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MAPPING THE RELATIONSHIP BETWEEN SITE CODING AND STREET SPATIAL CONFIGURATION: CASE STUDY IN NANJING, CHINA

Abstract: *Street spatial configuration is often regarded as the urban design object, as one of the characteristics of urban form, which is shaped by the buildings along the street. As is known to all, the positions of buildings are limited to their plot with site coding, building type and security rules, therefore, for urban designer it is important to know the correlation between street spatial configuration and those urban regularities. Based upon numerous urban rules referring to the street, our research has tried to study the longitudinal relationship between site coding, building type, various city rules and street spatial configuration, so mapping all kinds of rules becomes a necessary process and method. In order to do so, we have built a 3D mapping model consisting of all species and all the positions of plots and reflecting all the impacts of urban spatial regulations on plots and their buildings. Three groups of information data are mapped on the model: (1) urban planning, including land use and traffic network; (2) the plot size, shape, position and building types; (3) urban environment state and security rules. According to the mapping results, we tried to generate street spatial configuration model. The research shows clearly the importance of the urban regulations to the street spatial configuration and the problems of those rules while building urban form. Through statistical analysis our study shows not only the limitation of street design, but also the potential of the urban design and urban codes. Finally, this paper is focused on discussing how the urban coding acts in morphological process, especially in spatial configuration.*
Keywords: *street spatial configuration, urban regularity, site coding, building layout.*

Introduction

Street spatial configuration is one of the characteristics of urban form. It is shaped by the buildings along the street and is often regarded as the urban design object. As is known to all, the buildings alongside the street are related to its history, landowners and size of plots, therefore urban designers would provide design orders for architectural design based on these elements. Besides, urban morphological studies demonstrated that architectural design is also influenced by plot size, plot shape, land use indicators and urban regulations concerning security, health and setbacks (Talen, 2012; Marshall, 2011). Many decisions for urban design were made on the political stage and were even accepted as public policies ultimately; to a certain extent the urban designers can influence the decision-making process, but the effects of urban designers were limited due to political factors. Research on the morphological mechanism of the street spatial configuration is of great value for urban design.

Many researches on urban form factors in Nanjing have been carried out. Ding (2007) studied the urban policy on urban form control strategy in Nanjing, based on the building size, construction distance, building spacing, architectural facade and other aspects. Researches on blocks have been carried out, which include the redefining of a block and a secondary block in the Chinese conception, dividing the block and secondary block of old town and Hexi district in Nanjing (Lin, 2014) and studying the relationship between classification of plots and land use indicators in Nanjing (Wu, 2016). There are also many studies on characteristics of plot, building

and the relationship between building and a plot boundary within a single plot. For example, Zhang (2013) studied the distribution of the public space and the main entrance (into it) for cars within the commercial block. Jiang (2015) and Zheng (2016) successively counted the plot shape, plot size, the position of plot, land index and building arrangement of public building plots which were next to the main roads and secondary roads. Zhao (2015) has done a research on residential land with the research object being similar to public buildings. Based on researches above, this paper is going to find the specific effects that the urban regulations and design concept had on plots, buildings and street spatial configurations.

To figure out the morphological mechanism of the street spatial configuration under regulatory control and design concept, the paper tries to study and map how streets, plots, urban regulations, land use indicators worked together in building forms in Nanjing.

Methodology

In order to achieve the goal, we need to sort out the urban regulations of different age which clearly or vaguely affected urban construction and to set a model for mapping. The model consists of a street network which is made up of a main road, a secondary road, a branch road, and plots. The method used in the study has four dimensions. Firstly, we determined the traffic network by codes for urban road design and statistics on the types of roads outside blocks and the distribution of branch roads within blocks in Nanjing. Secondly, we selected one of the north-south direction main roads for the model and divided the land along the street into plots based on the regulations of plot area and summary of the relationship between plot area and building types in previous studies. Thirdly, one of the plots along the main road with the most complex boundary was used as the research object (Fig. 1). Then we studied how many kinds of building layout there are for this plot with a certain floor area ratio and building density when the plot used as commercial, office, mixed-use, secondary school and residential land respectively. Finally, this paper used wall density and near-line ratio to discuss how the urban coding acts in morphological process, especially in street spatial configuration.

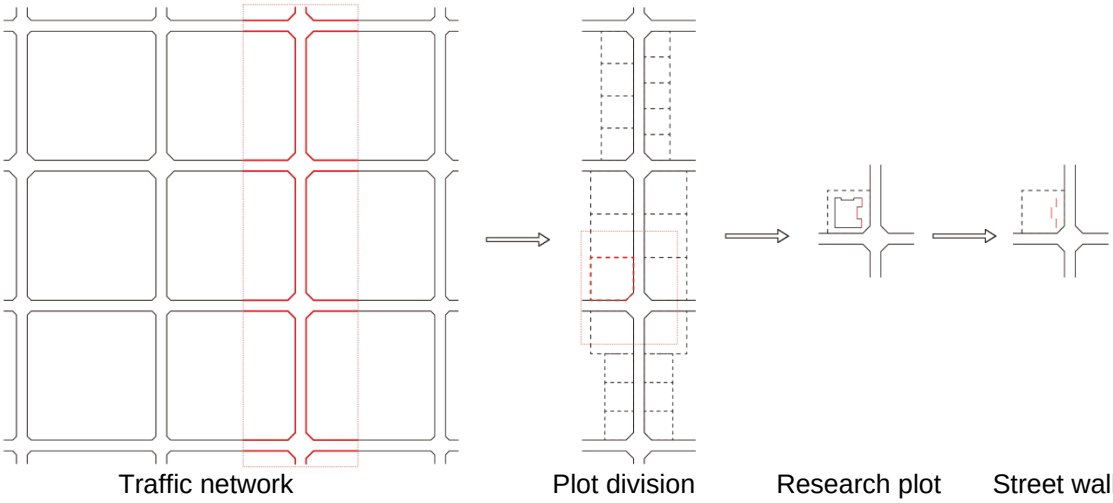


Figure1. Research path diagram

Mapping influences of urban regulations in Nanjing

Urban regulations regulate building form clearly or vaguely in many ways, including land use indicators, building setback and building arrangement. This paper searched for 52 urban rules and extracted from them 122 items, which are related to these four aspects mentioned above.

1. Land use

There are 17 regulations related to land use which mainly contain per capita land area index for construction, the proportion of various land usage and the size of new settlements, old residential and industrial blocks. For example, in "Urban land classification and planning construction land standard GBJ 137-90" No.4.1 regulation divides the per capita land area for construction into four levels. Newly-built city should belong to Level III and it can belong to Level II to make up for land shortage problem. Capital city and special economic zones should be regarded within Level IV, also they can belong to Level III to make up for land shortage problem. In "Guidelines for the preparation of regulatory plan in Jiangsu Province (2012)" No.3 Chapter six stipulates that the size of residential block should be 2-4 hectares in old town and public transport development area and less than 8 hectares in other areas, while the size of industrial block is usually no more than 12 hectares. These regulations play a certain role in the distribution of land.

2. Land use indicators

There are 10 regulations related to land use indicators including minimum site area for residential and non-residential buildings of different heights, the specified values of building densities and floor-area ratios of various building sites. For instance, "Technical Regulations on Urban Planning Management in Jiangsu Province (2011)" No. 2.3 give the minimum site areas for residential and non-residential buildings, they are respectively 500m^2 for low-rise residential buildings, 1000m^2 for multi-storey residential buildings, 1500m^2 for middle height residential buildings, 2000m^2 for high-rise residential buildings, 1000m^2 for multi-storey buildings and 3000m^2 for high-rise buildings.

3. Building setback

There are 20 regulations related to building setback. The regulations of building setback consist of building setbacks for roads and building setbacks for land boundary.

Building setback for roads in Nanjing underwent several modifications with economic development and policy updates, the main time nodes were 1928, 1978, 1987, 1995, 1998, 2004 and 2007 (Tang, 2017). From 1928 to 1987, every year the building setback for roads was a fixed value and would not change with the building height. But from 1995 to 2007 buildings of different heights had different setbacks. The regulations in 1998 stated the most kinds of setback distances, totally 10 kinds, while the other regulations enlisted 6 kinds of setback distances. That means that the setback distances would be much different as long as the building heights vary in the same street, and this leads to the complexity of the street wall.

Building setback for land boundary in Nanjing started to be specifically regulated in 1995, which is conditioned by the continuity of the street wall. The minimum distance of the building setback for land boundary corresponds to the width of building along the land boundary.

4. Building arrangement

There are 72 regulations related to building arrangement, including the minimum newly-built building spacing, fire protection spacing, daylighting spacing, entrance position, disposition of roads within the site and regulations specifically set for infrastructures such as kindergartens, schools, nursing homes and hospitals. For instance, "The implementation rules of urban planning ordinance in Nanjing (2007)" No.43 show that when the houses are arranged in parallel, the frontal space of the house shall be controlled according to the building spacing coefficient – no less than 1.25 in Nanjing old area and no less than 1.30 in Nanjing new area, and shall comply with the minimum spacing requirement; besides, vertical or angled arrangements have different corresponding provisions.

Most of the urban regulations do not only stipulate one of the aspects mentioned above, these regulations have different effects on building forms. For example, "Guidelines for the preparation of regulatory plan in Jiangsu Province (2012)" has regulations on land use and land use indicators. "Technical Regulations on Urban Planning Management in Jiangsu Province (2011)" gives regulations on land use, land use indicators, building setbacks and building arrangement.

Some of the regulations have specific numerical values for land use, like “Technical Regulations on Urban Planning Management in Jiangsu Province (2011)”. But other regulations only give directive suggestions for land use, the influence on building forms is not specific, like in “Code for classification of urban land use and planning standards of land development GB50137-2011”. To clarify the relationship between site coding and building forms, we mapped the influences of urban regulations in Nanjing (Fig. 2).

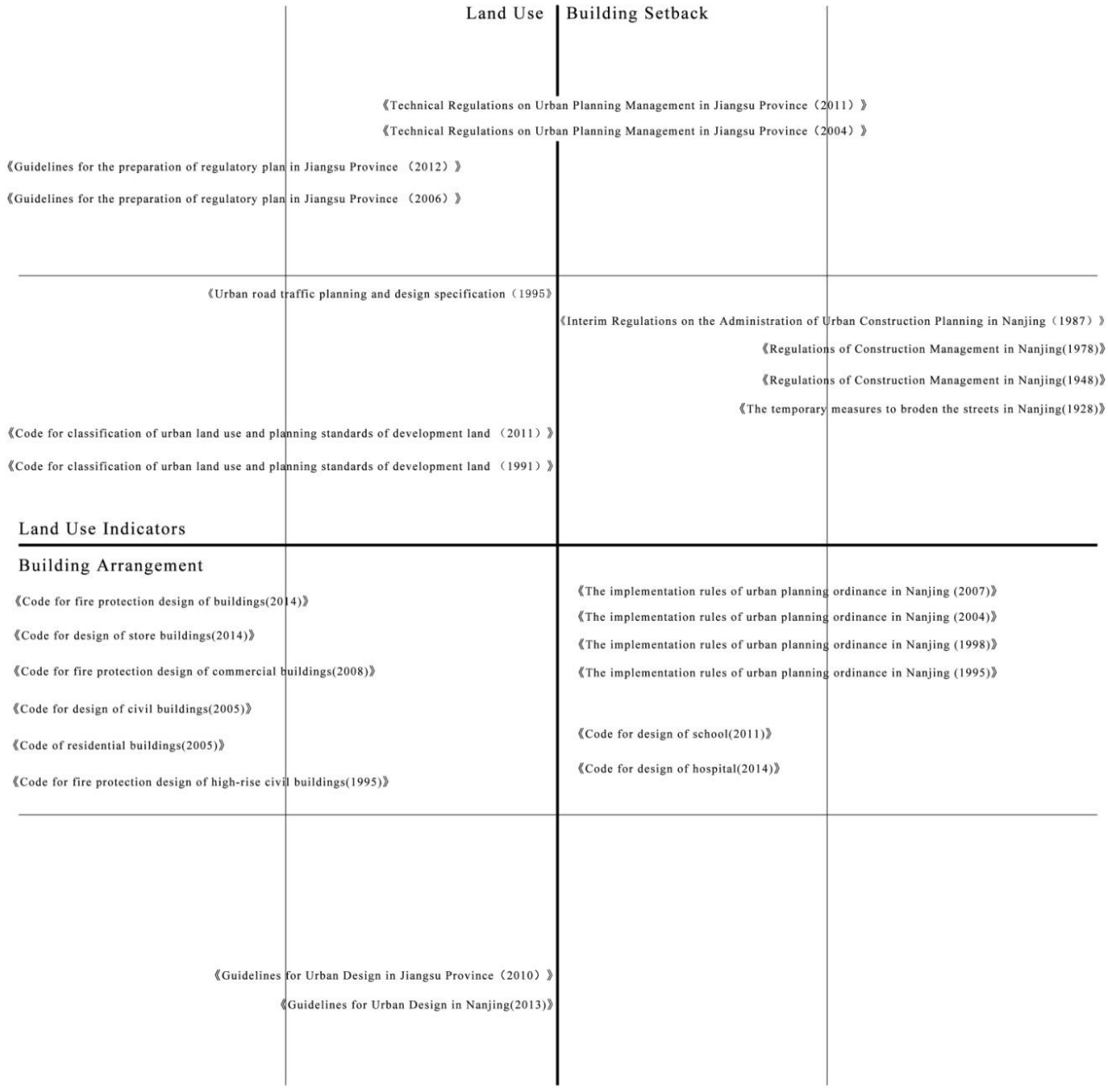


Figure 2. Mapping influences of urban regulations in Nanjing

Researches for building models

1. Identifying the street network in the model

In the studies of urban morphology, street networks, blocks and plots constitute three space scale concepts. Previous study has redefined the concepts of a block and a secondary block based on the road system of cities in China. Blocks are defined as the urban spaces enclosed by urban expressways, main roads and secondary roads. Secondary blocks are defined as the enclosed spaces created by the division of the block by branch roads based on land use and traffic

commands (Lin, 2014). In order to determine the street network in the model, two adjacent but totally different areas of Nanjing (an old urban area and a new district – Hexi) were selected as research cases. The researchers classified the blocks according to the characteristics of the block to determine the types of block in the model, and calculated the width of the blocks and secondary blocks adjacent to the expressway, the main road, and the secondary road to determine the block size. There are 290 blocks in these two areas, and these blocks were divided into 70 types according to the distribution characteristics of the branches within the block. These 70 type of blocks can be reclassified into 9 categories depending on the types of branch roads which can run through the block. We call these 9 types primary class block structures, and the 70 types – secondary class block structures (Fig. 3).

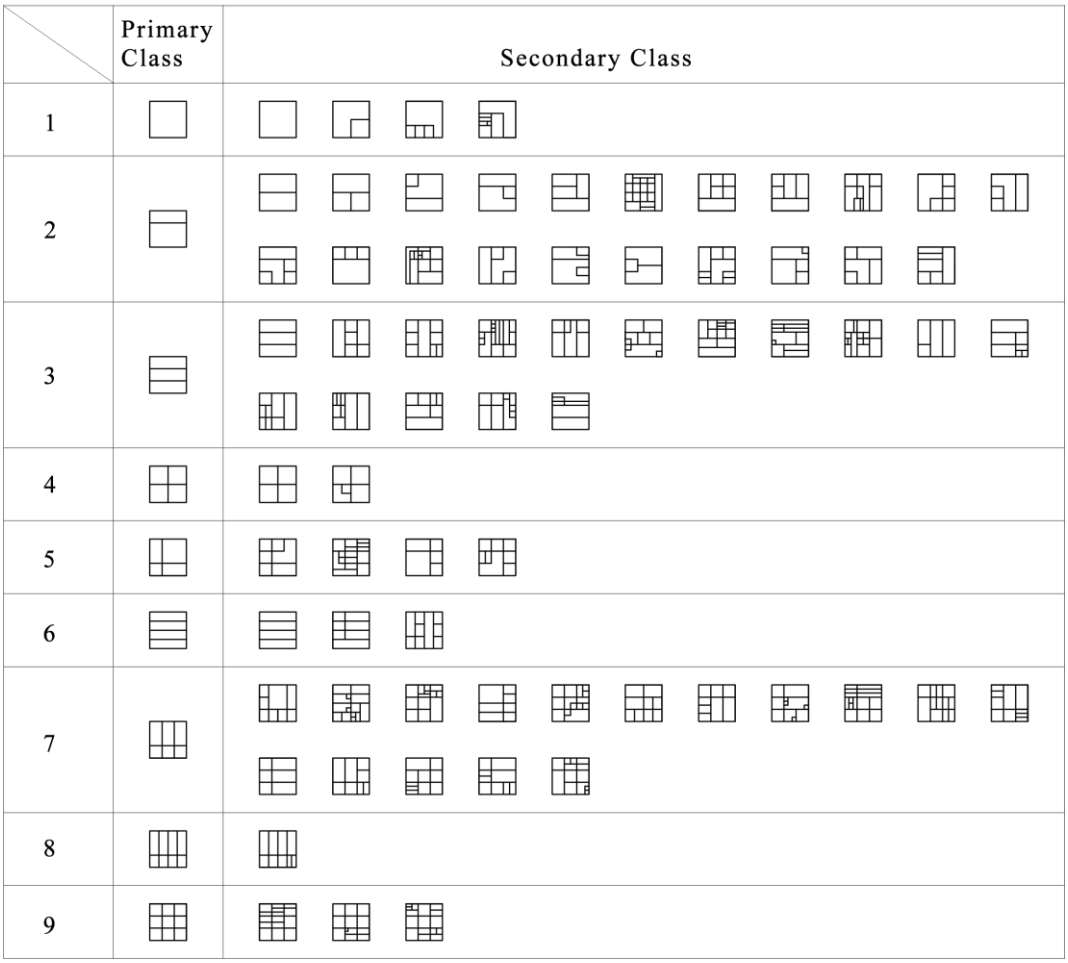


Figure 3. Primary Class and Secondary Class block structures

There are various possibilities of road types around these 9 primary class blocks. In order to determine the type of block in model, we numbered the block road type of these 9 primary class block structures and counted the quantity of each in Nanjing (Fig. 4). In addition, classes 2, 3, 6 and 7 were divided into two categories respectively, depending on the north-south direction or the east-west direction of branches. The east-west branches were indicated by capital letters, the north-south branches were indicated by lower-case letters, and the same letters were used for the same road conditions. For example, both 2B and 2b have an east-west main road and other three secondary roads, but the road branches are different in direction. Then, we elicited statistics for each type of block road (Fig. 5) and the length of the blocks (Fig. 6). Finally, types 1G, 2A, 3E, 4A, 5B, 6B, 7d, 8A and 9C were selected to make up the street network model, because they prevail in each of the 9 primary class block structures and the average width 500m was chosen as block side length for street network model (Fig. 7).

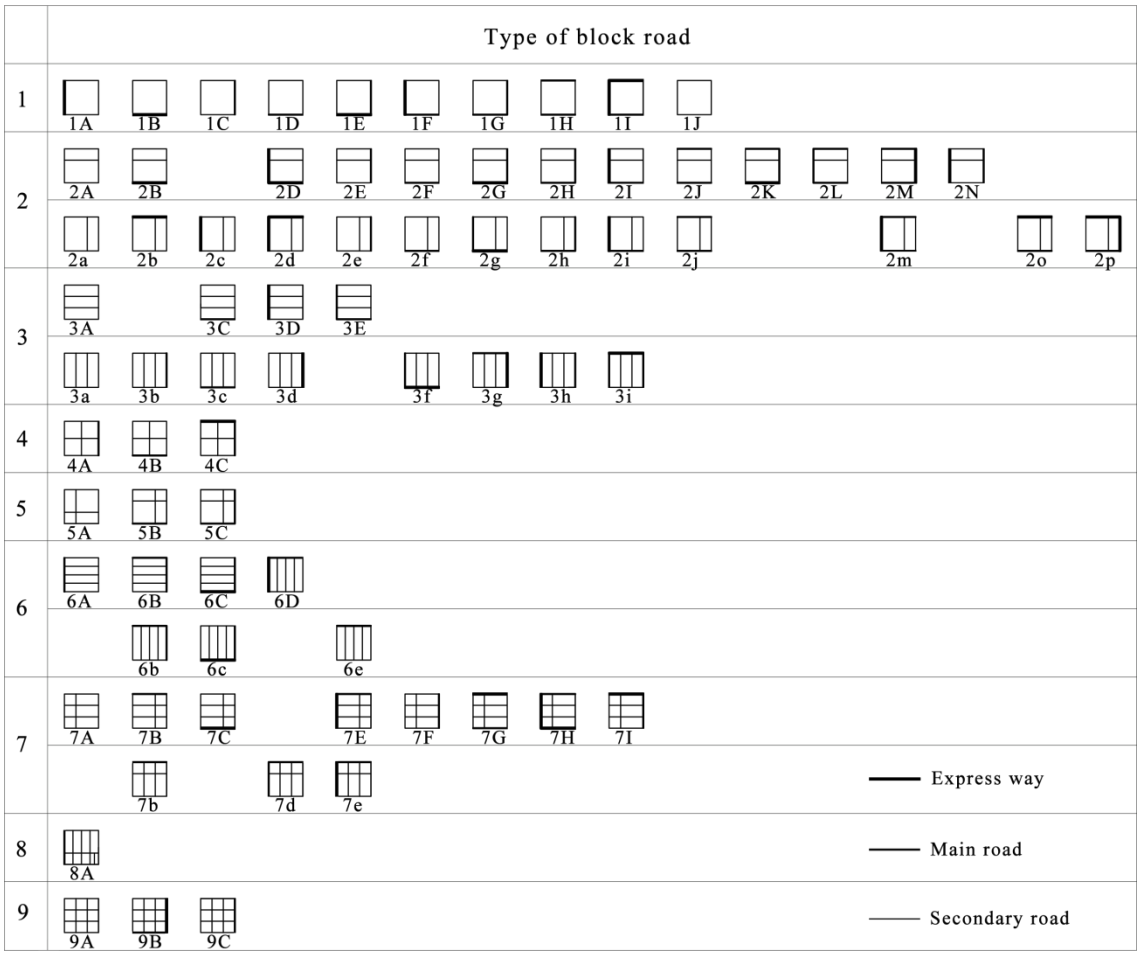


Figure 4. All types of the block roads for 9 Primary Class blocks in Nanjing

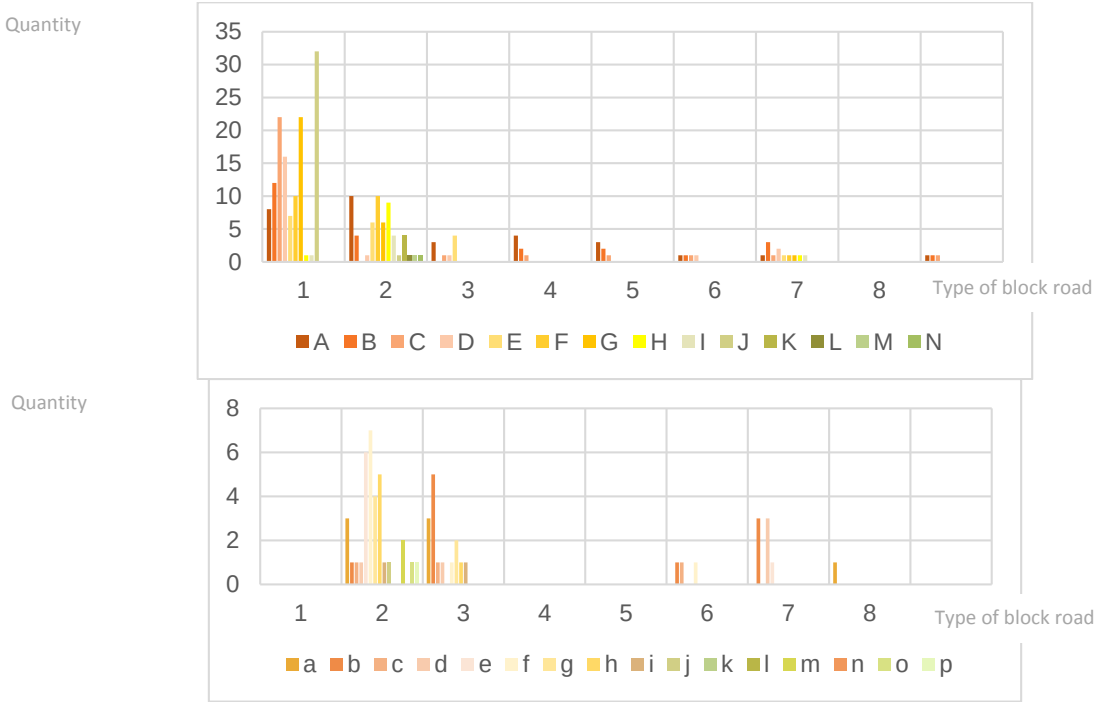


Figure 5. Statistics of each type of block road

Old town

Adjacent Road Type	Block Length		
	Max	Min	Mean
Expressway S-N	1417	141	710
Expressway E-W	1757	158	630
Main Road S-N	1273	140	592
Main Road E-W	1218	72	508
Secondary Road S-N	1935	76	509
Secondary Road E-W	1564	55	478

Hexi District

Adjacent Road Type	Block Length		
	Max	Min	Mean
Expressway S-N	1534	176	143
Expressway E-W	1671	157	480
Main Road S-N	948	117	420
Main Road E-W	1261	164	473
Secondary Road S-N	1307	140	415
Secondary Road E-W	1805	74	379

Figure 6. Statistics of block length

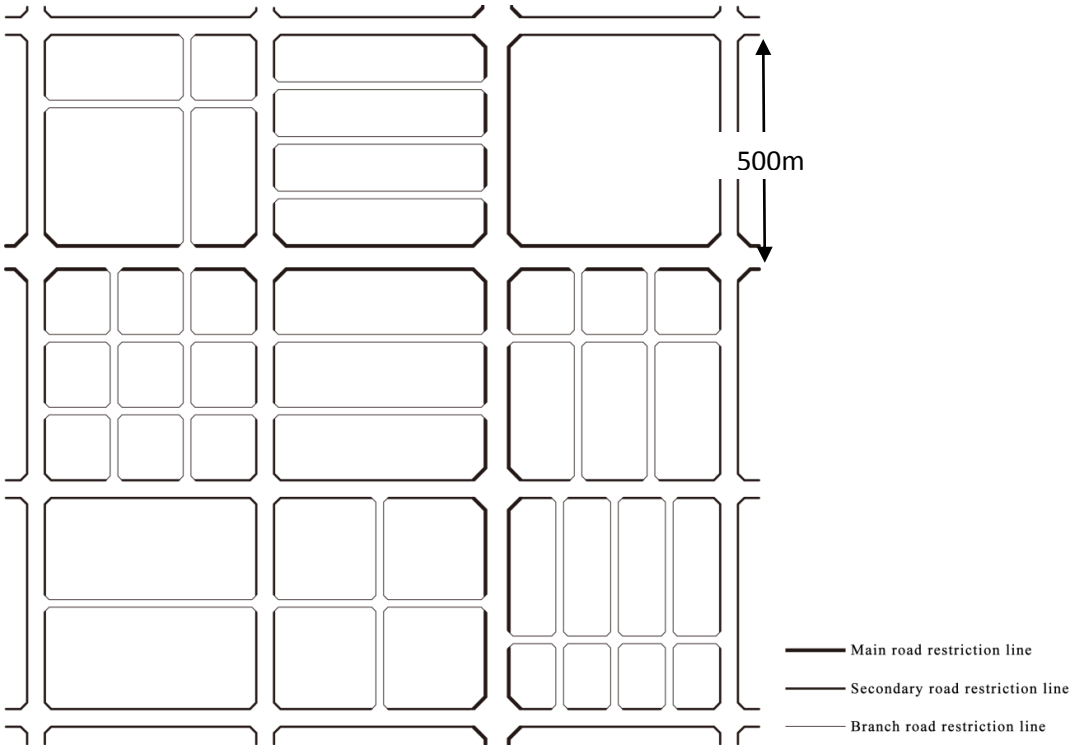


Figure 7. One of the most common street networks

3. Building forms in plot

The building forms were controlled by a series of building parameters which were regulated by urban regulations and design concepts, such as building setbacks for urban regulations and building setbacks for pedestrian plaza, landscape or entrance (Fig. 9).

There are four types of building layout in the plot: the building is located along the plot side, the building stands in the corner, the building is placed at the middle of the plot side and the building is situated in the centre of the plot. The building in the plot which is at the corner of the block tends to be placed at the corner of the plot or at the middle of the plot side. In addition to the building setbacks controlled by urban regulation, pedestrian plazas or outdoor parking lots would also be formed through the setback of building along the side of the plot, partially – through the setback of building at the corner of the plot or a U-shaped building enclosed plaza in the middle of the plot. We can get various building walls by changing the parameters, based on the urban regulations and the designer intention (Fig. 9).

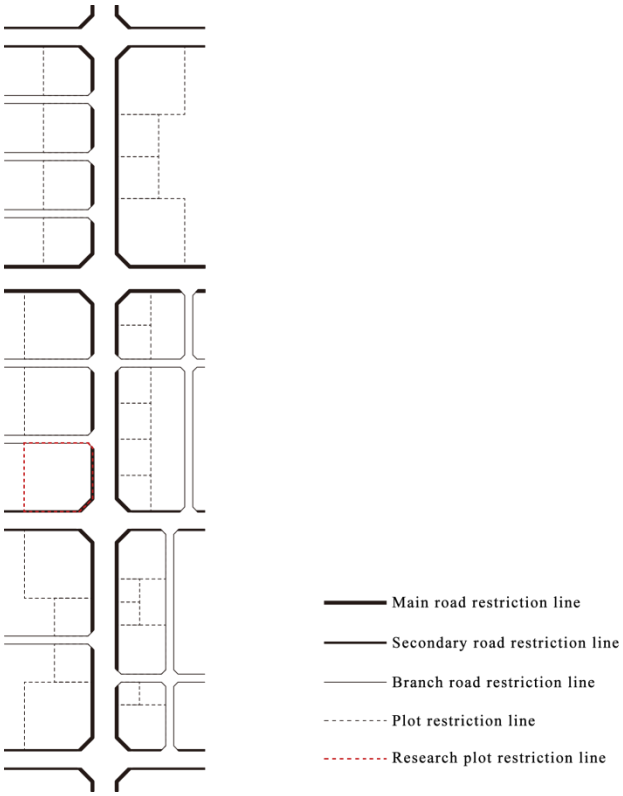


Figure 8. One of the plot divisions alongside the main road

The area of the selected plot is 23,000m^2 in the area range which exceeds 10,000m^2. In order to explore the effects of land use and land use indicators on building form, we chose two groups of variables for research. The first variable is land use. According to No.2.3.3 regulation on building density and floor area ratio of various types of building plots in "Technical Regulations on Urban Planning Management in Jiangsu Province (2011)", we chose a pair of the applicable variables for building density and floor area ratio – 35% and 2.5 for the plot used as commercial, office, mixed-use area, another pair of the applicable variables – building density and floor area ratio of 24% and 2.2 for residential buildings and secondary school for 16 tracks and 48 classes. The second group of variables is land use indicators – building density and floor area ratio. We set the plot as a commercial plot and chose three groups of building density and floor area ratio, respectively 35% and 2.5, 45% and 3, 55% and 4. As for the land use indicators of public building plot, the building tends to be placed at the corner of the plot or at the middle of the plot side when the area of plot is in the 5,000m^2-30,000m^2 range, according to the statistical results (Zheng, 2016), these arrangements provide venues for public spaces along the street. Besides, the buildings may be arranged along the road in order to obtain the largest commercial side.

3.1 The effects of land use on building forms

3.1.1 Building forms of public buildings

Here are some common dimensions of public buildings in Chinese concept. The depth of commercial buildings is 40-200 meters, centralized office buildings are 20-40 meters in depth and linear high-rise office buildings and hotels are about 20 meters along the short side and 70 meters – along the long side. The typical floor area of a high-rise tower has three levels: the small one is 500-1,000m^2, mostly it is characteristic of hotels and small office buildings; the medium is 1,000-2,000m^2, and large-scale is mostly 2000-2500m^2. Based on the above rules, this study draws out building forms of commercial, office, and mixed-use buildings, and divide the public building forms into four categories to facilitate research results (Fig. 10).

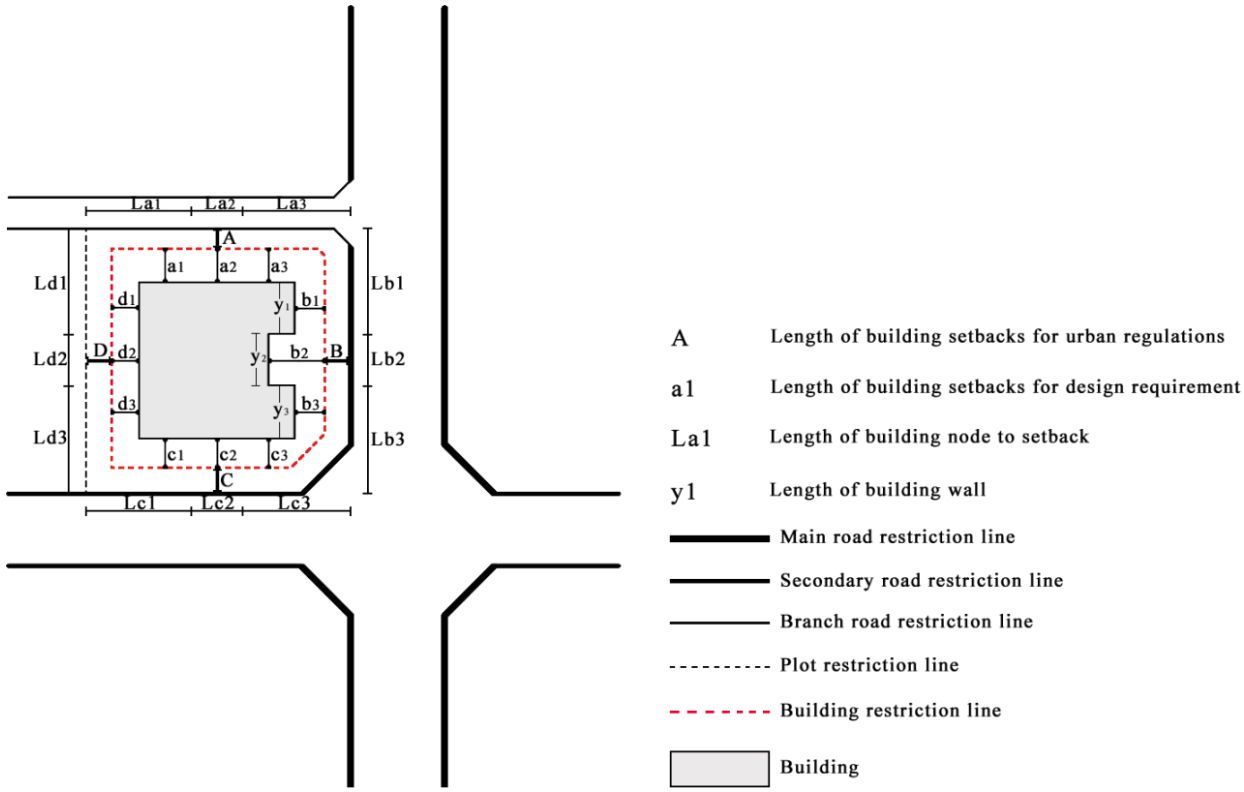
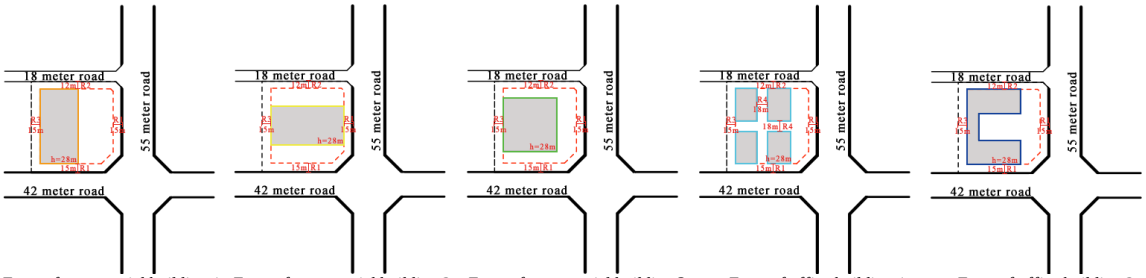
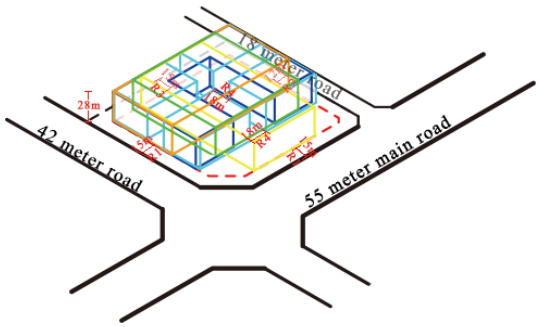


Figure 9. Parameters for building form controlling

Type1: Commercial buildings and office buildings. On the premise of mandatory meeting the regulations of building setbacks for land boundary and fire protection, the building backs away from plot boundary alongside the main road to form a public space site.



Form of commercial building 1 Form of commercial building 2 Form of commercial building 3 Form of office building 1 Form of office building 2



Building axonometric drawing overlap

R1: NO.42.1.2 When the width of urban road is more than 30m, the building setback for road shall be no less than 15 meters when the building height exceeds 24 meters and does not exceed 100 meters.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

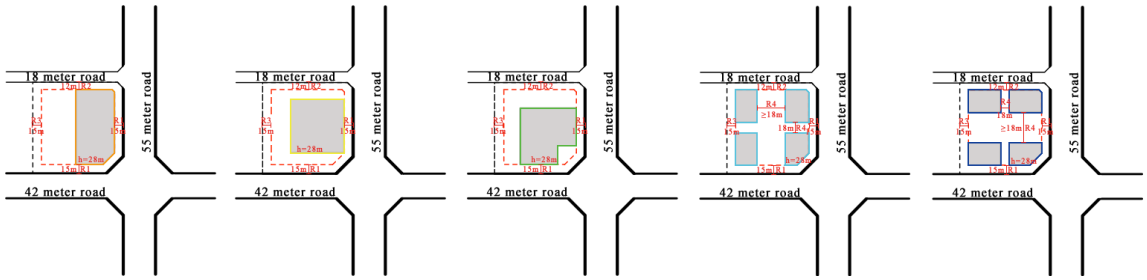
R2: NO.42.2.2 When the width of urban road is less than 30m, the building setback for road shall be no less than 12 meters when the building height exceeds 24 meters and does not exceed 100 meters.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

R3: NO.44.2 When the width of the high-rise building is more than 25 meters, the building setback for land boundary is not less than 15 meters.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

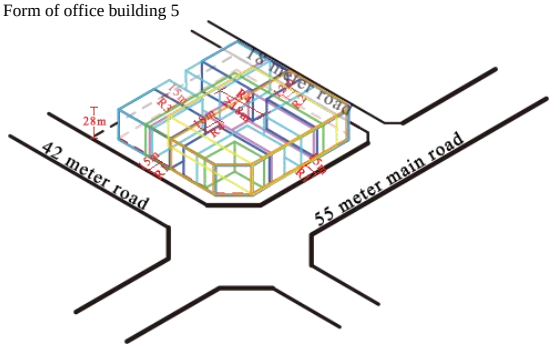
R4: NO.3.2.10 The minimum spacing between high-rise buildings is no less than 18 meters.
—— 《Technical Regulations on Urban Planning Management in Jiangsu Province（2011）》

Regulations used to control building forms

Type2: Commercial building and office building. On the premise of mandatory meeting the regulations of building setbacks for road and fire protection, the building stands near the plot boundary alongside the main road.



Form of commercial building 4 Form of commercial building 5 Form of commercial building 6 Form of office building3 Form of office building 4 Form of office building 5



Building axonometric drawing overlap

R1: NO.42.1.2 When the width of urban road is more than 30m, the building setback for road shall be no less than 15 meters when the building height exceeds 24 meters and does not exceed 100 meters.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

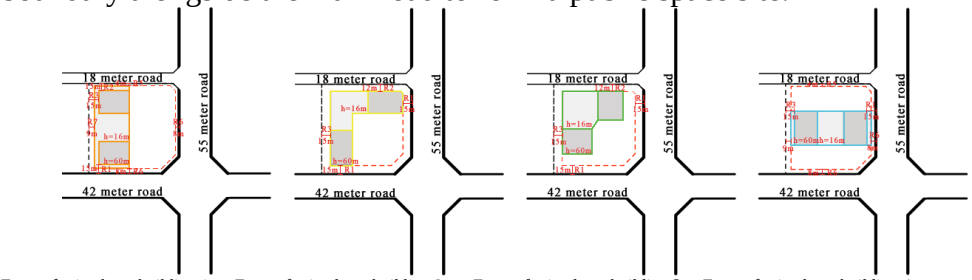
R2: NO.42.2.1 When the width of urban road is less than 30m, the building setback for road shall be no less than 12 meters when the building height exceeds 24 meters and does not exceed 100 meters.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

R3: NO.44.2 When the width of the high-rise building is more than 25 meters, the building setback for land boundary is not less than 15 meters.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

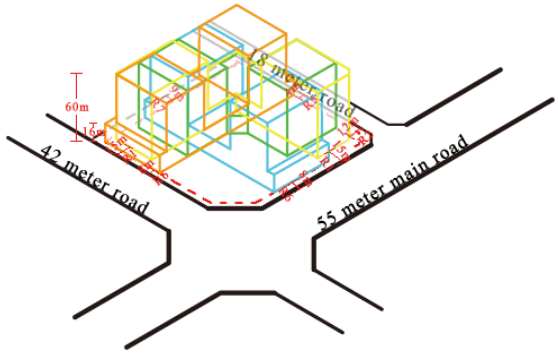
R4: NO.3.2.10 The minimum spacing between high-rise buildings is no less than 18 meters.
—— 《Technical Regulations on Urban Planning Management in Jiangsu Province（2011）》

Regulations used to control building form

Type 3: Mixed-use building. On the premise of mandatory meeting the regulations of building setbacks for land boundary and fire protection, the building backs away from plot boundary alongside the main road to form a public space site.



Form of mixed-use building 1 Form of mixed-use building 2 Form of mixed-use building 3 Form of mixed-use building 4



Building axonometric drawing overlap

R1: NO.42.1.2 When the width of urban road is more than 30m, the building setback for road shall be no less than 15 meters when the building height exceeds 24 meters and does not exceed 100 meters.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

R2: NO.42.2.2 When the width of urban road is less than 30m, the building setback for road shall be no less than 12 meters when the building height exceeds 24 meters and does not exceed 100 meters.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

R3: NO.44.2 When the width of the high-rise building is more than 25 meters, the building setback for land boundary is not less than 15 meters.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

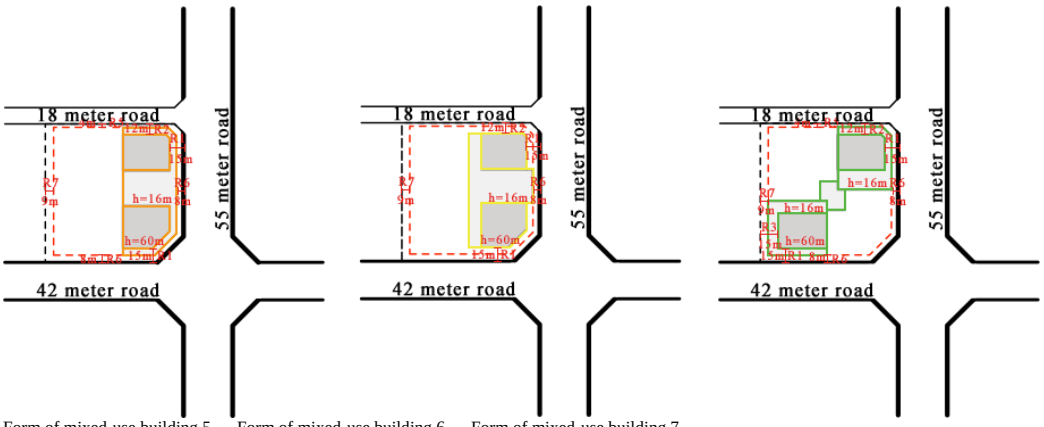
R5: NO.42.2.1 When the width of urban road is less than 30m, the building setback for road shall be no less than 4 meters when the building height does not exceed 24 meters.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

R6: NO.3.3.4.5 When the width of urban road is less than 40m, the building setback for road around the urban road intersection shall be no less than 8 meters when the building height does not exceed 24 meters.
—— 《Technical Regulations on Urban Planning Management in Jiangsu Province（2011）》

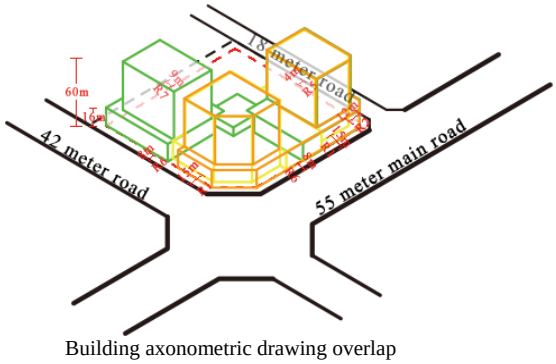
R7: NO.7.1.8 The net width and height of the fire lane must be no less than 4 meters.The edge of the fire lane against the external wall of the building should not be less than 5 meters and more than 10 meters.
—— 《Codes for fire protection design of buildings（2014）》

Regulations used to control building form

Type 4: Mixed-use building. On the premise of mandatory meeting the regulations of building setbacks for the road and fire protection, the building stands near the plot boundary alongside the main road.



Form of mixed-use building 5 Form of mixed-use building 6 Form of mixed-use building 7



Building axonometric drawing overlap

R1: NO.42.1.2 When the width of urban road is more than 30m, the building setback for road shall be no less than 15 meters when the building height exceeds 24 meters and does not exceed 100 meters.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

R2: NO.42.2.2 When the width of urban road is less than 30m, the building setback for road shall be no less than 12 meters when the building height exceeds 24 meters and does not exceed 100 meters.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

R3: NO.44.2 When the width of the high-rise building is more than 25 meters, the building setback for land boundary is not less than 15 meters.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

R5: NO.42.2.1 When the width of urban road is less than 30m, the building setback for road shall be no less than 4 meters when the building height does not exceed 24 meters.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

R6: NO.3.3.4.5 When the width of urban road is less than 40m, the building setback for road around the urban road intersection shall be no less than 8 meters when the building height does not exceed 24 meters.
—— 《Technical Regulations on Urban Planning Management in Jiangsu Province（2011）》

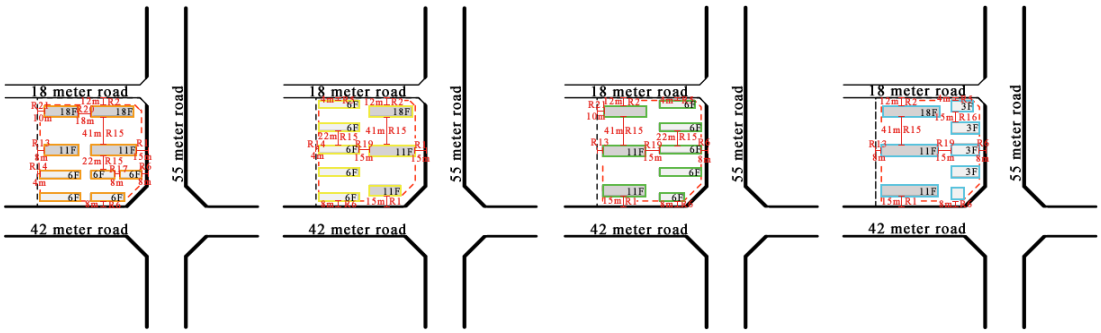
R7: NO.7.1.8 The net width and height of the fire lane must be no less than 4 meters.The edge of the fire lane against the external wall of the building should not be less than 5 meters and more than 10meters.
—— 《Codes for fire protection design of buildings（2014）》

Regulations used to control building form

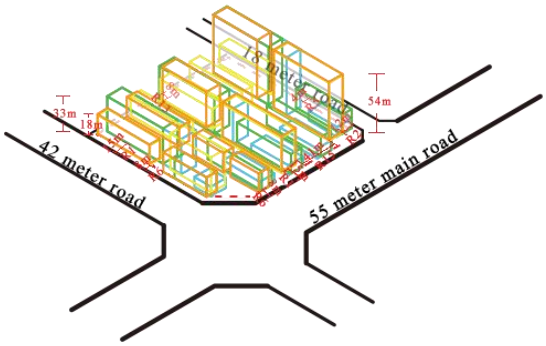
Figure 10. The form mechanism of public buildings (BD:35%, FAR:2.5)

3.1.2 Building forms of residential buildings

Here are some common dimensions of residences in Chinese concept. The length of 6-storey residential building is 30-60 meters and the width is 10-15 meters. 11-storey residential buildings and 18-storey residential buildings are 30-80 meters in length and 11-15 meters in width. The layout of residential buildings is controlled by regulations such as building setbacks for the road and plot boundary, the spacing of sunlight, building spacing and fire protection (Fig.11).



Form of residence 1 Form of residence 2 Form of residence 3 Form of residence 4



Building axonometric drawing overlap

R1: NO.42.1.2 When the width of urban road is more than 30m, the building setback for road shall be no less than 15 meters when the building height exceeds 24 meters and does not exceed 100 meters.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

R2: NO.42.2.2 When the width of urban road is less than 30m, the building setback for road shall be no less than 12 meters when the building height exceeds 24 meters and does not exceed 100 meters.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

R5: NO.42.2.1 When the width of urban road is less than 30m, the building setback for road shall be no less than 4 meters when the building height does not exceed 24 meters.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

R6: NO.3.3.4.5 When the width of urban road is less than 40m, the building setback for road around the urban road intersection shall be no less than 8 meters when the building height does not exceed 24 meters.
—— 《Technical Regulations on Urban Planning Management in Jiangsu Province（2011）》

R13: NO.44.2 When the width of the small high-rise building is less than 20 meters, the building setback for land boundary is not less than 8 meters.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

R14: NO.44.2 When the width of the multi-story building is less than 15 meters, the building setback for land boundary is not less than 4 meters.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

R15: NO.43.1 When low-rise residential buildings, multi-story residential buildings, small high-rise residential buildings and sheltered residential are arranged in parallel, the spacing is controlled by the building spacing coefficient.The building spacing coefficient in Nanjing is no less than 1.3.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

R16: NO.43.3 When low-rise residential buildings are arranged in parellel, the spacing between them is no less than 15 meters.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

R17: NO.43.3 When low-rise residential buildings are arranged in abreast, the spacing between them is no less than 8 meters.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

R18: NO.43.3 When low-rise residential buildings and the high-rise residential buildings are arranged in abreast, the spacing between them is no less than 15 meters.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

R19: NO.43.3 When multi-story residential buildings and the high-rise residential buildings are arranged in abreast, the spacing between them is no less than 15 meters.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

R20: NO.43.3 When high-rise residential buildings are arranged in abreast, the spacing between them is no less than 18 meters.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

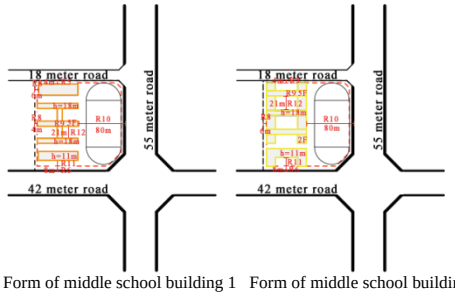
R21: NO.44.2 When the width of the high-rise building is less than 25 meters, the building setback for land boundary is not less than 10 meters.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

Regulations used to control building form

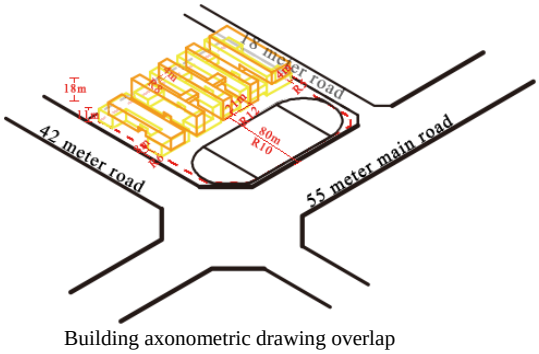
Figure 11. The form mechanism of residence (BD:24%, FAR:2.2)

3.1.3 Building forms of campus

The storey of main teaching rooms in primary and secondary schools is limited by regulations, and main teaching rooms are under the control of the spacing of sunlight and noise protection as well. In addition, the school buildings need to maintain good connections with each other (Fig. 12).



Form of middle school building 1 Form of middle school building 2



Building axonometric drawing overlap

R5: NO.42.2.1 When the width of urban road is less than 30m, the building setback for road shall be no less than 4 meters when the building height does not exceed 24 meters.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

R6: NO.3.3.4.5 When the width of urban road is less than 40m, the building setback for road around the urban road intersection shall be no less than 8 meters when the building height does not exceed 24 meters.
—— 《Technical Regulations on Urban Planning Management in Jiangsu Province（2011）》

R8: NO.44.2 When the width of the multi-story building is less than 15 meters, the building setback for land boundary is not less than 4 meters.When the width of the multi-story building is more than 15 meters, the building setback for land boundary is not less than 6 meters.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

R9: NO.4.3.2 The main teaching rooms in all types of secondary schools should not be located above the 5th floor.
—— 《Codes for Primary and secondary school design（2011）》

R10: NO.4.1.6 The distance between the external wall of the main teaching room and urban main road shall be no less than 80 meters.
—— 《Codes for Primary and secondary school design（2011）》

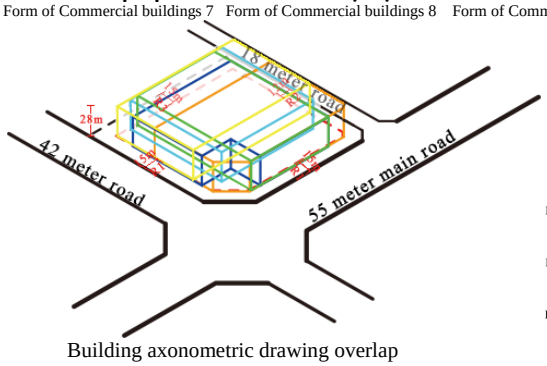
R11: NO.8.3.1 Primary and middle campus should have 2 entrances, entrances should not be connected to the urban main roads and buffering sites should be set on the main entrances campus.
—— 《Codes for Primary and secondary school design（2011）》

R12: NO.43.6 The spacing of common classrooms in primary and secondary schools is controlled by the building spacing coefficient.The building spacing coefficient in Nanjing is no less than 1.3.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

Regulations used to control building form

Figure 12. The form mechanism of secondary school buildings

Form of Commercial buildings 7 Form of Commercial buildings 8 Form of Commercial buildings 9 Form of Commercial buildings 10 Form of Commercial buildings 11



Building axonometric drawing overlap

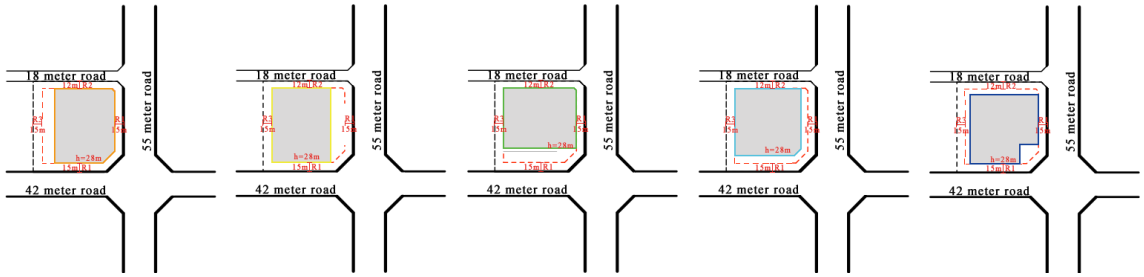
R1: NO.42.1.2 When the width of urban road is more than 30m, the building setback for road shall be no less than 15 meters when the building height exceeds 24 meters and does not exceed 100 meters.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

R2: NO.42.2.2 When the width of urban road is less than 30m, the building setback for road shall be no less than 12 meters when the building height exceeds 24 meters and does not exceed 100 meters.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

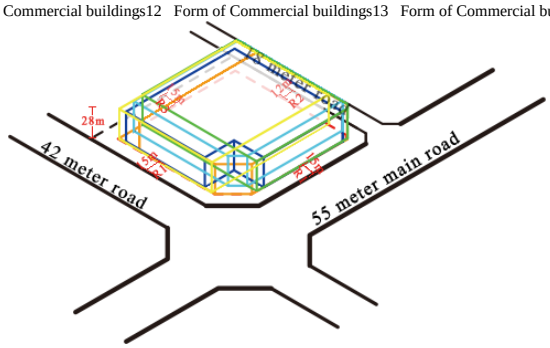
R4: NO.3.2.10 The minimum spacing between high-rise buildings is no less than 18 meters.
—— 《Technical Regulations on Urban Planning Management in Jiangsu Province（2011）》

Regulations used to control building form

Figure 13. The form mechanism of commercial buildings (BD:45%, FAR:3)



Commercial buildings12 Form of Commercial buildings13 Form of Commercial buildings14 Form of Commercial buildings15 Form of Commercial buildings16 Form of



Building axonometric drawing overlap

R1: NO.42.1.2 When the width of urban road is more than 30m, the building setback for road shall be no less than 15 meters when the building height exceeds 24 meters and does not exceed 100 meters.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

R2: NO.42.2.2 When the width of urban road is less than 30m, the building setback for road shall be no less than 12 meters when the building height exceeds 24 meters and does not exceed 100 meters.
—— 《The implementation rules of urban planning ordinance in Nanjing (2007)》

R4: NO.3.2.10 The minimum spacing between high-rise buildings is no less than 18 meters.
—— 《Technical Regulations on Urban Planning Management in Jiangsu Province（2011）》

Regulations used to control building form

Figure 14. The form mechanism of commercial buildings (BD:55%, FAR:4)

3.2 The effects of land use indicators on building forms

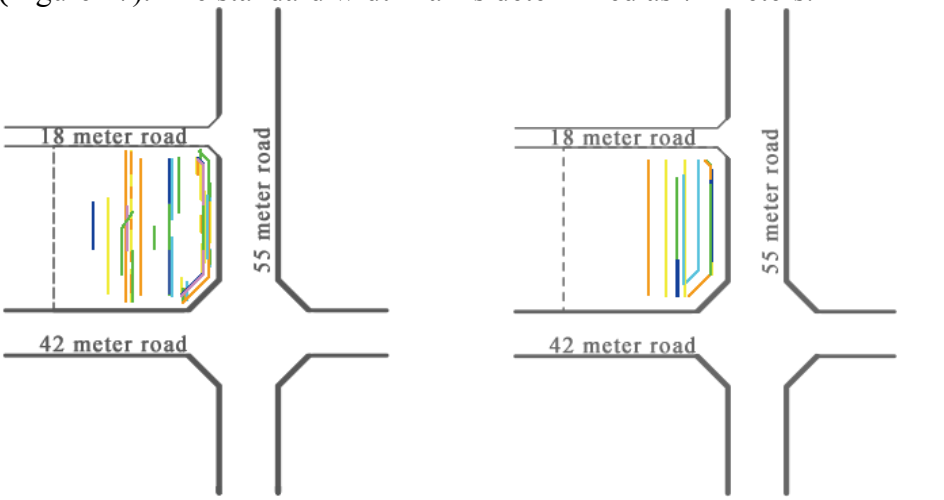
3.2.1 Building forms of commercial buildings when the building density and floor area ratio are 45% and 3 (Fig.13).

3.2.2 Building forms of Commercial buildings when the building density and floor area ratio are 55% and 4 (Fig. 14).

Discussion

There are many types of building forms for the selected plots under the control of a certain building density and floor area ratio and land use. We can find that the building walls were

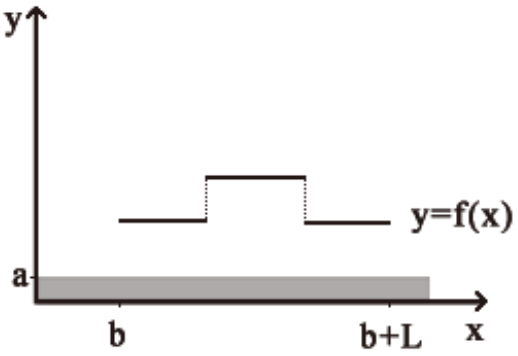
complicated when they aggregated all types of building forms (Figure 15). Zhou (2012) established the concept of "relevance of the wall" of the street, which is used to describe the overall differences of the street wall to grasp the spatial perception of the street wall, wall density and near-line ratio in it. Wall density refers to the ratio of the building projection width along the street to the length of the street. The near-line ratio (N) characterizes the positional relationship of the street wall, which is the ratio of the distance formed by y=f(x) and *x* to the standard width "a" (the distance between most buildings on both sides of the street) (Figure 16). This paper uses the two parameters – wall density and near-line ratio to describe the features of the building wall (Figure 17). The standard width "a" is determined as 71 meters.



Building wall overlap for different land use

Building wall overlap for different land use indicators

Figure 15. Building walls of plot



$$\text{当 } f(x) \geqslant a \text{ 时，} \quad N=\frac{1}{L}\int_{b}^{b+L}\frac{a}{f(x)}dx$$

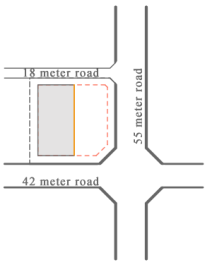
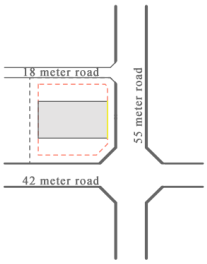
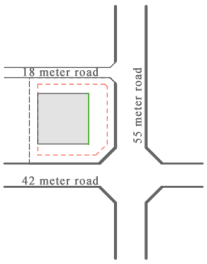
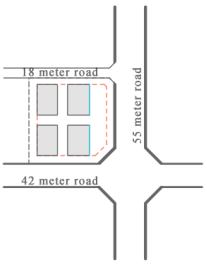
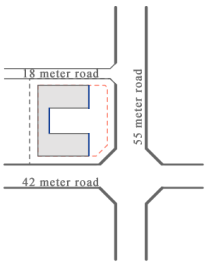
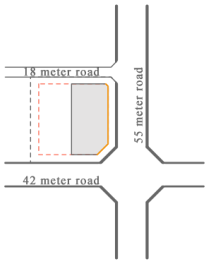
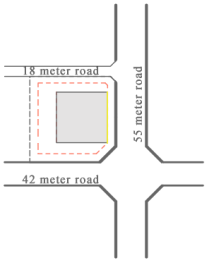
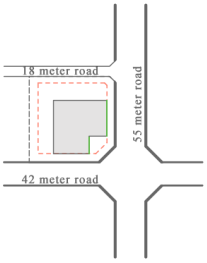
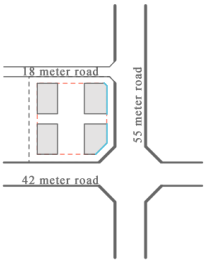
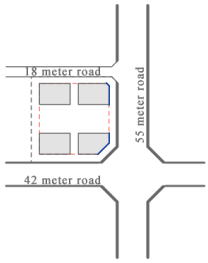
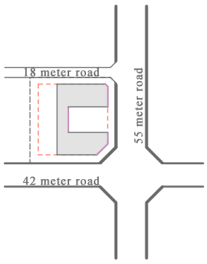
$$\text{当 } f(x) \leqslant a \text{ 时，} \quad N=\frac{1}{L}\int_{b}^{b+L}\frac{f(x)}{a}dx$$

Figure 16. Calculation formula of near-line ratio

After calculating, we got the information that when a commercial building is built in a plot with an area of 23,000m^2, building density of 35% and floor area ratio of 2.5, the maximum wall density and near-line ratio are 0.82 and 0.91, the minimum wall density and near-line ratio are 0.42 and 0.52. When an office building is built in this plot, the maximum wall density and near-line ratio are 0.82 and 0.91, the minimum wall density and near-line ratio are 0.49 and 0.52 (Table 1.1). When a mixed-use building is built in the plot, the maximum wall density and near-line ratio are 0.92 and 1, the minimum wall density and near-line ratio are 0.37 and 0.47 (Table 1.2). When the plot was determined as a residential plot with building density of 24% and floor area ratio of 2.2, the maximum wall density and near-line ratio are 0.51 and 0.92, the minimum wall density and near-line ratio are 0.29 and 0.83 (Table 1.3). If the size is 16 tracks and 48 classes of a secondary school, the maximum wall density and near-line ratio are 0.84 and 0.5, the minimum wall density and near-line ratio are 0.39 and 0.5 (Table 1.4). On the other hand, we conclude that for a plot with building density of 35% and floor area ratio of 2.5, the maximum

wall density of 0.92 and the maximum near-line ratio of 1 are obtained when the high-rise buildings with multi-storey podiums are situated along the street, the minimum wall density of 0.29 is acquired in residential area, the minimum near-line ratio of 0.47 is obtained when a building backs away from plot boundary alongside the main road to form a public space site.

Table 1.1: Wall density and near-line ratio of a commercial building and an office building

				
Wall Density: 0.82	Wall Density: 0.42	Wall Density: 0.58	Wall Density: 0.70	Wall Density: 0.82
Near-line Ratio: 0.52	Near-line Ratio: 0.91	Near-line Ratio: 0.64	Near-line Ratio: 0.66	Near-line Ratio: 0.52
				
Wall Density: 0.82	Wall Density: 0.58	Wall Density: 0.62	Wall Density: 0.70	Wall Density: 0.49
Near-line Ratio: 0.91	Near-line Ratio: 0.91	Near-line Ratio: 0.80	Near-line Ratio: 0.91	Near-line Ratio: 0.91
				
Wall Density: 0.82				
Near-line Ratio: 0.69				

For a commercial plot with building density of 35% and floor area ratio of 2.5, the maximum wall density and near-line ratio are 0.82 and 0.91, the minimum wall density and near-line ratio are 0.42 and 0.52 (Table 1.1). When the building density becomes 45% and floor area ratio reaches 3, the maximum wall density and near-line ratio are 0.82 and 0.91, the minimum wall density and near-line ratio are 0.54 and 0.59 (Table 2.1). When the building density becomes 55% and floor area ratio reaches 4, the maximum wall density and near-line ratio are 0.82 and 0.91, the minimum wall density and near-line ratio are 0.67 and 0.70 (Table 2.2). With the increase of building density and floor area ratio, the minimum wall density and near-line ratio are also growing.

Table 1.2: Wall density and near-line ratio of a mixed-use building

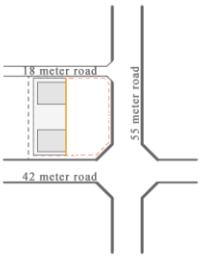
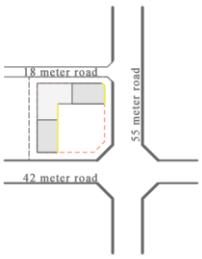
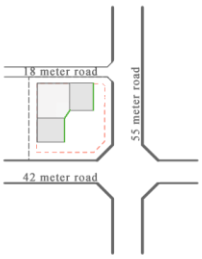
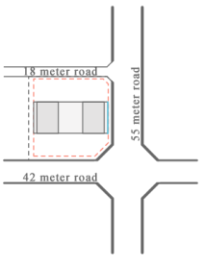
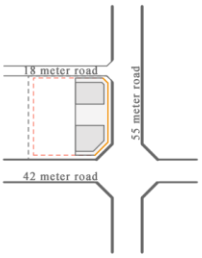
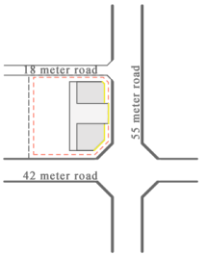
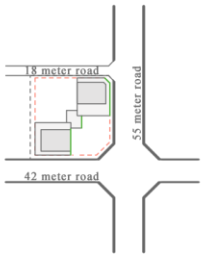
			
Wall Density: 0.92	Wall Density: 0.82	Wall Density: 0.68	Wall Density: 0.37
Near-line Ratio: 0.47	Near-line Ratio: 0.51	Near-line Ratio: 0.57	Near-line Ratio: 1
			
Wall Density: 0.92	Wall Density: 0.82	Wall Density: 0.92	
Near-line Ratio: 1	Near-line Ratio: 0.93	Near-line Ratio: 0.66	

Table 1.3: Wall density and near-line ratio of a residential building

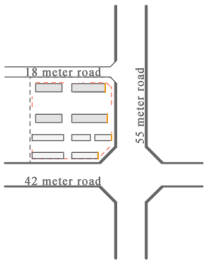
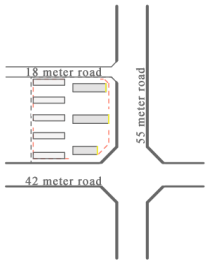
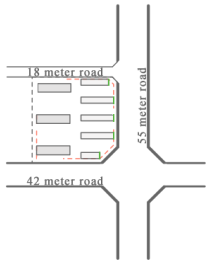
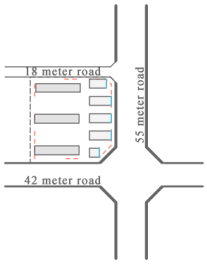
			
Wall Density: 0.33	Wall Density: 0.29	Wall Density: 0.35	Wall Density: 0.51
Near-line Ratio: 0.87	Near-line Ratio: 0.83	Near-line Ratio: 0.91	Near-line Ratio: 0.92

Table 1.4: Wall density and near-line ratio of a secondary school building

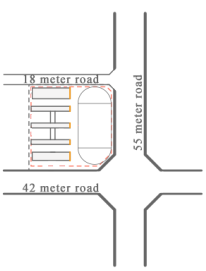
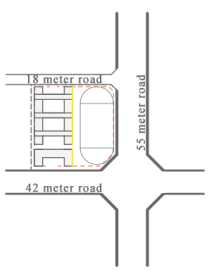
	
Wall Density: 0.39	Wall Density: 0.84
Near-line Ratio: 0.50	Near-line Ratio: 0.50

Figure 17. Wall density and near-line ratio of building wall on land use

Table 2.1: Wall density and near-line ratio of a commercial building ((BD:45%, FAR:3)

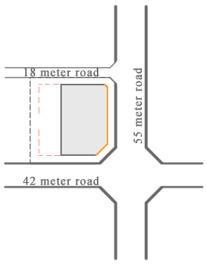
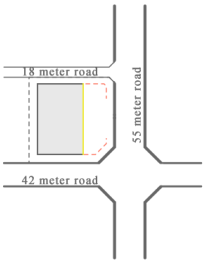
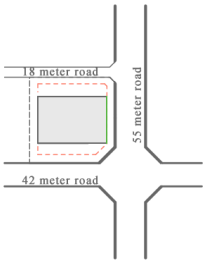
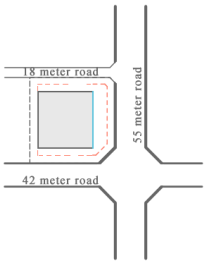
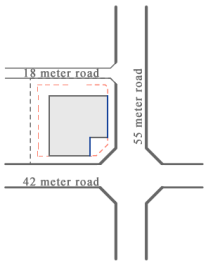
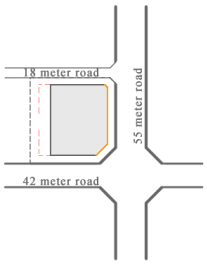
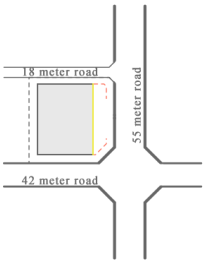
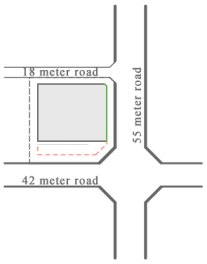
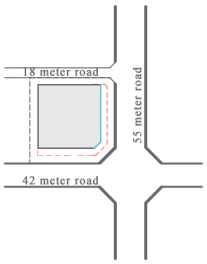
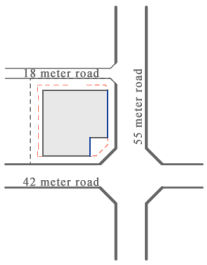
				
Wall Density: 0.82	Wall Density: 0.82	Wall Density: 0.54	Wall Density: 0.65	Wall Density: 0.69
Near-line Ratio: 0.91	Near-line Ratio: 0.59	Near-line Ratio: 0.91	Near-line Ratio: 0.69	Near-line Ratio: 0.81

Table 2.2: Wall Density and Near-line Ratio of Commercial building ((BD:55%, FAR:4)

				
Wall Density: 0.82	Wall Density: 0.82	Wall Density: 0.67	Wall Density: 0.74	Wall Density: 0.76
Near-line Ratio: 0.91	Near-line Ratio: 0.70	Near-line Ratio: 0.91	Near-line Ratio: 0.79	Near-line Ratio: 0.82

Conclusion

The paper describes a method to study the relationship between urban codings and street spatial configuration. Based on this method, we can create a database covering all types of building forms. The researchers selected a plot as research object to explore the building forms under the influence of land use, land use indicators, design concepts and latest urban regulations, then used wall density and near-line ratio to reflect people's perception of the building wall. We can draw a conclusion that the value range of street wall evaluation parameters was affected by urban regulations, land use, land use indicators, street width and so on, and these also became the limitations of urban design. Appropriate value of street wall evaluation parameters depends on consideration of the overall factors and more studies on building forms under the contorl of different plot size, urban regulations of different years and various building densities and floor area ratios.

Acknowledgments

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Illustrations