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QUANTITATIVE ANALYSIS AND FRACTAL MODELING ON THE MOSAIC STRUCTURE OF LANDSCAPE IN THE CENTRAL AREA OF SHANGHAI METROPOLIS

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ABSTRACT: The mosaic structure of landscape of the central area of Shanghai Metropolis is studied by quantitative methods of landscape ecology based on Remote Sensing (RS) and Geographic Information System (GIS) in this paper. Firstly, landscapes are classified into eight categories: residential quarter, industrial quarter, road, other urban landscape, farmland, village and small town, on-building area, river and other water bodies (such as lake, etc.). Secondly, a GIS is designed and set up based on the remote sensing data and field investigation, and a digital map of landscape mosaic is made. Then the indexes of diversity, dominance, fragmentation and isolation, and fractal dimension of each type of landscape in different periods are calculated by using spatial analysis method of GIS. With reference to the calculated results, a series of relative issues are discussed.
KEY WORDS: urban landscape; mosaic; modeling; Shanghai

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1 INTRODUCTION

Landscape, as the geographical entity with obviously visual characteristics (FORMAN and GORRON, 1986; FORMAN, 1995), is formed with different patches of land and inlaid with different ecosystems. It is a major subject studied by both ecologists and geographers (LI, 1999; XIAO, 1999). In ecology, particularly in landscape ecology, heterogeneity, visibility and physicality of landscapes are emphasized while geography is more focused on spatiality, regionality and comprehensibility of landscapes (XIAO, 1999).

In a particular region, various landscapes may form a landscape mosaic, in which one landscape is inlaid in a bigger landscape (FORMAN and GORRON, 1986; FORMAN, 1995). A city, as a typical landscape mosaic entity, is formed with the following three types of elements (ZHANG and NI, 2001): 1) artificial landscapes such as roads, residences, factories, markets and many other buildings; 2) semi-natural and semi-artificial landscapes such as parks, public green spaces and farmland; 3) natural landscapes under the disturbance of human activities such as rivers, lakes and nature reserves. Urban landscape mosaic may be different from other landscape mosaic in structure and functions. Cities usually have a simpler pattern of landscapes with a high degree of fragmentation. The main function of urban landscape mosaic is to supply a place for human's living and production.

Shanghai, as one of the largest cities in the world, is also a major economic center in China. During the past 50 years from 1947 to 1996, particularly after the foundation of the People's Republic of China in 1949, a drastic development and a tremendous change took place in Shanghai. Evolution of urban landscape mosaic in Shanghai is a direct exhibition of urban development. By using the landscape quantitative analysis methods and fractal theory based on GIS and RS, this paper studied the pattern of urban landscape mosaic and its evolution in the central area of Shanghai Metropolis in 1947–1996.

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2 STUDY AREA, DATA AND METHODS

2.1 Study Area

Since 1949 Shanghai has greatly expanded its urban area and its administrative districts have been readjusted for several times. In order to compare urban landscape mosaics in different periods, a study area is defined based on administrative boundary classification of Shanghai in 1988. The central urban area of Shanghai is divided into 10 districts, namely Huangpu, Nanshi , Luwan , Jing'an , Hongkou, Xuhui, Changning, Putuo, Zhabei, and Yangpu districts, with a total area of over 280.45km^2.

2.2 Data Collection and Pre-processing

Remote sensing image, the principal data source in our study, includes aerial photographs and astronautic ones. We have collected aerial photographs of seven time phases altogether (1947, 1964, 1979, 1984, 1988, 1993, 1994), MSS images from the early 1970s to the middle 1980s and TM images from the middle 1980s to the middle 1990s, based on which we can go on further interpretation and mapping.

Besides images of remote sensing, we also collected the administrative map of Shanghai in 1947 as a reference for interpretation, the topographic map (1:20 000) in 1958 for further modification, and topographic maps in 1993 (1:20 000) and 1996 (1:25 000) which served as base maps for interpretation after checked and modified.

The images in different periods reflected the real features of Shanghai objectively. Ministry of Construction of P. R. China published GBJ137-90 *Urban Land Use Classification and Planning and Construction Land Use Standards* (1991) including urban land-use classification, which consists of 10 larger sorts, 46 middle sorts and 73 smallest sorts. This classification standard is employed in our image interpretation so that land-use classification is based on the same classifying standard and different maps and data are compared.

The range of image interpretation is the central city map while the topographic map (1:20 000) is a basic map for transformed mapping. In the images before 1988, main geographic features such as roads and rivers were not modified, but which in the images after 1988 were modified when we transformed various sorts of patches to the topographic map.

After interpretation and feature transformation, we digitalized the land-use map gotten from the topographic map (1:20 000) with transformed geographic features, and finally mapped land-use maps (electric maps) of 1947, 1958, 1964, 1979, 1984, 1993 and 1996.

In order to study dynamic raws of the evolution of urban landscape mosaic, urban land uses were divided into eight landscape types of residential quarter, industrial quarter, road, other urban landscape, farmland, village and small town, on-building area, river and other water bodies according to the above land-use maps as well as landscape heterogeneity and different functions of urban landscape ecosystems. And the classification results were shown in Table 1.

2.3 Methods

2.3.1 Landscape indicators

Having consulted a number of relevant references (WANG, 1999; XIAO *et al.*, 1997; ZHANG *et al.*,

Table 1 Types of landscape in Shanghai

Landscape type	Function	Connotation
Residential quarter	Residence for urban inhabitant	Residential districts, streets, compact settlements and residential quarters of enterprises and institutions, etc.
Industrial quarter	Production (of the secondary industry)	Factories, mines and their attached facilities etc.
Road	Movement of people and flow of materials	Main roads, secondary main roads, and feeder roads(excluding roads in residential quarter and industrial quarter)
Other urban landscape	Production and service (of the tertiary industry)	Public places such as plazas and parks etc. and other service places such as markets, hotels, schools, hospitals and banks, etc.
Farmland	Production(of the primary industry)	All kinds of agricultural landscape such as vegetable plots, fields, cultivated lands, etc.
Village and small town	Residence for villagers and people in towns	Villages and small towns being different from urban landscape
On-building area	Urban construction and landscape renovation	Land being constructed
River and other water bodies	Natural circulation and purification of water	Rivers and other water surfaces

2000; HULSHOFF, 1995; TURNER and GARDNER, 1991), different landscape indices were compared, and diversity, dominance, fragmentation and isolation etc. were selected as indicators to make a quantitative study of the landscape mosaic structure in Shanghai.

(1) Diversity. It is used to describe the abundant degree and even degree of landscape type in a comprehensive way. The diversity index is calculated by formula (1):

$$H=-\sum_{i=1}^{S} P_i \ln P_i \quad (1)$$

where, S is the number of landscape types, P_i is the proportion of area of the ith landscape type in total landscape area; H is landscape diversity index. The greater the value of H is, the more abundant the landscape type is and the larger the diversity is.

(2) Dominance. It is used to indicate the dominant degree of one or several landscape types.The dominance index is calculated by formula (2):

$$D=\ln S+\sum_{i=1}^{S} P_i \ln P_i \quad (2)$$

where, S is the number of landscape types, D is dominance index. The greater the value of D is, the more dominant the one or several landscape types are.

(3) Fragmentation. It is expressed in the number of patches in per unit area, indicating the fragmentation degree of landscape patches. The calculation formula of fragmentation index is:

$$F=\sum_{k=1}^{S} n_k/A \quad (3)$$

where, S is the number of landscape types, n_k is number of patches of the kth landscape type, A is the total landscape area and F is the fragmentation index. The bigger the value of F is, the more fragmentary the landscape patches are.

(4) Isolation. It reflects the distribution of the different patches in the same type in landscape mosaic entity. The isolation index can be calculated by:

$$I_k=\frac{\frac{1}{2}\sqrt{\frac{n_k}{A}}}{\frac{A_k}{A}} \quad (4)$$

where, I_k is the isolation of the kth landscape type, n_k has the same meaning as the formula (3), A_k is the area of the kth landscape type.

2.3.2 Fractal model

Landscape patch is a typical fractal geometric object in nature (AI and LI, 1993; XU *et al.*, 2001a, 2001b, 2001c; ZHAO and WANG, 1995). The forms of landscape patches can therefore be studied quantitatively by using fractal theory methods.

MANDELBROT (1982) studied the form of fractal geometric structure and set up the following model:

$$[S(r)]^{\frac{1}{D}} \sim [V(r)]^{\frac{1}{3}} \quad (5)$$

where, $S(r)$ is the area of surface area , $V(r)$ is the volume, r is the measuring scale and D is fractal dimension.

DONG Lian-ke(1991) got the fractal structure model fit for Euclid space of n dimensions as following:

$$[S(r)]^{\frac{1}{D_n-1}}=kr^{(n-1-D_{n-1})/D_{n-1}}[V(r)]^{\frac{1}{n}} \quad (6)$$

where, supposing n=2, we can get the fractal structure model of 2 dimensions space:

$$[P(r)]^{1/D_1}=kr^{(1-D_1)/D_1}[A(r)]^{1/2} \quad (7)$$

where, $P(r)$ is perimeter, $A(r)$ is area, k is a constant, D_1 is the fractal dimension in a two-dimensional Euclid space.

Whether the perimeter and area of a landscape patch could be satisfied in the formula (7) or not? Or does a landscape form be a fractal structure? As some relevant studies have proved (XU *et al.*, 2001a, 2001b, 2001c; ZHAO *et al.*, 1995; LI, 2000; TURNER and GARDNER, 1991), for any type of landscape, its form is a fractal.

If formula (7) transposes at logarithm, we can get:

$$\ln[A(r)]=\frac{2}{D_1}\ln[P(r)]+C \quad (8)$$

For a certain landscape, we can get the fractal dimension D_i if we set up a regression model and calculate the coefficient $2/D_1$ according to the area and girth data of patches.

3 RESULTS AND DISCUSSIONS

3.1 Spatial Expansion of Urban Landscape

In order to show the evolution of landscape mosaic in Shanghai in 1947–1996, both GIS and RS have been used to set up a spatial-temporal database. Based on such a database, electronic maps can be made to describe landscape mosaic in different periods (1947, 1958, 1964, 1979, 1984, 1988, 1993, 1996). These maps reflect vividly the spatial-temporal evolutionary process of landscape mosaic structure in Shanghai. Fig.1 demonstrates only the urban landscape mosaic borders of Shanghai in different periods.

The spatial expansion of urban landscape in Shanghai in 1947–1996 was different from other cities in China, which usually expanded evenly from center to periphery. The expansion of the urban landscape of

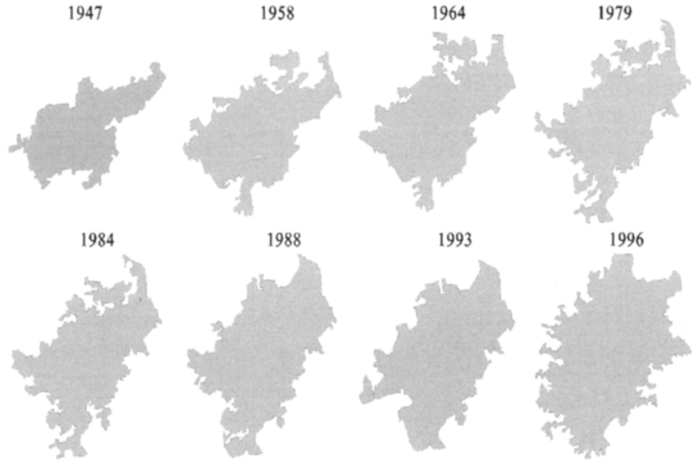

Fig.1 Urban boundary of Shanghai in different periods

Shanghai was uneven not only in time, but also in space. Industrial quarter and residential quarter, as two major types of landscape in Shanghai, have been playing a decisive role in the formation of urban landscape pattern since 1950.

In 1947 industrial quarter, mainly scattering at the periphery of residential quarter was located on the urban border like a piece of "lace". Yangpu industrial quarter, Putuo industrial quarter and Nanshi industrial quarter were discontinuous in space and residential landscape dominated in the whole central area of Shanghai. Owing to rapid development of industries in the early 1950s, more than 1800 factories were set up inside the present inner ring road in 1964, which turned the discontinuous industrial quarter into a circular zone. In 1979 this industrial circular zone totally surrounded the central urban area, and residential quarter and industrial quarter were inter-located, so the whole urban landscape appeared in a form of mosaic. Afterwards with expansion of urbanized area, industrial quarter stretched out like "feelers" along several main development axes. Some residential quarters were formed between feelers. They alternated with industrial quarters that extended along development axes, while some farmland (vegetable plot) spread between more distant feelers. So the spatial pattern that green space landscape alternated with urban landscape was formed.

3.2 Comprehensive Quantitative Characteristics of the Landscape Mosaic

In order to reveal evolution of the landscape mosaic structure in the central area of Shanghai Metropolis, we calculated indexes of diversity, dominance, and fragmentation in 1947, 1958, 1964, 1979, 1984, 1988, 1993, 1996 respectively by using formula (1)-(3). The results are shown in Fig. 2.

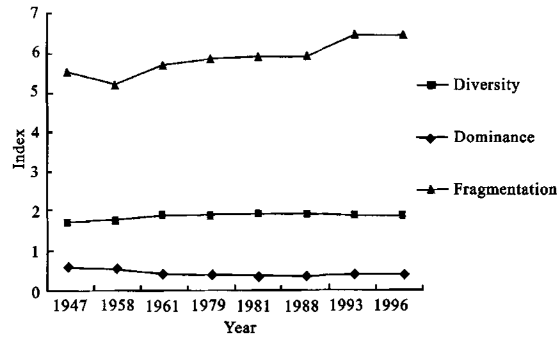

Fig.2 Indexes of diversity, dominance, fragmentation of landscape in different periods

As shown in Fig. 2, diversity index became bigger while dominance smaller prior to 1988. In 1947 diversity was 1.6281 and dominance was 0.4514 while fragmentation was 5.5661, which means the number of landscape patches was 5.5661 per square kilometer. At that time, in present central area, farmland, as a single dominant landscape, accounted for 48.11% of total land while residential quarter and other urban landscape accounted only for 14.14 % and 9.50 %, respectively. After the foundation of the People's Republic of China in 1949, urban construction in Shanghai sped up. Although farmland was still a dominant landscape in 1958, its proportion dropped to 39.75% while the area of residential quarter and other urban landscape rose to 20.16% and 12.32 % in total area, respectively. The indexes of diversity, dominance and fragmentation were then 1.6913, 0.3881 and 5.2380, respectively. During the period from the 1960s to the 1970s indexes of diversity and fragmentation increased furthermore while index of dominance reduced in Shanghai. Diversity index rose to 1.7998 in 1964 and 1.8229 in 1979 and fragmentation index increased to 5.7479 in 1964 and 5.9119 in 1979, while dominance index dropped to 0.2797 and 0.2566, respectively in 1964 and 1979. Up to 1979 there had been no major dominant landscape type when residential quarter, industrial quarter, other urban landscape and farmland accounted for 23.64%, 16.50%, 16.80% and 24.41% of total area, respectively. Since implementation of the policy of reform and opening up in the 1980s, urban construction of Shanghai sped up again. In the central area of Shanghai diversity index rose to 1.8380 and 1.8518, and fragmentation index to 5.9654 and 5.9761, respectively in 1984 and 1988 while dominance index dropped to 0.2414 in 1984 and 0.2277 in 1988. In 1988 residential quarter, industrial quarter, road, other urban landscape and farmland accounted for 27.84%, 18.70%, 6.64%, 18.58% and 15.03% of total area respectively. In the 1990s when government had a greater control on urban development (including readjustment of urban functions) and Pudong New Area(the eastern area of Huangpu River) had gone through a rapid development, diversity index in the central area of Shanghai dropped a little, and dominance index had a slight increase despite of a rise of fragmentation index. Diversity index reduced to 1.8039 in 1993 and 1.8045 in 1996 while dominance index rose to 0.2755 and 0.2749 and fragmentation to 6.5252 and 6.5324 in 1993 and 1996, respectively. In 1996 residential quarter, industrial quarter, road, other urban landscape and farmland accounted for 34.50%, 18.58%, 6.70%, 17.97% and 6.83% of total area, which showed that residential quarter had been a dominant landscape type. Particularly to mention, the 1990s was a period when Shanghai saw a drastic development in urban construction. There were 247 and 248 landscape patches under construction in the central urban area of Shanghai in 1993 and 1996, which accounted for 4.98% and 5.65% of total area, respectively.

3.3 Change of Isolation Index

As for a certain landscape, isolation index indicates the degree that this landscape was cut off or separated by other landscapes and corridors. That is to say, the bigger the isolation index is, the more dispersed the patches of such landscape are.

Using formula (4), the isolation indices of the central area in Shanghai Metropolis in 1947,1958,1964, 1979,1984,1988,1993 and 1996 were calculated (Table 2).

Table 2 Isolation index of different landscapes in different periods

Landscape type	1947	1958	1964	1979	1984	1988	1993	1996	Average
Residential quarter	3.1592	2.3691	2.2105	2.0679	1.9820	1.8853	1.9088	1.9256	2.1886
Industrial quarter	7.3309	5.7659	3.8992	3.5181	3.3430	3.3148	3.1757	3.1695	4.1896
Road	2.8495	2.8418	2.8480	2.9175	2.6348	2.5453	2.7095	2.7126	2.7574
Other urban landscape	4.3203	3.8157	3.5821	3.1836	3.1740	3.0995	3.1828	3.1734	3.4414
Farmland	1.2018	1.2768	1.7184	2.0542	2.2111	2.3923	4.1647	4.4551	2.4343
Village and small town	7.8695	8.1957	10.0546	10.6398	10.7364	11.8221	12.1808	12.3040	10.4753
On-building area	12.5109	45.1393	21.0566	28.6236	21.5226	12.1772	9.4187	8.3215	19.8463
River and other water bodies	1.8942	1.7897	1.9037	1.8585	1.7315	1.8915	1.7133	1.7152	1.8122

From Table 2 we find out the change of isolation index. 1) In the time series of landscape evolution, isolation indices of residential quarter, industrial quarter and other urban landscape showed a declining tendency, isolation indices of farmland and villages and small towns showed a increasing tendency and isolation indices of roads and river changed a little. 2) Isolation index of on-going area was the greatest in 1958 (45.1393), second in 1979 (28.6236) and began to reduce since 1988. Their isolation indexes were 12.1772, 9.4187 and 8.3215, respectively in 1988, 1993 and 1996. Despite of irregularity in their change, the indices may have shown the rhythms of urban construction in Shanghai. The greatest isolation index in 1958 may reflect that landscape patches under construction were very few and the average distance between patches once greatly increased when there was little urban construction. During the late 1980s and 1990s when Shanghai Metropolis was in a rapid urban construction, an increasing number of landscape patches under construction appeared and the average distance between patches reduced. Isolation index was therefore becoming smaller. 3) Of all types of landscape, river and other water bodies enjoyed the smallest isolation index since their distribution patterns were determined by the natural water system and usually remained to be not changed despite of many new bridges constructed during the past 50 years. Moreover, isolation indices of residential quarter, industrial quarter, other urban landscape and farmland were smaller since population density in Shanghai was very high, industries and trade were developed and farmland was cut into pieces by other types of urban landscape.

3.4 Fractal Characteristics of Patch Form Evolution

For a landscape, the fractal dimension shows the complexity and stability of its patch form. The value of D_l may range from 1 to 2. The greater the value is, the more complicated the patch form is. D_l=1 shows that the patch form is a square. D_l=2 shows the patch form is most complicated. When D_l=1.5, it shows the mosaic structure of the patch form is in a random state similar to a Brownian movement, namely in a most unstable state. The more close to 1.5 D_l is, the less stable the patch form is (DONG, 1991; ZHAO and WANG, 1995; XU *et al.*, 2001c). Some relevant studies indicated that the patch form of natural landscapes is more complicated and less regular than that of artificial landscapes (AI and LI, 1993; XU *et al.*, 2001a, 2001b, 2001c).

In order to study evolution of different landscapes in 1947–1996, a fractal model for landscape form has been established and the fractal dimensions of landscape form in 1947, 1958, 1964, 1979, 1984, 1988, 1993 and 1996 have been calculated (Fig. 3).

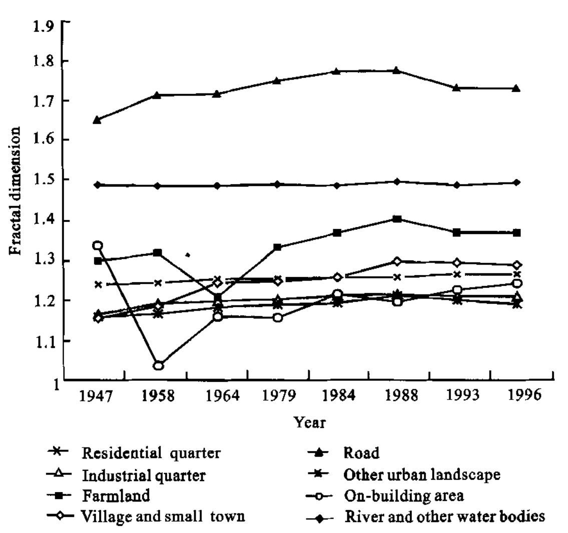

Fig.3 Fractal dimensions of landscapes in different periods

According to the calculation, the following results can be presented:

(1) In terms of average value of fractal dimensions, landscapes types can be ranked as: road (1.7507)> river and other water bodies (1.4925)> farmland (1.3470)> residential quarter (1.2531) > village and small town (1.2449)> industrial quarter (1.1960)> on-building area (1.1945) >other urban landscape (1.1803). The rank can be understood as the rank of complexity of landscape patterns. Of all landscapes, road was the most complicated landscape pattern, and river and other water bodies was a relatively less complicated landscape pattern since they are determined by environment and natural water system in Shanghai. Industrial quarter landscape, other urban landscape and on-building area landscape were simpler and may be close to a regular square.

(2) Concerning evolution of landscape patterns, we can make conclusions as follows: 1) Fractal dimension of residential quarter showed a slowly increasing trend. It was 1.2392 in 1947, 1.2519 in 1964, 1.2575 in 1988 and 1.2623 in 1996. This indicates that the patch form of residential quarter tended to become more and more complicated since houses may be constructed as long as there is a piece of empty land. 2) Fractal dimensions of industrial quarter, road, other urban landscape, farmland and village and small town showed an increasing trend in 1947–1996. For all these landscapes, their fractal dimension were the lowest in 1947 and increased to the greatest in 1988. Since 1988 their fractal dimension have begun to reduce gradually. All these show that evolution of the above five landscapes have gone through a process from simple to complicated and then to simple again. It can be concluded that urban planning did play an important role in urban construction before 1998, make urban landscapes more and more complicated. Since 1988 urban landscape patterns have become simpler and more regular again due to the effect of urban planning. 3) Since on-building areas were transitional landscapes, their patch patterns were irregular. Their fractal dimension may change irregularly. 4) Fractal dimension of river and other water bodies did not show great change since their patch form did not change much.

3.5 Factors Affecting Landscape Pattern and Its Evolution

By utilizing GIS functions on spatial analysis (overlay and buffer etc.), we find that the factors affecting landscape pattern of Shanghai and its evolution include river corridors, original foundation of the city, traffic corridors, economic development and urban planning, etc.

(1) River corridors. The Shanghai Metropolis was revitalized and developed due to its advantageous geographic location and natural environment. River corridors have played an important role in the formation of urban landscape pattern of Shanghai. Of all river corridors, the Huangpu River may have a most influential effect on the city's landscape pattern. Before 1990 development of Shanghai was chiefly concentrated in the western part of the Huangpu River (Puxi Area) while development in the eastern part of the Huangpu River (Pudong Area) was limited only to the riverside zone. Urban development on both sides of the Huangpu River seemed asymmetric. Only when a new bridge and a tunnel crossing the river were finished and opened in the 1990s that the landscape pattern in Shanghai began to be changed. Despite of a drastic development in Pudong area in the past 10 years, the asymmetric pattern of urban development has not changed. The main direction for urban development in Shanghai since 1949 has been along with the Huangpu River and the Wusong River.

(2) Developmental foundation. Though Shanghai has gotten a rapid development since 1949, its developmental base formed before 1949 is still important for the formation of the present urban landscape pattern in Shanghai. In 1947 when landscape of Shanghai looked like " σ ", the main part of Shanghai was in the south and west of the confluence of the Huangpu River and the Wusong River and its tail pointed to the lower reaches of the Huangpu River in the northeast. Except for the northeastern part of Yangpu District, the old city was all situated within the inner ring road of present Shanghai (with an total area of 115.22km^2, in which Puxi Area is 84.36km^2 and Pudong Area is 30.86km^2). The old city is still the core of present Shanghai. In addition, the three old industrial areas formed before 1949 have laid foundation for establishment of new industrial belts.

(3) Traffic corridors. A convenient transportation system is fundamental for rapid urban development. The rise of Shanghai is partially due to its convenient water transportation. Shanghai lies in the mouth of the Changjiang (Yangtze) River and in the middle part of China's coastline. It is also connected with Taihu Lake Basin by the Huangpu River and the Wusong River. Water traffic corridors have been the bases for formation of present landscape pattern in Shanghai. Urban landscape usually extends along roads. Development of road may promote exchange between the city and its adjacent areas. The several conspicuous "feelers" may extend along traffic corridors. Traffic corridors in the city may undertake the task of exchanging matter, energy and information between different urban landscape patches.

(4) Economic development. The evolution of landscape pattern in Shanghai has been irregular or rhythmic on time scale. During 1947-1964 the area of urban landscape increased fast. During 1964-1979 urban expansion was not so fast as that in the previous period. During 1979-1988 urban expansion speeded up again. In the following four years there was a slight decline for speed of urban development. After 1993 urban development was rapid again. These rhythmic changes have been in conformity with economic development in Shanghai. Economic development played a major role in evolution of urban landscape pattern in Shanghai.

(5) Urban planning. Urban planning may play a decisive role in formation of urban landscape pattern and its evolution. Urban landscape under the strict control of urban development in accordance with urban planning usually shows a regular and simple form with a clear classification of urban functions. If urban planning is not implemented or urban development is not strictly controlled, there would be no classification of urban functions. In the process of urban development in Shanghai, Puxi and Pudong had different policies for urban development. Puxi has been implementing the "radiating" and "filling up" policy while Pudong attached more importance to development of new districts with a clear function. At present there have been many new functional districts in Pudong. Puxi is however facing the problem of readjusting functions of urban districts. Urban planning may need to be revised in different periods of urban development.

4 CONCLUSIONS

According to above analysis, we can get the following conclusions:

(1) Urban expansion in Shanghai was irregular not only on spatial scale but also on temporal scale. For this viewpoint Shanghai was different from many other cities in China, which usually expanded concentrically from center to periphery evenly.

(2) On the whole, the diversity and fragmentation indexes of urban landscape in Shanghai had an increasing tendency, while dominance index had a de-

creasing tendency.

(3) Of all types of landscape in Shanghai, residential quarter, industrial quarter, and other urban landscape were less isolated during their evolution while farm land, village and small town were more isolated. Isolation degrees of road and river and other water bodies have not largely changed.

(4) In regarding fractal dimension at an average level of different types of landscape, road > river and other water area > farmland > residential quarter > village and small town > industrial quarter > on-building area > other urban landscape. This hierarchy may show the complexity of different types of landscape pattern.

(5) As evolutionary process of different types of landscape pattern indicates, fractal dimension of patches of residential quarter showed a slowly increasing trend, which reveals that patches of residential quarter tends to be more and more complicated. Fractal dimensions of patches of industrial quarter, road, other urban landscape, farmland and village and small town showed an increasing trend in 1947–1988. After reaching the highest in 1988, they began to reduce gradually. It shows that the five types of landscape have experienced a process from simple to complicated and then to simple again.

(6) The main factors affecting formation of landscape pattern in Shanghai and its evolution are river (river corridor), original foundation of the city, road (traffic corridor), economic development, and urban planning.

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