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MULTI-FACTOR CORRELATION ANALYSIS OF URBAN LANDSCAPE NETWORK BASED ON A TOURISM CITY OF HANGZHOU, CHINA

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ABSTRACT: Urban landscape, as an important impact factor on the quality of urban life, has been paid much attention to by citizens, governments and construction enterprises. Meanwhile, the issue that many cities follow some similar international styles degrades local customs and regional features. This trend should be pertinently analyzed and answered by researchers. Urban landscape comprises some spots and regions and is a dynamic system. Based on the current situation and academic proceedings, this research puts forward the concept of urban landscape network. By a case study of Hangzhou City construction, this paper conducts a grid analysis of the landscape grid network, and builds four sub-networks: natural scenery, historical development, road transportation, and land use. Using variance analysis, correlation analysis, multiple regression analysis, this paper examines the relationship between the four networks, and finally achieves a regression equation of the landscape network in accordance with the subjective satisfaction evaluation concerning the landscape.

Urban, landscape, network, grid.

INTRODUCTION: URBAN LANDSCAPE AND ITS NETWORK

In the book Urban Landscape, British planner Gordon Cullen (1995) recognizes the urban landscape as the art of mutual relations, i.e. including various visual objects and the surrounding spatial organizations. Therefore, the art is an objective reality that can also be perceived by human visions. Yan (2001) also addresses that urban landscape is the overall vision consisting of a variety of visual objects and events in a city.

With in-depth development of the researches in the areas such as landscape design, Architecture, urban planning and other related areas, the visual element of the landscape is no longer considered to be the sole influencing factor. Especially in the field of environmental psychology, many scholars believe that people's perception of landscape should be results of a combination of multiple sensory (Ge, 2004; Wei, 2004; Qin, 2005; Mao, 2006). For instance, sound landscape design has become a newly developing inter-

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discipline of environmental acoustics and landscape architecture. Therefore, urban landscape can be defined as the integration of various perceived objective objects and incidents in outdoor space, including natural materials, natural phenomena as well as artificial materials and human activities. Urban landscape should be an organic and dynamic system of a number of nodes, surfaces and domains. It consists of two meanings, i.e. the first is the overall network structure of associated dots, lines and planes; the second is the dynamic process of the landscape elements, contents and patterns constantly changing.

The goal of this study is to examine and explain the network where the structure of some urban perceived elements. Much existing research has touched the application of neural networks, ecological networks, and transportation networks, and such specific networks all show that it will be useful to understand the integrity and complexity features of a multi-factor system from a viewpoint of network (Han, 1995).

In order to clarify the complicated state of land cover, the analysis of the features should divide and classify those landscape elements. Both theoretical and practical experience shows that the landscape is formed from the inlay of landscape components on various spatial layers (Wu, 2002). Landscape has a unique structure and many functional units in different temporal-spatial scales, so it is effective to analyze the landscape by integrating different scales.

Landscape network is an effective medium to conduct systematic analysis of the landscape. First of all, the landscape network is a spatial entity linking the corridors and the patches; secondly, the landscape network is a structure connecting different dimensions. It not only sustains the internal migration of species, but also has an impact on the peripheral landscape substances and patches.

Recently, some proceedings have advanced the landscape network research. Zhang (2005) summarizes the landscape network research into two major aspects: (1) infrastructure network - it mainly probes into the infrastructure construction and urban spatial planning from the perspective of economic development; (2) ecological network - it probes into the landscape structure and composition meeting the ecological needs from the perspective of species protection, environmental security and human's leisure needs. The existing landscape network studies mainly start from a single-scale pattern and species. Comber (2008) firstly analyzes the structural features of the green landscape accessibility and then explores the influence of various landscape elements in the network on social groups. It is a landscape network purely emphasizing transportation or spatial structure.

The concept of landscape network in this paper provides an effective viewpoint for further study. Network and networking are two related but different concepts. Network is static description and attributive analysis, while networking is dynamic research and correlation analysis. Therefore, network is the record of real patterns, element combination and different dimensional transection, while networking is the process of developmental trend, system evolution and vertical development (Zeng, 2001). In real life, urban landscape

network structure represents a form of spatial organization, namely a spatial relationships make entities and virtual bodies of different landscapes interconnected through the countless channels (the various elements of linear infrastructure and streams). Urban landscape networking is manifested in the continuous improvement of landscape's reticular formation and spatial organization degree.

RESEARCH METHODS AND FRAMEWORK

Research Methods

This paper applies a method of geographical information system: grid data formats and correlation analysis. Much research has applied it into various scenarios (Matsushita, 2006). Grid data is generally divided into two categories: Thematic data and Image data. Thematic grid data value indicates some sort of measurement values or the classification of a particular phenomenon such as elevation, pollution level or population. A grid data set is just like a map that describes the location and feature of a region and its spatial position. A single grid data set typically represent a single topic such as land use, soil, road, river or elevation value, and a multiple grid data set should be created to completely describe a region.

The plane appearance of the study area is divided into rows and columns according to a certain division scale. It is to form a multi-grid panel and each grid cell is called a pixel. The grid data structure is actually a pixel matrix comprised of a collection of meanings. Each pixel in the grid is the most basic information storage unit, whose coordinate can be determined by its line number and column number. Because the grid data is arranged according to certain rules, the relationship between the physical locations hides in line and column numbers. The code of each grid element represents its material attributes or the encoding of the attributes. Each pixel can be represented by different gray values according to the information expressed by the appearance differences. The Entities can be divided into point entity, line entity and surface entity, i.e. point entity is expressed as a pixel in the grid data; line entity is expressed as clusters of adjacent pixels connecting in a certain direction; surface entity is expressed as an aggregation of adjacent pixels in various directions (Figure 1).

The Grid Analysis is mainly divided into three methods: direct superposition method, factor-weighted evaluation method and ecological factors combination method. The direct superposition method is applicable into land suitability analysis, making the planning effectively integrates social factors and environmental factors. Factor-weighted evaluation method can be divided into equal weighting and range weighting methods.

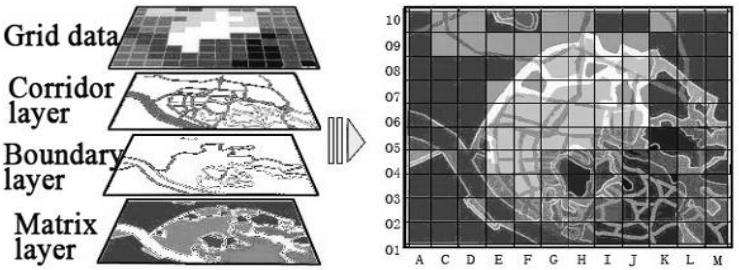

Figure 1. A Demonstration of Map and Data Overlap

The direct superposition and the factor-weighted evaluation method require various independent factors, while many factors are interdependent. The factor-combination method believes that for specific land use different combinations of the various interrelated factors determine particular land use suitability. Ecological factors combination method can be divided into hierarchical and non-hierarchical combination method. Hierarchical combination method firstly uses a combination of factors to judge the suitability of land level, and then combines this group of factors with other factors at the historical level and transportation level.

Research Framework

The layer-cake model, landscape pattern optimization and multi-solution plan method are combined together to do the research based on the ideas above and the specific circumstances of Hangzhou. The first step is to select the Hangzhou City map and extract networks. Then analysis and evaluation are conducted for further research.

The second step is to divide the whole network layer-photography maps into 1 square kilometer uniform samples of mesh slices and give annotation to slices of typical landscape patterns in each sample;

The third step is to conduct network-level correlative analysis to extract the principal components of the landscape patterns; The fourth step is to overlay a variety of networks to construct the landscape network of Hangzhou city. Appropriate analysis methods and other methods will be used to explore the urban landscape network that is suitable for a sustainable development.

MULTI-LAYER LANDSCAPE GRID NETWORK

Layer-Photography

Urban landscape is a highly composite ecosystem. It's more than the usual sense of beauty, but also has a wide range of social, historical and cultural context (Xu, 1998). A

combination of various factors should be considered in the urban landscape network, but advantage factors can exist in different cities and even in different areas of a city. Through analysis of natural and socio-cultural factors affecting the urban landscape network, it can be concluded that the natural landscape factors, urban roads factors, land use factors and the historical development factors play an important role in the formation of urban landscape. In this paper, these four factors will serve as the starting point to construct multi-layer compound in Hangzhou city landscape network. And the urban landscape network suitability of sustainable development model will be argued.

This study does not bring into more comprehensive analysis of the network level because too many levels would make the analysis process too cumbersome and would be adverse to seize the key to the problem. The four kinds of levels above are the optimized results of the documentation and the actual design of the project. They have great explanatory power and coverage.

Network of natural scenery

Important ecological functions of city's natural scenery network include transport of material, purification of pollutants, migration and spread routes of flora and fauna as well as habitat of aquatic and terrestrial flora and fauna (Wang, 2003). Water bodies have lots of features in urban development, including landscape features, water features, transportation features, recreation and sports features, ecological edification and updating features as well as cultural and historical features. Because of the close relationship between urban development and urban rivers, traces of the city's rich history and culture can still be found in urban river landscape. Therefore, urban river landscape is the most lifeblood and changable in the city landscape patterns. It is the ideal city habitat corridors as well as the highest quality green lines of the city. Moreover, the city has mountains as its surroundings, which greatly enrich its contour lines at the three-dimensional level and also provide a multi-viewpoint urban landscape.

The well-known Beijing-Hangzhou Grand Canal begins in Hangzhou and runs through Hangzhou city; the West Lake surrounded by the mountains lies in the west of the city; the Qiantang River meandering into the sea in the south of the city. They all form a unique city's natural environments of rivers and hills. Hangzhou blends with the West Lake, the surrounding mountains and the Qiantang River, forming a basic urban landscape network with the plain water network.

(1) The mountains in Hangzhou

Hangzhou is a mountainous city with an area of 16,000 square kilometers, of which mountains and hills account for 66%. It is also the largest city of Zhejiang Province with an urban area of 3068 square kilometers and a mountainous area of 881,3 square kilometers. West Lake Scenic Area covers an area of 60 square kilometers. In addition to West Lake and the surrounding parks, almost all lands are mountains and hills. The mountains in western urban area meander all the way from the territory of Fuyang and Linping to the city, surrounding the West Lake from the South, North and West.

The West Lake Scenic Area is usually divided into Nanshan Mountain area and Beishan Mountain area. The dividing line is Tianzhu Mountain and Fenghuang

Mountain Range (Longjing Road), to which the south is called Nan Shan Mountain area. In addition, the Gaoting Hill in the northeastern part of Hangzhou City, and such mountains stretching more than 10 kilometers from west to east, forming a north barrier of the city. The mountains in Hangzhou bear numerous historical and cultural heritages as well as its natural beauty. As Hangzhou has a history of 2200 years, the mountains in Hangzhou recorded its history and simultaneously created a favorable environment.

(2) The water in Hangzhou

Hangzhou has the rivers, streams, lakes, reservoirs, ponds, wetlands, springs, canals and the sea all in its area and all of them belong to Qiantang River and Taihu Lake two major river systems (Figure 2).

(a) Qiantang River: Running through south-eastern Hangzhou, the Qiantang River is world-famous for the Qiantang Tide. As the largest river in Zhejiang Province, the Qiantang River basin has an area of about 13,227 square kilometers in the urban areas, accounting for about 80% of the city's total area. Its water area accounts for about 84% of the city's water area.

(b) Urban rivulets: This city with the Grand Canal as the backbone has a water net of high rivulet density. There are more than 140 channels located around the urban area. The main stream of Beijing-Hangzhou Grand Canal from the west to east has a total number of more than ten tributaries.

(c) West Lake: West Lake has an area of 6.03 km2, with a length of 3.3 km from south to north and a width of 2.8 km from east to west. Its approximate circumference is 15 km and has a lake drainage area of 27.25 square kilometers.

(d) Wetlands: Located in the city's western edge, Xixi Wetland National Park was formed in Shao Stream in the Tian-Mu Mountain. It is well-known as the kidney of the city, it covers an area of 16.15 km2 and a core area of 11.15 km2 of wetlands.

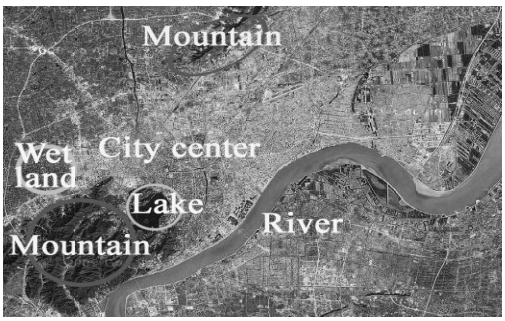

Figure 2. A Demonstration of Hangzhou Mountains and Water

In this study, a statistical analysis is given to calculate the area and the eccentricity of the internal and external natural elements for the 400 grid units, and finally to obtain a natural scenery index for each unit. Six grades from 0 to 5 are drawn from shallow to deep based on the index to form a distribution map of natural scenery network, as is shown in Figure 3. The following four factors are taken into account in natural scenery index: the percentage and the eccentricity of the green area and the water area inside each grid unit; the percentage and the eccentricity of the corresponding elements in the eight adjacent grid units around. This algorithm refers to the theoretical dynam and fully considers the quantity-quality superposition.

Network of historical development

At different time and development process, urban landscape shows history, heritage and dynamics in nature. People believe that the images of an old city have more meanings than the new cities'. In essence, it is the dynamic and variable time that makes the old city slowly and spontaneously takes shape through a long-term formation, expansion, integration of physical environments and human societies. During the gradually incremental accumulation of socio-cultural history, the present city is an interpretation and succession of the old city. Therefore, the urban landscape we are experiencing has rich meanings for it shows people's understanding in each period through continuous deposits. In construction and development of a city, the historical traditions and customs should not be put aside as well as the continuity and context of history and time. By interpreting the tradition and collection information, people make the modern city in coordination with ancient times (Qian, 2003).

Hangzhou is a historical city of 2200 years and carries a profound cultural accumulation, which gives the urban landscape numerous features. This study takes the temporal periods as a clue to study the historical development of the city. Five temporal periods (within 10 years, 11-25 years, 26-50 years, 51-100 and over 100 years) are determined to construct the historical development network. Correspondingly, five color grades from shallow to deep are chosen to depict the historical development network diagram (Figure 4).

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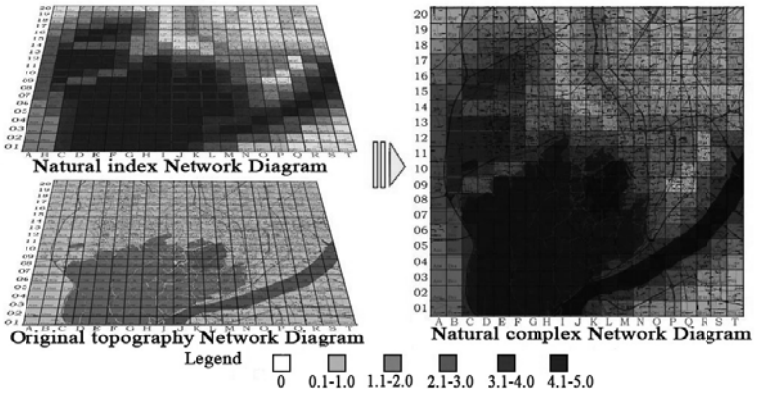

Figure 3. Network of Natural Scenery

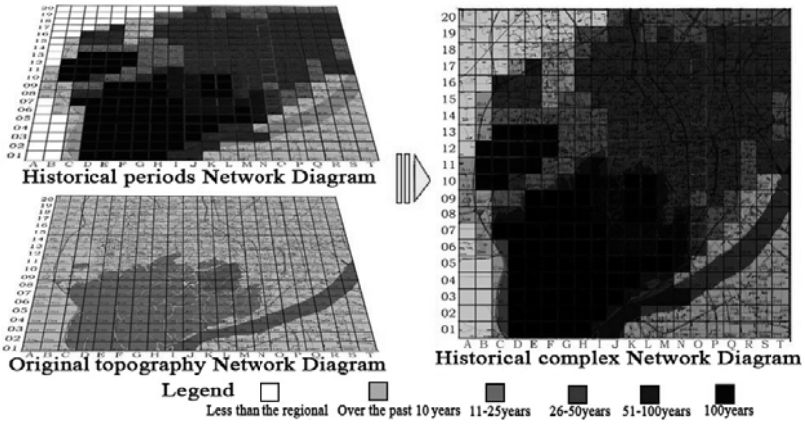

Figure 4. Network of Historical Development

The temporal periods refer to the correlative literature of domestic urban development and architectural history of Hangzhou. The first time period is set as 1999-2008 (the sampling time of this study was theoretically set as 2008), which are the most flourishing 10 years of Hangzhou's infrastructure construction and real estate development; The second time period is set as 1983-1998 when the policy of the Reform and Opening was developing; The third time period is set from the foundation of PRC to the start of the Reform Policy; The fourth period of time is from the end of the Qing Dynasty to the year before the liberation; The fifth period of time generally refers to a wide era before the late Qing Dynasty. Due to various uncertain factors of urban development, the time division is not precisely delimited.

Network of transportation

The city has trunk roads, branch roads and pedestrian streets, connecting city squares. In urban transport systems, the city squares are turning points between the roads and the convergence point of them. In this study, the road density value in each grid cell is divided from small to large into six levels, from shallow to deep colors. The transportation color distribution map is drawn as Figure 5. The calculation of the road density mainly considers two factors: the road grade and the length.

Network of land use

With the process of urbanization and the adjustment of industrial structure in recent years, the scope and the nature of the urban land use of Hangzhou changes a lot. The adjustment of the urban landscape style is influencing the old districts and the new districts. Therefore, constructing the network of the urban land use is of great significance to the study of Hangzhou urban landscape network. The Hangzhou urban land use distribution network is shown as in Figure 6 (the mixed land use is a mixture of two or more land use, and each takes more than 30%).

Three networks (natural scenery network, historical development network and transportation network) are distinguished as ratio scale type of data. The land use network therefore is used as the judgment criteria in the process of variance analysis, to observe the differences among the other three networks in each land grids.

(1) ANOVA of land use and natural scenery
Through data analysis of 400 grid units, the F value of 56.789 is much larger than discriminate threshold F 1.977. The significance level was almost 0, less than 5% (Table 1). It shows that there are significant differences between different land blocks on the natural scenery dimension.

(2) ANOVA of land use and historical development
Through data analysis of 400 grid units, the F value of 17.012 is much larger than discriminate threshold F 1.977. The significance level was almost 0, less than 5% (Table 2). It shows that there are significant differences between different land blocks on the historical development dimension.

(3) ANOVA of land use and transportation
Through data analysis of 400 grid units, the F value of 17.396 is much larger than discriminate threshold F 1.977. The significance level was almost 0, less than 5% (Table 3). It shows that there are significant differences between different land blocks on the transportation dimension.

Multi-Correlation Analysis of Complex Network

According to the continuous observation of the mutual relations among the natural scenery network, historical development network and road transportation network on the base of single-factor variance analysis, the data of 400 grid units shows a high degree of correlation and its significance level reaches more than 99% (Table 4). Among them, the network of natural environments and historical development has a positive correlation and the correlation coefficient 0.374; both of them have a negative correlation related to road transportation network and the correlation coefficients were -0.434 and -0.467. It shows that the blocks rich in natural landscapes elements have a relatively long history and traditions; Most of the blocks where the road system is well-developed are developing in recent years

Regression Analysis of The Landscape Network

In the survey, each landscape block is conducted on-site satisfaction score to analyze the visual impact of natural scenery network, historical development network and road transportation network. The multiple regression analysis method is used while solving equations of the suitability of the landscape network (Table 5, 6). After stepwise regression, it can be found that the satisfaction with the landscape is mainly determined by natural landscapes and historical development and the determination coefficients are respectively 0.706 and 0.107. So the regression equation is: $Y = 0.706\ X1 + 0.107\ X2$, where Y is human subjective satisfaction; X1 is the value of natural scenery; X2 is the value of historical development.

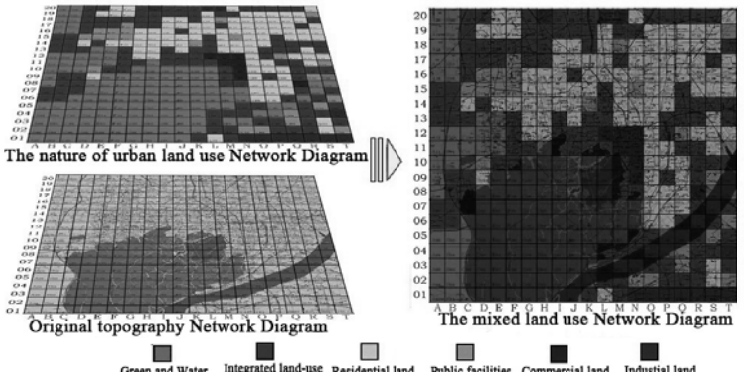

Figure 5. Network of Land Use

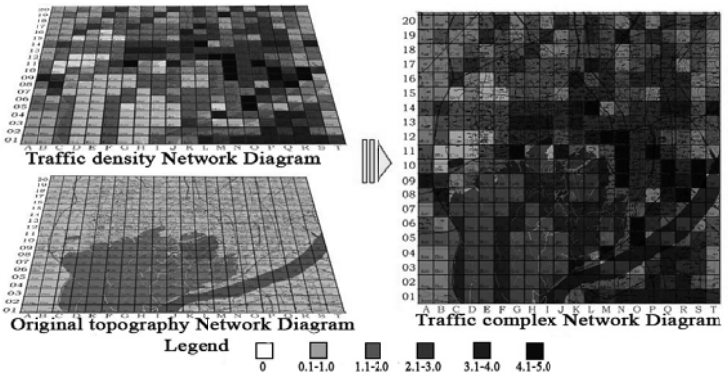

Figure 6. Network of Transportation

The result shows that the landscape quality of Hangzhou is mainly affected by its unique natural and historical conditions. In fact, the natural beauty and the historical culture are appreciated by citizens and visitors. The data results of this survey are fully consistent with the pre-judgment of reality. Hangzhou is different from other new cities, old industrial cities and purely scenic cities. The reason is that it not only has a historical and cultural accumulation of one thousand years, but also is located in the southern coastal area of water and mountains. Therefore, this city has diverse terrain forms. Consequently the planning and design of Hangzhou should be distinguished from other cities. The analysis should be focus especially on its natural landscape organization and its historic cultural heritage protection.

Table 1.
ANOVA of Land Use and Natural Environments

land use classification	count	sum	mean	variance		
1. commercial land	3	8.22	2.74	7.9932		
2. residential land	65	83.77911	1.288909	1.712015		
3. industrial land *	1	0.1	0.1	#DIV/0!		
4. green land **	85	461.9922	5.435203	0.652636		
5. mixed land use	74	123.3196	1.666481	2.685508		
6. government use	10	30.36932	3.036932	4.691985		
7. external transport site	2	5.569697	2.784848	4.005308		
8. roads, squares*	2	6.88961	3.444805	5.291807		
9. municipal facilities	10	22.82025	2.282025	2.347241		
Variance source	SS	df	MS	F	P-value	F crit
Between Groups	839.5743	8	104.9468	56.78876	2.09E-51	1.97663
Within Group	449.069	243	1.848021			
Total	1288.643	251				

Table 2.
ANOVA of Land Use and Historical Development

land use classification	count	sum	mean	variance		
1.commercial land	3	11	3.666667	1.333333		
2.residential land	65	172	2.646154	0.450962		
3.industrial land *	1	2	2	#DIV/0!		
4.green land **	85	356.6	4.195294	1.599025		
5.mixed land use	74	173	2.337838	0.856905		
6.government use	10	24	2.4	1.377778		
7.external transport site	2	8	4	2		
8.roads,squars*	2	3	1.5	0.5		
9.municipal facilities	10	28	2.8	7.288889		
Variance source	SS	df	MS	F	P-value	F crit
Between Groups	173.0082	8	21.62602	17.01236	5.18E-20	1.97663
Within Group	308.9004	243	1.271195			
Total	481.9086	251				

Table 3.
ANOVA of Land Use and Transportation

land use classification	count	sum	mean	variance		
1.commercial land	3	7.4	2.466667	5.173333		
2.residential land	65	144	2.215385	0.996635		
3.industrial land *	1	2.2	2.2	#DIV/0!		
4.green land **	85	74.05	0.871176	0.677999		
5.mixed land use	74	164	2.216216	0.868227		
6.government use	10	15.7	1.57	1.222333		
7.external transport site	2	6	3	1.28		
8.roads, squares*	2	5.1	2.55	0.605		
9.municipal facilities	10	34.4	3.44	2.138222		
Variance source	SS	df	MS	F	P-value	F crit
Between Groups	130.2866	8	16.28582	17.46498	1.71E-20	1.97663
Within Group	226.5937	243	0.932484			
Total	356.8803	251				

Table 4.
Correlation Analysis Of Nature, History And Transportation

	Nature	Transportation	History
Nature	1	-.434(**)	.374(**)
Transportation	-.434(**)	1	-.467(**)
History	.374(**)	-.467(**)	1

** Correlation is significant at the 0.01 level (2-tailed).

Table 5.
Regression Analysis Summary

R	R2	Adjusted R2	Std. Error
.867(a)	.752	.750	20.04094

A Predictors: (Constant), VAR00002, VAR00001

Table 6.
Regression Analysis Coefficient

	Unstandardized Coef.		Std. Coef.	t	Sig.
	B	Std. Error	Beta		
(Constant)	33.686	3.572		9.429	.000
Nature	8.341	.620	.706	13.462	.000
History	2.394	1.177	.107	2.033	.043

A Dependent Variable: VAR00006

Urban landscape is a complex network of various grid units. A high-quality urban landscape network supports the organic dynamics of urban culture, urban heritage, urban life, and many other environments in multiple dimensions.

In this paper the grid analysis of the four layers is conducted and the data is put into the database based on the actual situation of the city. Several analytical methods are used to analyze the relationship between the four layers. Finally the suitable regression equation concerning the landscape network is obtained to examine the relationship between human subjective satisfaction and urban objective conditions.

From the results of this study, (1) Hangzhou has its natural landscape network of mountain and water streams as a link to form the basis of the urban development; and (2) its history and culture also endows the sustainable continuity and the balanced dynamics to urban landscape elements; and (3) its classification of primary and secondary roads also forms the skeleton of the urban landscape; and (4) its land use partition also reflects the influences of human activities on the urban landscape network.

This study provides a new idea for the urban landscape study, but it still has limitation, e.g. inadequate empirical survey, insufficient data into the cases and the measure criteria of network sampling data. The future in-depth studies need to go beyond these limitations with data processing techniques and the extension of study areas. In this paper, the planar-based (2D) urban research in planning and design only focuses on the function and the layout. Therefore, it has faced too much difficulty to meet the future urban research development and people's needs. The quality of three-dimensional, multi-sensory landscape has become a topic with widely public concerns.

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