

Research Paper

Urban landscape units and spatial grid networks of the land, water and mountain system using a multiple factor overlap approach: A lowland case study of Hangzhou City, China

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ABSTRACT

The issue that many Chinese cities follow similar international styles degrades local cultural customs and regional ethnic features, and it is drawing much attention of citizens, governors and designers. Some research has corroborated the effectiveness of correlation and integrity of native urban sceneries, to deal with the above issue. Urban landscape can be regarded as a dynamic network system, comprising some interlinked spots and regions. Based on the current situation and academic proceedings, this research introduced the concept of urban landscape network. By a case study of Hangzhou City construction, this paper conducted a grid analysis of the landscape grid network, and built 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 sub-networks, and finally achieved an appropriate regression equation of the landscape network in accordance with the subjective satisfaction evaluation concerning the landscape quality.

1. 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, including various visual objects and the surrounding spatial organizations. Therefore, the art is an objective reality that can also be perceived by human visions. Zheng et al. (2009) also addresses "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 such as Landscape areas 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; Yin, 2007; Wu, 2007; Kang, 2007). For instance, sound landscape design has become a newly developing inter-discipline of environmental acoustics and landscape architecture, and Kim (2013)

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examined the acoustic effects of landscape designs in a courtyard. 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, 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 exists. 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 (Lei, 2005).

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 at different landscape levels.

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 - "EN" can recover and maintain ecological connectivity and environmental continuity (Jongman, 1995; Forman, 1995 and Montis et al., 2015), 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 and firstly analyze the structural features of the landscape network function then explore the influence of various landscape elements

in network on internal species. It is a landscape network purely emphasizing function 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 (Liu, 1997; Zhang, 2005). 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 "channel" (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.

2. Research methods and framework

2.1 Research methods

This paper borrows a method of geographical information system: grid data formats and analysis method. 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 levels or population. A grid data set is just like a map that describes the location and feature of a region and its spatial relative position. For a single grid dataset typically represent a single topic such as land use, soil, roads, rivers or elevation values, multiple grid datasets should be created to describe a region completely.

The plane appearance of the work area is divided into rows and columns according to a certain division force. It forms a multi-grid system and each grid cell is called a pixel. The grid data structure is actually a pixel matrix comprised of a collection of pixels. Each pixel in the grid is the most basic information storage unit called grid data, 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 value according to the information expressed by appearance differences. Entities can be divided into point entity, line entity and surface entity, i.e. point entity is expressed as a pixel in the grid

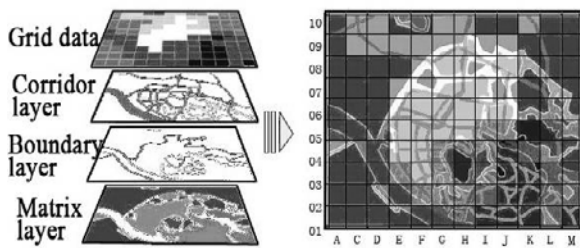


Fig. 1. A demonstration of map and data overlap.

data; line entity is expressed as clusters of adjacent pixels connecting in a certain direction; surface entity is expressed as a gather of adjacent pixels (Fig. 1). This data structure helps the computer dealing with the area patterns.

Grid analysis of the mathematical model 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 two methods.

The direct superposition method 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 combination method 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, transportation level.

2.2 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 1km² 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.

3. Multi-layer composite landscape grid network of Hangzhou City

3.1 Layer-photography of various landscapes network

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 (Wang, 2009). 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.

3.1.1 Network of natural environments

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 (Zhang, 2005). 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 changeable 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.

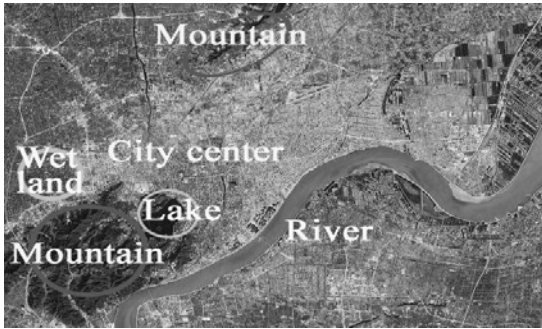


Fig. 2. The mountain-water system of Hangzhou City.

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 (Fig. 2).

(1) The mountains in Hangzhou. Hangzhou is a mountainous city with an area of 16000 km², of which mountains and hills account for 66%. It is also the largest city of Zhejiang Province with an urban area of 3068 km² and a mountainous area of 881.3 km². West Lake Scenic Area covers an area of 60 km². 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.

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 myself the Yellow

Crane Mountain, Mid-levels and such mountains stretching more than 10 km 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 West Lake two major river systems.

(a) Qiantang River: Running through south-eastern Hangzhou, the Qiantang River (formerly known as Zhe River) is world-famous for the Qiantang River Grand Tide. As the largest river in Zhejiang Province, the Qiantang River basin has an area of about 13,227 km² 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 river network: The water network of the northern region with the Millennium canal as the backbone has high river net densities. There are more than 140 rivers within the surround urban freeway. The main stream of Beijing-Hangzhou Grand Canal from the west to east has a total number of more than ten tributaries. The existing urban area includes the main channel River, East River, Tiesha River, Guxin River, Shangtang River and so on.

(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 km².

(d) Wetlands: Located in the city's western edge, Xixi Wetland National Park was formed in Shao Stream in the Tian Mu Mountain. It's separate from West Lake by only one mountain. 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.

In this study, statistical analysis is given to the internal

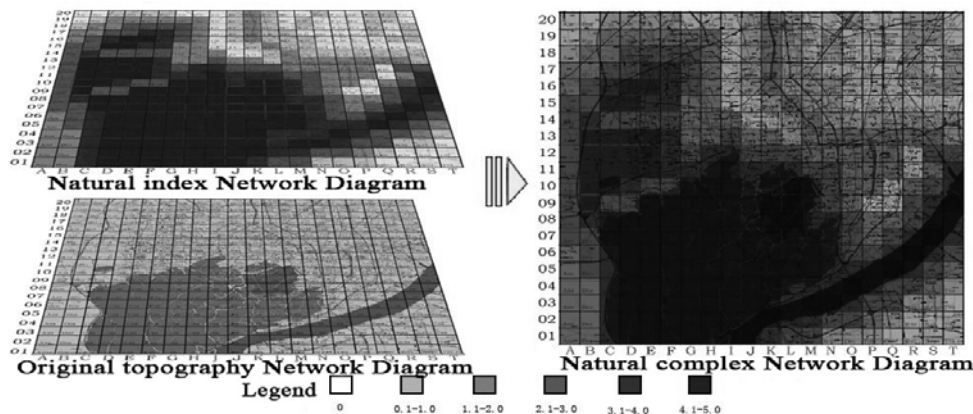


Fig. 3. Network of natural environments.

and external natural elements as well as the eccentricity of the 4001 km² grid unit to derive the natural elements index of each unit. Six grades from 0 to 5 are drawn from shallow to deep base on the index to form a natural landscape Network distribution map, as is shown in Fig. 3. The following four factors are taken into account in natural elements index: the percentage and the eccentricity of the green area and water area in the network unit; the percentage and eccentricity of the corresponding elements in the eight adjacent network units around. This algorithm draws on theoretical physics in the moment and fully considers the impact of quantity and quality of superposition.

3.1.2 Network of historical development

At different time and development process, urban landscape shows history, heritage and dynamics in nature. People think 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 take shape through long-term formation, expansion, integration of physical form environment and human factors slowly and spontaneously. During the gradual socio-cultural factors accumulation, the latter work is an interpretation

and re-interpretation of the former one. Therefore, the urban landscape we experience now has rich meanings for it shows people's understanding in each period through constant deposition. In construction and development of a city, the historical traditions and customs can not be put aside as well as the continuity and context of history and time. Only by interpreting the tradition to get information and symbols suitable for today's development can people make the city follow the tradition of the urban landscape and in coordination with modern times (Li, 2007).

Hangzhou is a historical and cultural city with a history of 2200 years and carries a profound historical and cultural accumulation, which gives the urban landscape features a strong support. This study takes the historical periods as clues to study the historical development of Hangzhou's urban landscape context. Five time periods (within 10 years, 11-25 years, 26-50 years, 51-100 and over 100 years) are divided to construct the historical development of Hangzhou urban landscape network. And according to the time periods, five colour grades from shallow to deep are built to draw the historical development network diagram (Fig. 4).

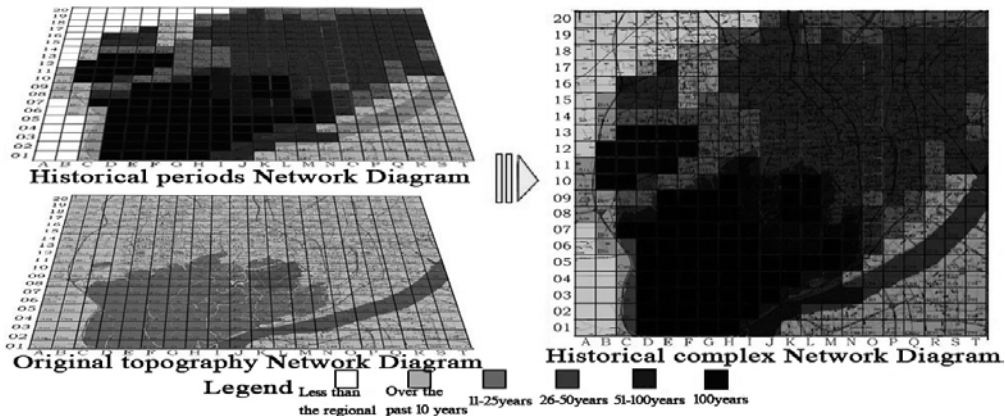


Fig. 4. Network of historical development.

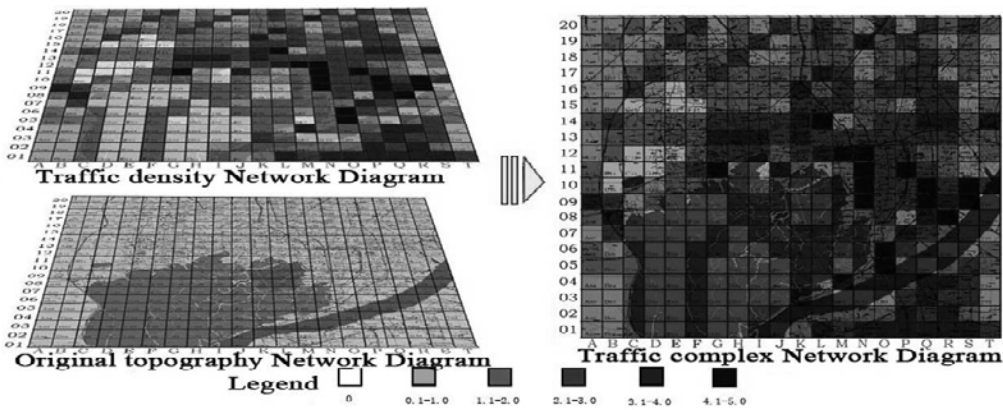


Fig. 5. Network of transportation.

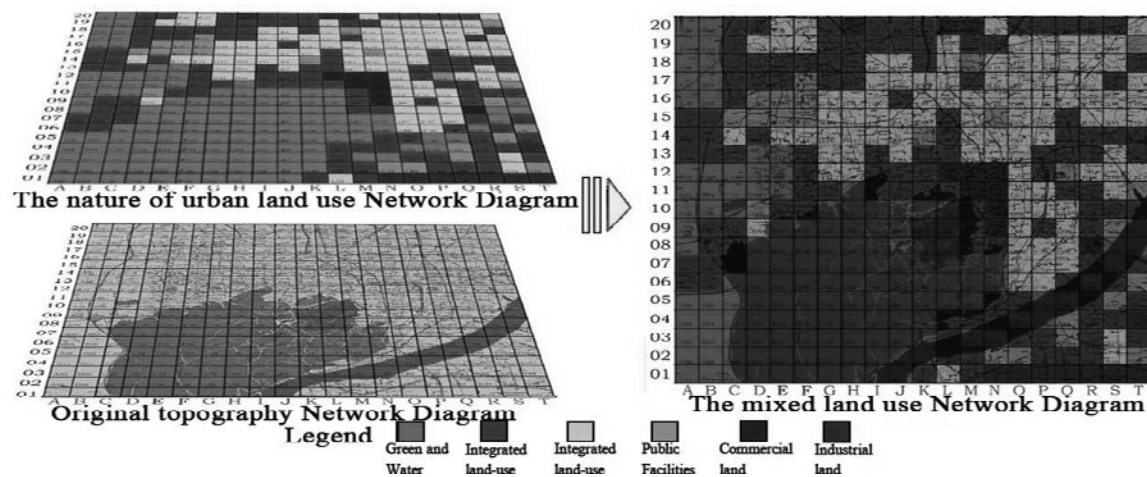


Fig. 6. Network of land use.

To explain, the time periods refer to the correlative literature of domestic urban development and architectural history and take the specific development of Hangzhou into account. The first time period is set as 1995-2014 (the latest sampling time of this study was theoretically set as 2014), which are the most flourishing 20 years of Hangzhou's urban infrastructural construction and real estate development; The second time period is set as 1980-1995 when reform and opening-up is in full swing and has unceasing development and perfection; The third time period is set as the 25 years from the foundation of PRC to the start of reform and opening up; The fourth period of time is from the end of the Qing Dynasty to the 50 years before the liberation; The fifth period of time generally refers to the wide-area before the late Qing Dynasty. Taking multiple factors of urban development changes into account, the time is not very precisely delimited.

3.1.3 Network of transportation

The city has transportation artery, living streets and connected city square roads respond to it. In urban road transport systems, urban transportation artery is the aorta; The subsidiary road is the subsidiary aorta and the feeder road is the capillary. The city Plaza is its turning point between them and the point of convergence. This study is based on the above analysis of the traffic network in Hangzhou. Road density value in each grid cell is divided from small to large into six levels, from shallow to deep the road transportation network's color distribution map is drawn (Fig. 5). The calculation of the Road density value mainly considers the road grade and length these two factors.

3.1.4 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 are attendant of the adjusting old districts and the changing 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 Fig. 6 (the mixed land use is a mixture of two or more land use, and each takes more than 30%).

3.2 ANOVA of Multi-layer composite landscape network

Among the four levels of urban landscape network mentioned above, the land use network is distinguished as nominal scale data while the other three networks (natural scenery network, historical development network and road traffic 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.

3.2.1 ANOVA of land use and natural environments

Through data analysis of 400 grid points, the F value of 56.789 is much larger than discriminate threshold F 1.977. The significance level was less than 5% (Table 1). It shows that there are significant differences between different land blocks nature in natural scenery elements.

Table 1. ANOVA of land use and natural environments.

land use classification	count	sum	average	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			
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	average	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			
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, squares*	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	average	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			
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 natural environments, historical development and transportation.

		Natural Landscape	Traffic	History
Natural Landscape	Pearson Correlation	1	-.434(**)	.374(**)
Traffic	Pearson Correlation	-.434(**)	1	-.467(**)
History	Pearson Correlation	.374(**)	-.467(**)	1

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

3.2.2 ANOVA of land use and historical development network

Through data analysis of 400 grid points, the F value of 17.012 is much larger than discriminate threshold F 1.977. The significance level was less than 5% (Table 2). It shows that there are significant differences between different land blocks nature in historical development elements.

3.2.3 ANOVA of land use and transportation network

Through data analysis of 400 grid points, the F value of 17.396 is much larger than discriminate threshold F 1.977. The significance level was less than 5% (Table 3). It shows that there are significant differences between different land blocks nature in road traffic elements.

3.3 The multi-correlation analysis of complex visual 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 points 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 traffic is well-developed are developing in recent years.

3.4 Organization of the landscape network and analysis of the suitability

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" on landscape. The multiple regression analysis method is used while solving equations of the suitability of the landscape network (Tables 5 and 6).

176 participants were surveyed with a questionnaire for their satisfaction evaluation on the amenity of the landscape at the level of visual perception. All the pictures represent the respective scenes at each network spot and unit. The evaluation was conducted with a scale of 100 points.

After a 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 (satisfaction) = 0.706x (natural environments of X1) + 0.107 x (historical development of X2).

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 5. Regression analysis summary.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.867(a)	.752	.750	20.04094

A Predictors: (Constant), VAR00002, VAR00001

Table 6. Regression analysis coefficient.

Model		Unstandardized Coefficients		Standardized Coef.	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	33.686	3.572		9.429	.000
	Natural Landscape	8.341	.620	.706	13.462	.000
	History	2.394	1.177	.107	2.033	.043

A Dependent Variable: VAR00006

4. Conclusions

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 weaknesses of the above approach include the following points: (1) lack of extraction of specific visual factors, failing to direct the design process; (2) lack of pedestrian routing data, failing to discriminate stronger-weaker connections among the network spots.

The distinctive strength of the multi-factor overlap approach shows its potential to combine with the GIS technology. For example, the construction of urban ecological landscape networks need fully consideration of different purposes, such as species migration, ecological protection and recovery, residents' leisure and so on. On the basis of different scales, there are higher requirements on the detailed data and index system. With the development of GIS technology, it will be a dynamic, real-time and 3D visualization, and even a true 3D display will be possible. By using GIS and Spatial Grid Networks in combination, the landscape designers and planners can extract accurate data of urban landscape, so the research in planning and design not only focuses on the functional layout on a plane, but also extends to 3D spaces. Therefore the overlap method is able to: (1) further strengthen the study on the object-oriented classification, especially of different landscape characteristic parameters; (2) improve the interpretation precision include vegetation data segment, and the precision of the mixed pixels in remote sensing image classification; (3) conduct an in-depth study of the landscape index to better reflect the existing forms of the landscape pattern; (4) enhance the specific monitoring on the landscape security, landscape attributes and landscape resistance value. With the support of the GIS technology, we can delve landscape ecology network from an all-round multi-layer angle. Based on a 3D perspective, it can promote the construction of urban ecological networks, optimize the healthy development of urban landscape, and implement monitoring on urban ecological security pattern.

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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