IOP Conf. Series: Materials Science and Engineering **730** (2020) 012021 doi:10.1088/1757-899X/730/1/012021

Construction and Application of Height Control Model of Urban Building based on GIS: Taking Guanyun County as an Example

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Abstract. It has become an urgent demand of urban residents to shape the appropriate urban space style and strengthen the sharing of landscape resources through the height control of urban buildings. Starting from the visual corridor of urban landscape, taking Guanyun County , Jiangsu Province as an example , a scientific and efficient height control model and planning technical framework for urban buildings were constructed based on GIS. Based on the demonstration of the surrounding area of Dayi Mountain in Guanyun County, scientific viewpoint selection and multi-dimensional line-of-sight control analysis were carried out to construct the three-level urban building height control model: reference model of urban height control, modified model of urban height control, status quo correction model of urban height control. Finally, the height control zones of urban buildings were divided and planning guidelines were proposed. It can provide reference for the research on height control of urban buildings and related planning and construction.

1. Introduction

In 2013, the central urbanization work conference proposed that "relying on the existing landscape context and other unique scenery, let the city blend in with nature, so that residents can see mountains, water and remember homesickness ". As a concrete expression of the vertical dimension of urban space, the height of urban buildings is an important window to display overall landscape pattern and overall spatial form of a city. In the process of urban overall planning and design, both the urban spatial form design at the overall level and landmark system, visual corridor system and skyline landscape planning at the sector level are closely related to the urban height form. Therefore, the overall planning and design for the height of the city is very necessary.

Building height control on the overall level of a city was traced back to Urban Beautification Movement and Zoning regulations[1] that emerged successively in western countries in the 19th century .Its core idea is to strengthen the control ability of the height of urban buildings and realize overall order of urban space through targeted planning, design and control strategy. At present, relevant researches at home and abroad are classified into three types:(1) Traditional methods of urban vertical control based on intuitive judgment. In order to realize the overall control of urban vertical form, the corresponding height limits for different types of blocks or land are set qualitatively. This method is suitable for macro and overall control, but it relies more on the intuitive judgment of the planner. Typical applications included the height control of the old city of Paris in France and the height control zoning of the ancient city of Matsumoto in Japan[2]. At the beginning of this century, Beijing also applied this height control method to protect the historical features of the ancient capital[3]. With expansion of urban scale and increasing complexity of urban structure, it was difficult to accurately grasp the overall urban pattern by relying solely on the subjective judgment of planners. (2) Quantitative instrumental assistance such as multi-factor evaluation method based on GIS database. This method was widely practiced in China. For example, based on the conditions of urban spatial development and layout of Nanjing City, we the impact evaluation factors were determined, including historical features, land price, accessibility, culture, construction potential and urban landscape and proposed specific optimization plan[4]. The method was also been applied in Hangzhou, Qingdao and other cities[5, 8]. (3) Visual analysis based on aesthetic perception, that is, the vertical form control method through human visual perception. It was mainly applied in the specific key areas of city. It can obtain the precise limit of vertical form control through the field landscape feedback and become a supplement to overall vertical form control.

In London, "strategic overlooking control" was put forward. In China, Weihai, Jianou ancient city and Jiangxin island of Wenzhou discussed the application of visual analysis method in the control of urban vertical form[9,11]. The above methods and practices provided valuable references for the height control of urban buildings, but it was difficult to deal with the overall and comprehensive requirements in the practice of overall urban planning and design due to different degrees of subjectivity and one-sidedness.

Aiming at the limitation of height control in the current urban planning and construction, based on the current working framework of overall urban design compilation, we constructed an vertical form control method that included rigid pattern, evaluation model, multiple scenarios, aesthetic correction, and other technical processes in order to explore a relatively rational and objective technical method for the overall urban planning and design practice .

2. Research Objects and Methods

2.1. Research Objects

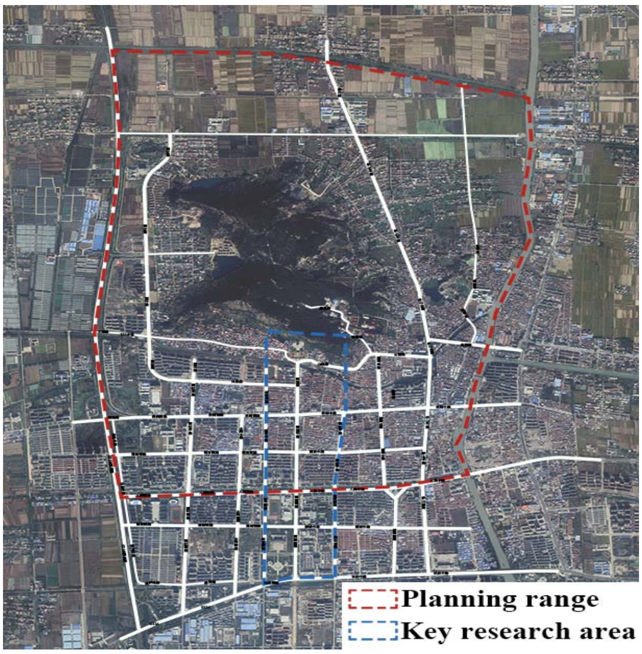

Figure 1. Study object range

Guanyun County which is under the jurisdiction of Lianyungang City is located in northeast Jiangsu Province, bordering the Yellow Sea on the east(Fig.1). The overall urban plan of Guanyun County (2017-2030) proposed to build an ecological leisure city with the integration of mountains and waters. Dayi Mountain Scenic Area which was a buddhist culture tourist area with Shifosi temple as the center was located in the central city of Guanyun County. Building height control around Dayi Mountain Scenic Area was a key factor to build Guanyun County's urban features. Building a height control system around Dayi Mountain was conducive to improving the quality of Guanyun City, guiding the healthy and orderly development of the city, and shaping a more beautiful three-dimensional spatial pattern of the city. The planning area was 18.3km2, north to Xinxinggou, west to Changshen highway, south to Renmin Road, east to Yanhe, among which the key control research area was 1.92 km^2.

2.2. Research Methods

Based on ArcGIS platform, the inverse skyline interface method was established to guide the process of viewpoint selection through 3D modeling. A comprehensive technical framework was constructed for height control of urban buildings based on "subtraction thinking"(Fig.2). Firstly, the space of possible viewpoints was collected extensively through primary selection. Secondly, some viewpoints were eliminated through modifying models and correcting models, so as to enhance the rationality of selected viewpoints and urban height control process.

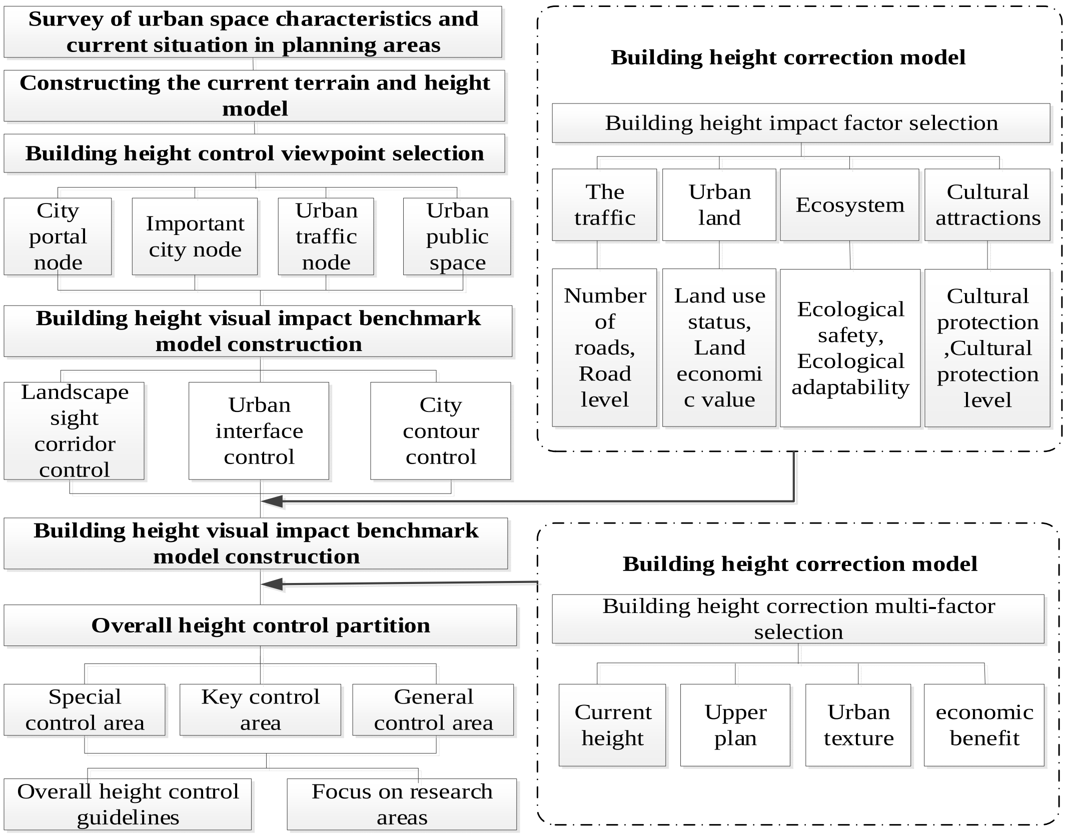

Figure 2. Urban building height control technology route

3. Construction and Modification of Urban Building Control Model in Guanyun County

3.1. Reference Model of Urban Building Height Control with Visual Impact

*3.1.1 Viewpoint selection and visual corridor analysis control.*With Dayi Mountain as the main visual landscape, the vision wasn't blocked by buildings as far as possible to create a good landscape corridor when looking at Dayi mountain from each important node within the planning scope. According to the domestic general planning standards and guidelines, the distance between each viewpoint and the mountain meets the requirement of D/H>=3, so as to relize to see 20% of the mountain scenery below the mountain contour and ensure the continuity and integrity of the city

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contour. The observation points must be directly facing Dayi Mountain because of the actual situation of the central urban area in Guanyun County. Considering the above factors as well as urban gateway, traffic nodes and urban public space, 33 viewpoints were initially selected.We selected the main travel data of people in four different periods including working days, weekends at 9:00am, 2:00pm, 5:00pm and 9:00pm (Fig. 3)based on Baidu thermal data, big data technology , analyzed the vitality of people in central urban areas, further guided the selection of viewpoints. Finally, 14 viewpoints were determined to construct height control reference model.

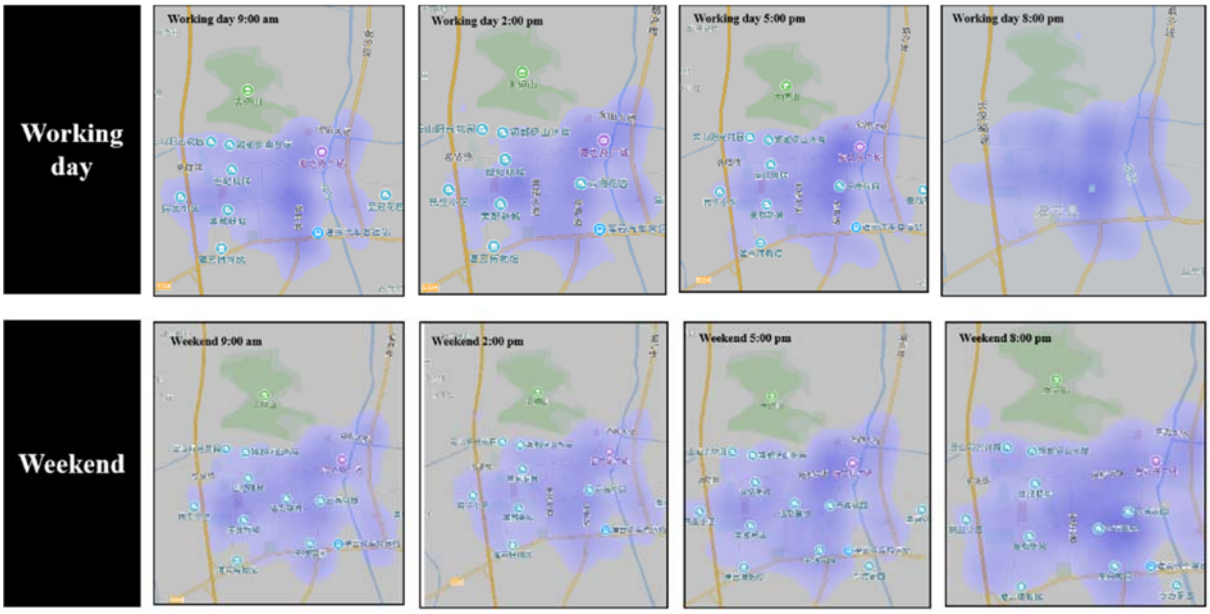

Figure 3. Population distribution of central urban population in different periods

By connecting important viewpoints in the central urban area of Guanyun County to form visual corridor, the height of buildings within the visual corridor can be controlled to form a good visual Line of landscape. Taking Dayi Mountain and buddha statue as viewing objects, combined with the overall planning and related planning of Guanyun County, 6 important viewing corridors were selected to form viewing corridor space by controlling surrounding buildings.

Firstly, applying visual psychology theories such as horizontal/vertical perspective theory and dynamic vision theory, viewing corridor was controlled comprehensively from maximization of visual sharing and the integration of citizens' dynamic visual points. Taking Dayi Mountain and buddha statue as viewing objects, the street interface requiring analysis of dynamic visual rhythm was determined by controlling dynamic visual rhythm sense of pedestrians. Secondly, according to the height of visual objects and street interface, the number of dynamic visual levels were divided to form hierarchical and rhythmic dynamic visual experience. On this basis, the view space was divided into three levels: near scenic area, middle scenic area and prospect area(Fig.4).

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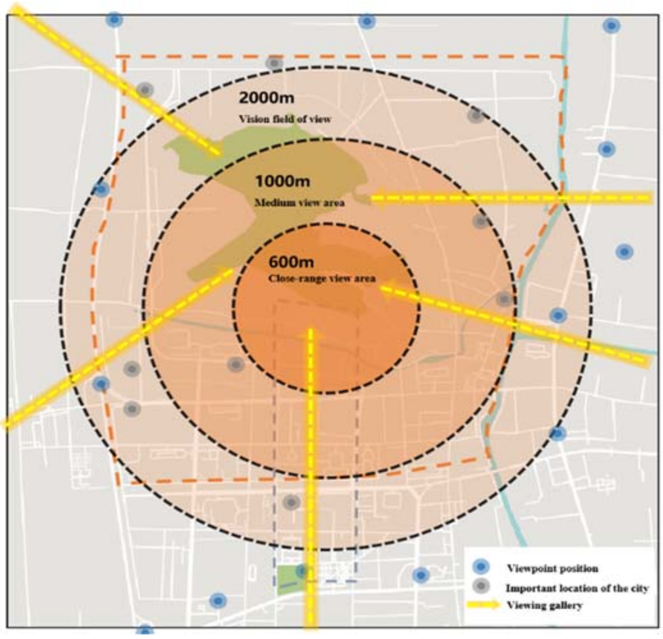

Figure 4. Distribution of important corridors and multi-dimensional control of the field of view

*3.1.2 Construction of building height control reference model.*The building height control grid of each view point was obtained by dealing with the obstacle surface of the skyline . The grid graph of terrain was converted to a point, and then to a raster. By subtracting terrain grid graph with ArcGIS grid calculator tool, the building height control grid of viewpoint 1 was obtained by using height as attribute, and the building height control grid of other viewpoints was generated similarly. Each block height limit was divided into 5 levels: 0-24m,24-40m,40-60m,60-80m,>80m. Building height control grid analyzed by sight comprehensive model was constructed through superposition calculation of multiple grid (Fig.5).

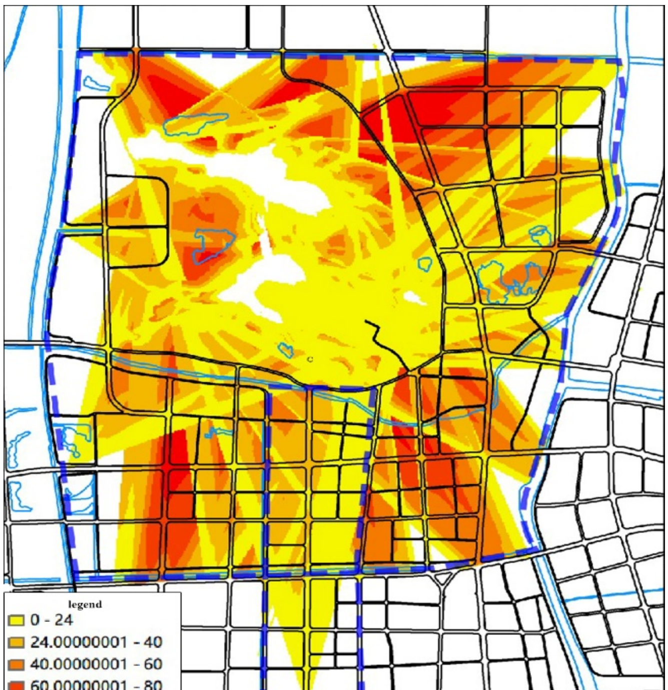

Figure 5. Building height control benchmark model

3.2. Construction of Modified Model of Building Height Control

The reference model only considering the visual corridor was insufficient for the overall control of urban building height, multi-factor analysis should be added to further supplement and modify the reference model.

*3.2.1 Comprehensive evaluation of impact factors based on analytic hierarchy process.*On the basis of relevant case studies and expert consultation and demonstration, we preliminarily constructed the framework of building height "growth force" evaluation system of 6 first-grade factors, including land location factor, traffic capacity factor, public service facilities factor, ecological environment factor ,and cultural landscape factor,and 13 sub-factors .

After classifying each factor by Delphi method, the weights of each factor were determined by analytic hierarchy process. Firstly, each factor was numbered, and the evaluation index system matrix was constructed. During multiple comparison, according to the "nine-bit" evaluation standard of the importance of the two factors, the importance of the factors was graded for several times, and finally the weight of each factor was obtained（Tab.1）. In order to avoid the error caused by the difference between before and after standards caused by human factors, the consistency test was carried out on the above evaluation results.

Table 1. Building height impact factor weight

principal factor	Weights	Secondary factor	Weights	principal factor	Weights	Secondary factor	Weights
Land location	0.28	Urban structure	0.19	Open space	0.07	Green space accessibility	0.34
		Distance from the center	0.49			Park Plaza Accessibility	0.66
		Land use	0.32				
Traffic capacity	0.16	Road convenience	0.56	ecosystem	0.16	Water system protection	0.39
		Road nature	0.44			Near mountain sensitive area	0.61
Public service facility	0.18	Educational research service	0.18	history and culture	0.15	Historical heritage protection	0.15
		Commercial financial services	0.65				
		Medical service	0.17				

Six factors were assigned to weights by applying YAAHP. The grade distribution of comprehensive evaluation of building height within the planning scope was obtained by ArcGIS multi-factor weighted overlap analysis(Fig.6). Since result of factor evaluation was the grade value, and result of sight influence model was the value of building restricted height, the original data of evaluation index was processed dimensionless and converted into specific evaluation value. Calculation results showed that the higher the evaluation coefficient, the higher the allowable height of the building; On the contrary, the smaller the evaluation coefficient, the stricter the control of the building height. Its calculation formula was as follows :

$$Z_i = \frac{X_i}{X_{il}}$$

Where, Z_i : evaluation value of X_i, X_i : actual original value,X_{il} : standard value.

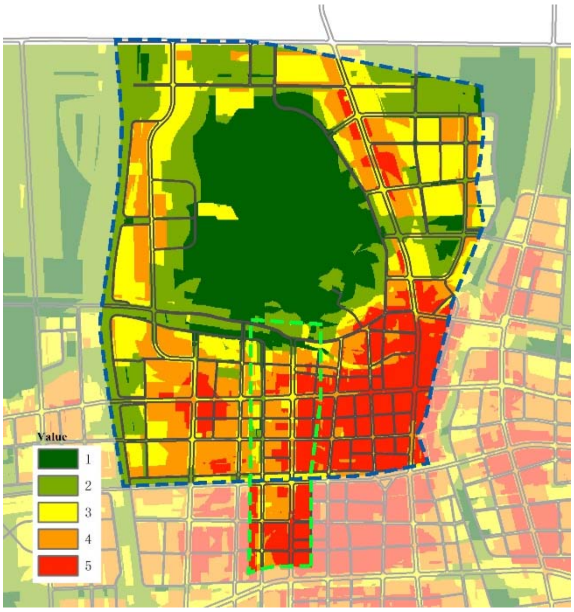

Figure 6. Multi-factor integrated overlay results

3.2.2 Construction of modified model of building height control. Applying GIS platform, the results of visual impact model and multi-factor comprehensive evaluation were given reasonable weights. After the weighted overlap analysis, the building height control distribution within the planning area was calculated .Based on the approved restricted-height of building and the upper limit of building height (100m) determined by the upper planning, the building height of each block was divided into 7 levels: 0m~15m, 15m~24m, 24m~36m, 36m~45m, 45m~60m, 60m~80m, 80m~100m.

3.3. Construction of Status Quo Correction Model of Building Height Control.

According to the correction model of current obstacle surface of each viewpoint, the height of some current buildings exceeded the obstacle surface of viewpoint(Fig.7).It mainly included high-rise residential buildings and public service buildings such as hospitals under construction on the southwest of the study area.

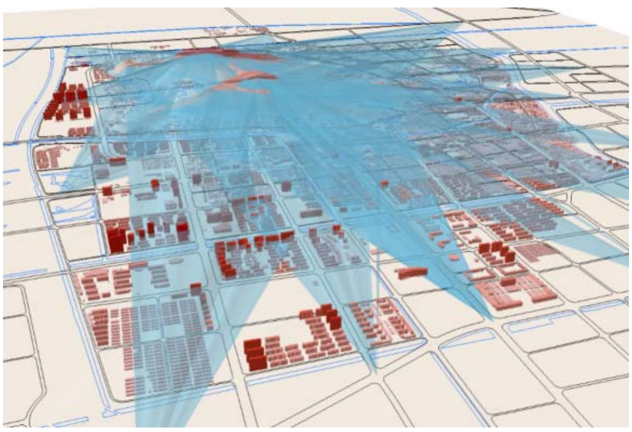

Figure 7. Evaluation of viewpoint obstacle surface correction model

After one round of multi-factor influence correction and two rounds of status quo correction, the results of building height control were obtained(Fig.8) .According to the building height control regulations approved by Lianyungang and Guanyun County, the building height control of each block was divided into 7 levels: 0m-15m,15m-24m,24m-36m,36m-45m,45m-60m,60m-80m,80m-100m.

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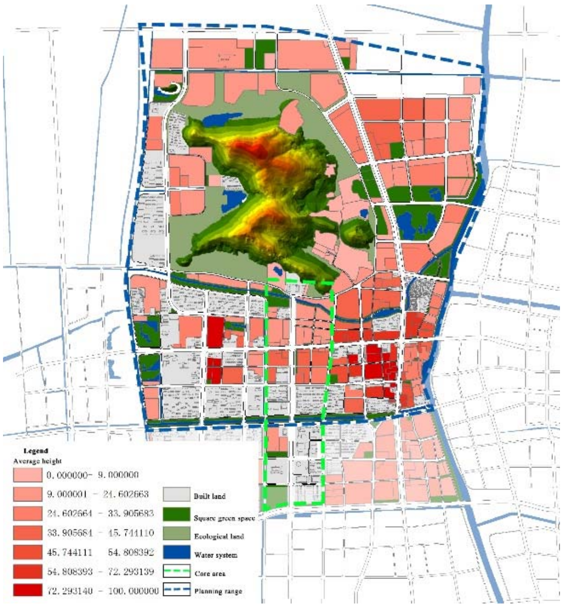

Figure 8. Urban Building Height Correction Model

4. Zoning and Control Guidelines of Overall Height Control

4.1 Zoning of Overall height control

According to construction of reference model, modified model and correction model of urban height control in planning area, the overall height control of Guanyun County was zoned to control and manage of planning.

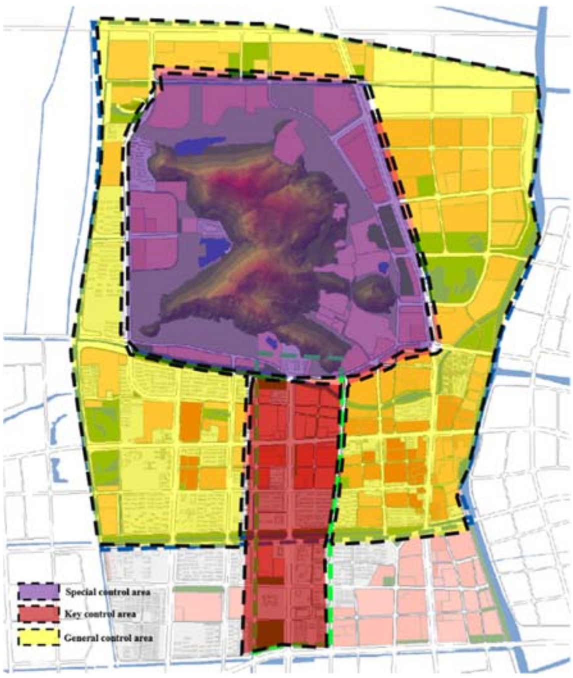

Figure 9. Overall height control partition map

The special control area included range of urban blue line and urban green line, the surrounding 100-200m was determined as ecological landscape coordination area, the 30-50m area near the Dayi

Mountain Scenic Area was designated as characteristic landscape protection area. The special control area adopted rigid control which could not exceed the upper limit.

The key control area of Guanyun County was delimited according to current development situation and relevant planning. The building height was controlled according to the functions and construction features of blocks in the key area, and it was connected with viewing the Buddha statue in Yinshan. The building height of the visual corridor in the key control area adopted rigid control and could not exceed the maximum limit. The building height outside the visual corridor adopted flexib control and the control strength could be appropriately relaxed in combination with other factors.

Other area of planning area was general control area .The building height which wasn’t regulated accord with urban function and relative standard requirement. The height of most of buildings were middle-high level. Under the condition of reasonable capacity of road and municipal facilities, the high-rise buildings can be developed moderately.

4.2 Indexing of Guidelines for building height control

The control method of "point, line and surface" was adopted in the height control guidelines of block buildings in order to control urban building height scientifically and effectively.

Point control: The high-rise construction area was determined through comprehensive analysis, the height control of other regions was lower than that of planning analysis value.

Line control: To ensure a good view, the building height within the main visual corridor area was strictly controlled.

Surface control: The building height in the characteristic control area was strictly controlled. The area was dominated by multiple and low-rise buildings with no high-rise buildings to protect integrity of city style.

5. Conclusion

Based on ArcGIS technology platform, we constructed a three-level control model: reference model, modified model and correction model of urban height control . Applying the big data method, POI data of urban public services, commercial facilities, etc. and population thermal data were selected to provide quantitative support for the selection of viewpoints and visual corridor of the control model. The building height control zones were carried out by urban building control model, and the control guidelines were implemented at the level of "point, line and surface". However, this study has a certain subjectivity, such as: the viewpoints were determined subjectively, supplemented by population thermal data screening. In addition, after multi-factor evaluating, the previous round of control model needed to be re-examined to realize dynamic two-way feedback. With the development of spatial analysis technology and big data, etc. it will provide beneficial assistance and reference for the study of urban building height control planning.

6. Acknowledgments

This research was supported by the National Natural Science Foundation of China(51778002) and the Humanities and Social Sciences Project of Anhui Jianzhu University (SK2019JD11).

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