by eschewing, and supplemental increase, and a total of 274 commercial points within the site were finally obtained.

Through the renewal project of the "Gaochun Old Street" historic block in Nanjing, we have identified two key conclusions or considerations:

1) The differences in the significance of correlation between the accessibility parameters of road network and the building densities of the various commercial formats in the district are identified.
2) Using the results of the correlation study, we optimized the synergy between the commercial layout and the road network structure of the historical cultural block.

2 Digital Analysis of Urban Blocks

2.1 Distribution Characteristics of Commercial Businesses

The commercial layout of Gaochun Old Street was shown based on the ArcGIS kernel density analysis module. The image radius is set to 0.1m, and the search radius is set to 50m to analyse the POI data of commercial facilities of each industry in Gaochun Old Street respectively. The kernel density estimation results were classified into 9 categories according to the natural breakpoint method.

The distribution of commercial businesses in Gaochun Old Street is characterized by a strong agglomeration phenomenon (Figure 2). The number of shopping buildings accounts for 39.47% of the total. The number of catering buildings accounts for 32.24% of the total, while the number of living buildings is relatively small at only 2.92%.

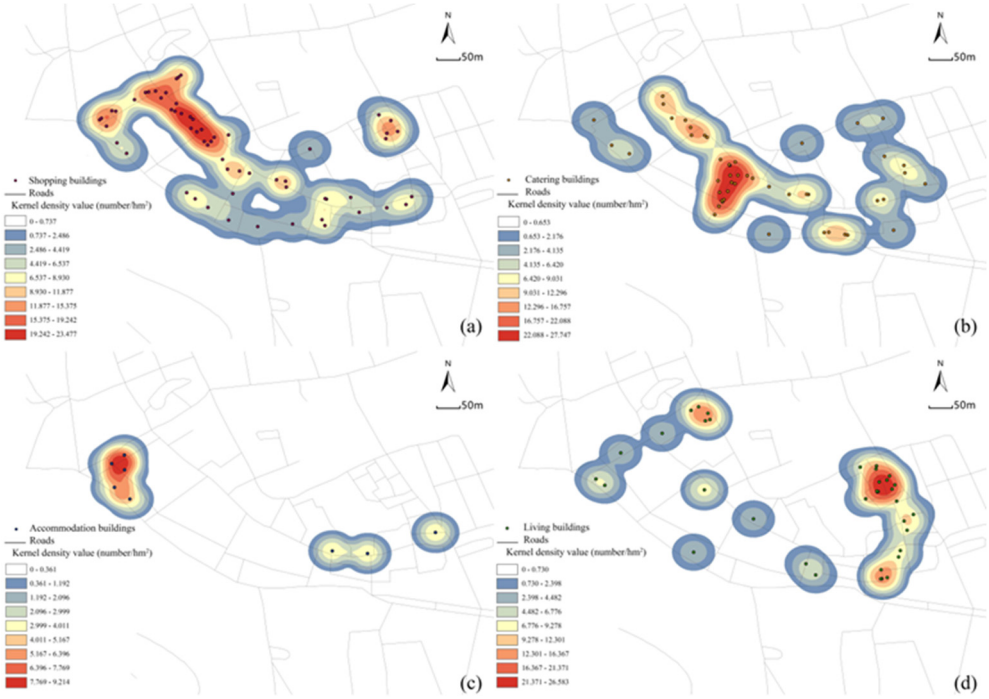

Fig. 2: Kernel density analysis of various types of commercial buildings in Gaochun Old Street: Shopping buildings (a), Catering buildings (b), Accommodation buildings (c), Living buildings (d)

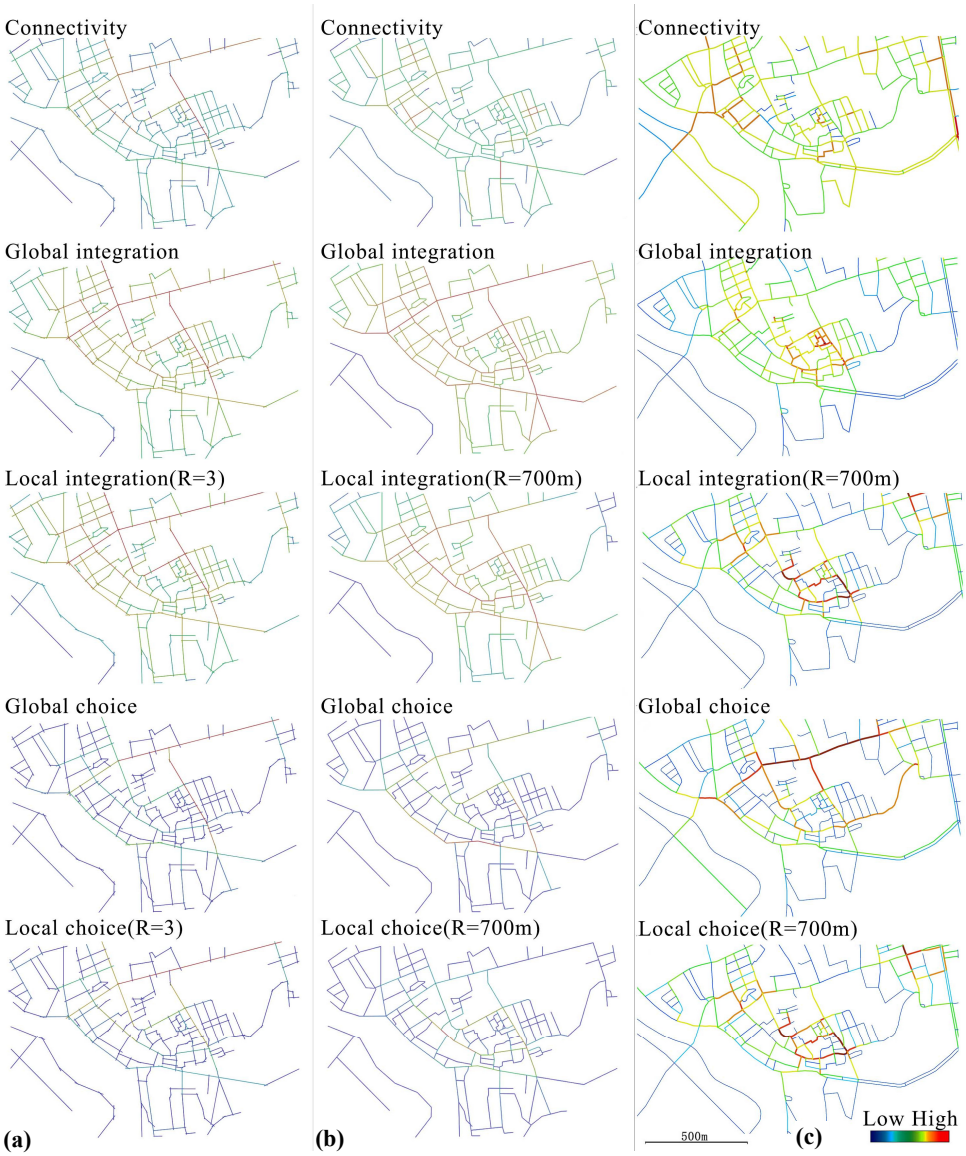

Fig. 3: Space syntax measuring results of three model (a. Axial model, b. Segment model, c. sDNA model)

2.2 Road Network Structure Characteristics

Space syntax was proposed by Professor Bill Hillyer, and is most widely used in two software applications, Depthmap and sDNA (SONG et al. 2020). In this study, three different algorithms, namely, topology algorithm, folding angle, and distance algorithm, were selected, and three types of important syntactic parameters, namely, connectivity, integration, and

choice, were used. The road network structure of Gaochun Old Street was analysed under global and local scales.

In addition, the radii metric is an important concept in street network analysis, which is mainly used to limit the spatial scope of the network involved in the calculation, indicating the multi-scale analyses are conducted in terms of topological distance or metric distance (HUANG et al. 2017). In the metric distance, 100m was selected as the interval to set 100-1000m and infinity (N) as the calculation scale respectively. The distance with distinct results was selected to characterise the road network at local scale (Figure 3).

2.3 Analysis of the Correlation

In order to study the distribution of commercial facilities within the actual influence of the road network, according to the walking characteristics of tourists and the corresponding time-distance relationship (HUANG et al. 2017), a strip buffer zone with a diameter of 50m was established for each road section respectively, and the end type was circular. Pearson bivariate correlation analysis was used to calculate the type and degree of association between the structural parameters of the block road network and the quantity of each type of commercial buildings.

We calculated the comprehensive correlation results under the three algorithms of the space syntax method, and finally chose the line segment model with the best results. The correlation analysis between the road network pattern and commercial layout of Gaochun Old Street was conducted (Table 1). We also compared the significance results of different commercial formats at different distance radius scales, and found their optimal service radius.

Table 1: Significance Comparison of Correlations at Different Distance Radii under Line Segment model

Variable Road network parameters	Commercial format	Distance radius				
		n	300m	500m	700m	900m
Integration	All	0.008	-0.052	0.030	0.036	0.024
	Shopping	0.233**	0.086	0.222**	0.264**	0.239**
	Catering	0.086	0.062	0.171*	0.177*	0.124
	Accommodation	0.155*	-0.041	0.018	0.076	0.107
	Living	-0.288***	-0.209**	-0.260***	-0.310***	-0.279***
Choice	All	-0.042	-0.143	-0.044	-0.017	-0.039
	Shopping	0.102*	-0.117	0.050	0.103	0.096
	Catering	-0.008	-0.067	0.086	0.112	0.061
	Accommodation	0.007	-0.029	-0.050	-0.051	-0.033
	Living	-0.161*	-0.104	-0.160*	-0.175*	-0.182*

(Note: Where *** denotes significant at the 0.1 per cent level, ** denotes significant at the 1 per cent level and * denotes significant at the 5 per cent level)

Under the scale analysis perspective, the distance radius when the correlation of multiple types of businesses is the strongest is distributed at approximately 700m. 700m is the length of a normal person's hiking path of about 10min, which is also consistent with the validation

results of Huang Duo et al (HUANG et al. 2018). At this scale, it can be seen from Table 1 that the ranking of the commercial sectors in relation to integration is: Shopping (0.264**) > Catering (0.177*) Accommodation (0.076) > Living (-0.310***). The ranking with the degree of choice is: catering (0.112) > shopping (0.103) > accommodation (-0.051) > living (-0.175*).

In addition, the optimal service radius of different commercial buildings varies, such as the distance radius of dining and living commercial buildings is slightly lower than the average distance radius of 700 m, while the accommodation commercial facilities are higher than 700 m. The ordering from largest to smallest is accommodation > shopping > dining > living. This is also basically in line with the ordering of the topological radius calculated by the topological model.

3 Discussion

Improve the efficiency of visitor use and space utilization per unit of roadway within the block. Reasonable diversion of crowd lines should be promoted to achieve higher commercial efficiency within the unit road section. Therefore, the commercial locations should be rationalized according to the distance radius.

1) Shopping buildings have the highest degree of correlation with the road section characteristics and a larger service radius. The buildings are mostly located in the straight section of the main street, and should be combined with the characteristics of cultural and creative development.
2) Catering buildings are more significantly related, but the service radius is small. It is recommended to combine the distribution of places next to shopping buildings, which can attract extra people.
3) Accommodation buildings should be located at the road network branches.
4) Living buildings are negatively correlated with the road section characteristics, mostly distributed in various branch locations, and the service radius is the smallest. The site selection requirements for its commercial layout are not stringent. It is recommended to combine with the northeastern part of the block to reunite people flow with a net-like route space and enhance the stopping time of tourists.

4 Conclusion and Outlook

Space syntax and correlation calculations are not unfamiliar to planning and design. In fact, they are commonly used by civil engineers, designers and planners for analyzing urban problems and decision making (DUANG 2015, GU et al. 2018, SHENG 2016, WANG 2021). However, apart from analysis, the use of computational results in planning and design is still relatively rare. This study demonstrates the role played by space syntax and correlation analysis in the digital design and updating of commercial formats layout in city blocks. The main innovations include the combined application of digital data and field research, and we explored the empirical research method of commercial format layout based on the correlation significance of the results.

However, there are still some shortcomings in the conduct of the project. The generalization of this method still needs more blocks and computational support of more data, and the results will be somewhat different from block to block. In addition, the results of the road network parameters of Gaochun Old Street do not exclude the influence of different algorithms on the way of automatic segmentation of road sections. Finally, the urban renewal process is limited in the scope of the street's ability to coordinate, and even if problems can be identified through physical examination, they are often difficult to solve when different property owners are involved.

Nevertheless, the development of spatial analysis technology for our block data has been able to initially build an effective workflow covering the path from problem diagnosis, analysis to optimization. And this has made the complex process of urban renewal clear in its objectives, comprehensive in its means and predictable in its effects, providing strong support for scientific decision-making and precise design.

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