Ancient Urban Land-Use Based on Geographic Information System

Subjects: Architecture And Design | Archaeology

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As ancient cities are spaces that represent the development of civilization, it is worth exploring and studying their characteristics and conceptions of land use. The city plan was calibrated with the help of satellite remote sensing images and sites. By constructing the “urban element area acquisition and analysis model”, various operations for areas in the city plan were realized, including an area value calculation, land use structure calculation, area modulus analysis, area ratio analysis between areas, and determination of the cultural significance of numbers and ratios. Taking the Sui and Tang dynasties capital city of Chang'an as an example, it will be described in detail below.

Keywords: GIS ; geographic information system ; ancient urban land use ; Chang’an City of the Sui and Tang Dynasties

1. Introduction

A city is the spatial representation of a particular human civilization. The function and distribution modes of land in the city relate to the quality and efficiency of the city’s operations and also highlight the idea of urban planning. Ancient urban heritage is an important aspect of human cultural heritage, and exploring its planning concepts is of great significance. However, as few drawings or detailed texts related to the planning of ancient cities have been preserved, modern people can only study the land use characteristics of ancient cities based on sites or relics and then speculate on the urban planning ideas of the ancients. This creates research difficulties that must be solved using multidisciplinary knowledge.

The study of ancient urban land planning involves a variety of issues, of which two challenges stand out: the extraction and quantitative analysis of data on ancient urban land use, and the intelligent exploration and interpretation of planning ideas based on land use characteristics.

1.1. The Extraction and Quantitative Analysis of Data on Ancient Urban Land Use

In terms of data extraction, quantity structure, spatial structure, and intensity are the main indicators used to measure urban land use. The quantity structure is fundamentally related to the allocation of related urban resources, and the spatial structure is intuitively correlated to the urban form; meanwhile, there are few research results on land use intensity due to the lack of ancient data. Scholars have mainly extracted relevant data by measuring satellite images (often in conjunction with geographic information system (GIS)s) [1][2], measuring archaeological sites in the field [3], and searching ancient literature and maps [4][5], and other scholars have worked with algorithms for image recognition to achieve the functional classification of land [6]. In terms of quantitative analysis, scholars have used statistical tables, GISs, and other research tools to conduct analysis. The statistical table is a more traditional tool, but its analytical power is limited and not suitable for the intuitive analysis of large amounts of data [7][8]. The GIS is a good tool that integrates data acquisition and analysis, specific plug-ins can be developed to achieve specific research functions, and there are also analyses that combine GISs with spatial syntax theory [9][10][11][12][13][14][15][16][17]. This theory abstracts the interrelation between spaces into a connection graph and then carries out the relevant numerical analysis [18][19]. The main variables used for calculation include connectivity, depth, control, integration, and choice. This can effectively transform perceptual visual analysis into rational mathematical analysis, which has certain advantages for the analysis of urban form.

The above tools can be used to analyze the composition and size (area) of each functional land space in the city, obtaining the percentage of each area in the whole city area through a calculation. According to these results, different attribute areas of the city can be compared [20][21].There are also analyses of broader regions (such as provinces) [22][23][24]. Furthermore, the same functional area can also be compared between different cities, considering questions such as the difference in the proportion of residential land in city A and city B [7]. Ancient and modern comparisons can also be made in order to examine the evolution of specific functional spaces over hundreds of years [8][25], allowing researchers to reach some valuable conclusions. However, due to the limited types of functional zones (generally no more than 10) in a

specific city, only some preliminary understanding can be obtained merely by analyzing the share of each area, and it is difficult to carry out in-depth urban data analysis.

At present, the analysis of the internal relationships between various spatial areas in ancient cities is very scarce, and it is also difficult to answer key questions such as whether there is an area modulus (minimum area unit) in urban design. Therefore, in order to solve the problems related to ancient cities, researchers should undertake the necessary optimization according to the specific research needs of urban land use analysis, strengthening the secondary development of existing GISs and other tools to achieve specific research functions.

1.2. The Intelligent Exploration and Interpretation of Planning Ideas Based on Land Use Characteristics

Ancient planning ideas are embodied in land use characteristics, and it is necessary to find suitable methods to reveal the links between characteristic data and planning ideas, and to interpret the relevant ideas as a whole. The characteristics of land use mainly relate to the distribution of land use structures and the ratio between areas; multiple characteristics based on the specific area modulus may also exist, which all involve a number of specific numerical values and numerical ratios. Ancient people tended to select culturally significant numbers or numerical ratios and integrate them into the design to highlight the planning ideas. In most of the current studies, the data (especially the ratio data) are obtained by manual graphing analysis. The comparison and interpretation of data are also done manually; if these data are consistent with the knowledge already obtained by experts, it is concluded that they may represent a certain strain of cultural thought. For example, Andrea Palladio (1570) conducted a graphic analysis of the ratio of ancient cities and gave explanations of the cultural aspects of these ratios [26]. Kostof (1999) studied the land division mode of ancient urbans and analyzed the order reflected in their dimensions and proportions through a number of examples of cities with a grid pattern [27]; Wang Nan (2018) analyzed hundreds of ancient Chinese cities and architectures using the circle and square graphing method and posited that most of these cases fit the ratio of √2, 3:2 and √3:2 [28] (which he called “the harmonious ratio between heaven and earth”). Fu Xi’nian (1995) found that the length and width of many ancient capital cities in China were proportional to those of the Imperial Cities and explained this as the “emperor-centered” planning idea [29]. Wang Shusheng (2009) found evidence of the use of nine and five to symbolize imperial power (the Chinese called the emperor “Nine-Five Extreme”) in Chinese ancient capitals [30]. Peixoto, R. F. (2021) investigated the urban grid of Thourioi and revealed its orthogonal planning technique and thoughts [31]. Park, E. and J. M. Shaikh. (2023) analyzed the spatial framework of the ancient Indian urban space and found that its significance derived from the Indus Script Pictorial Form [32].

Despite the many trends found by the above research, this method also has some limitations, which largely arise from the fact that there are many accidental factors involved in analysis based on expert experience, and there is a lack of intelligent and standardized analysis. For example, the objects in the analysis and the values and ratios of these objects may be deliberately screened rather than comprehensively investigated; when dozens of groups of ratios or values appear in the same city object, there is no clear countermeasure on how to choose between them. There is actually a limited number of important values and ratios in a specific culture, but their boundaries have not yet been defined, and a standard database for repeated use has not been established. In addition, there is no uniform threshold standard for screening the analysis results obtained in previous studies, which greatly affects the scientificity and reliability of the analysis. In fact, most of the values and ratios in a specific culture have been established by academics (in line with the cultural consensus and specific mathematical laws). The process of revealing cultural ideas is the process of comparing the values and ratios discovered in cases where the target values and ratios are established. If there are many consistent phenomena, this may be evidence of some kind of cultural idea. This process can be fully realized by computer intelligence; on this basis, a more in-depth analysis of planning ideas can be carried out.

2. Characteristics and Ideas of Ancient Urban Land-Use Based on GIS

Chang’an City of the Sui and Tang Dynasties

Chang’an City of the Sui and Tang Dynasties (hereinafter referred to as “Chang’an City”) was located near Xi’an, Shaanxi Province, China, with geographic coordinates of 108.88°–108.99°E, 34.19°–34.31°N. The city (**Figure 1** and **Figure 2**) was founded in 582 AD by Yang Jian (杨坚), Emperor Wen of the Sui Dynasty; Gao Jiong (高颎), Yu Wenkai (宇文恺), Liu Long (刘龙), and others were responsible for its planning and construction. After its founding, the city was the national capital of the Sui Dynasty. After the collapse of the Sui Dynasty, the Tang Dynasty continued to use it as the national capital. Chang’an City was one of the largest (over 80 square km) capitals in the world from the 6th to the 10th centuries, accommodating up to one million people. It is currently an important heritage site under state protection in China, and the

Daming Palace site in the northeast of the city is a world cultural heritage site; therefore, the city has prominent historical and cultural value and research significance [33].

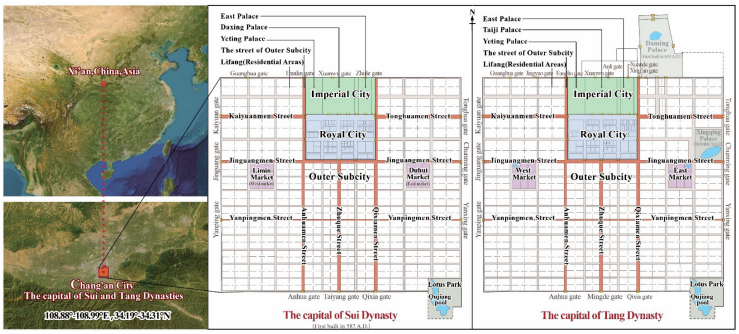

Figure 1. Location Map and ichnography of Chang'an City of the Sui and Tang Dynasties.

Figure 2. Restored model of Chang'an City of the Sui and Tang Dynasties in Xi'an Museum.

The shape of Chang'an City is basically a regular rectangle, with a transverse width of about 9.6 km and a longitudinal length of about 8.5 km and the ratio of transverse width to longitudinal length is close to 9:8. The Lotus Park in the southeast corner protrudes slightly to the south. If the longitudinal length of the city is calculated according to the south boundary of the Lotus Park, the transverse width is almost equal to the longitudinal length, and the overall urban scope is nearly a standard square. The main body of Chang'an City consists of three parts. In the north of the city is the Imperial City. In the center of the palace is Daxing Palace, which was the residence of the emperor and empress. On the east side is the East Palace, which was the residence of the prince and his subordinates. On the west side is Yeting Palace, which was the residence of the maids and servants; adjacent to it south is the Royal City, which was the office area of government departments. The Imperial City and the Royal City have their own walls, and outside them is a larger Outer Subcity, which is also surrounded by walls and is where the public lives. The East Market and West Market are also located in the Outer Subcity. There are gates on the four sides of the city, with three gates on the east, west, and south sides, and five gates on the north side (at the beginning). The streets in the city are north–south or east–west. The widest street is Zhuque Street, which is about 155 m wide, while other streets vary in width, ranging from 19 to 134 m [33].

Some scholars have found that if Chang'an City is regarded as a regular rectangle, the city is exactly 20 times the size of Daxing Palace [29] and 9 times the size of the Imperial City and the Royal City, and the size of the Imperial City and the Royal City is 5 times that of Daxing Palace [30]. These values indicate that Chang'an City was carefully planned and designed, and this planning deserves further study.

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