

# The Interactions among Urban Land Use, Environment and Transportation Systems: Draw Miniatures from Five Cities

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**Abstract:** *Urban, symbolizes a certain stage in the evolution of human civilization. Recently, people have discovered some laws in the operation of urban areas and summarized some characteristics of urban systems. This article aims to introduce the urban sub-systems in the complex urban systems, and to study the interactions among urban sub-systems in the operation of urban areas. The first chapter briefly introduces three urban sub-systems, namely the urban land use system, the urban environment system and the urban transportation system, and analyzes their components and importance in the urban system. The second part through the study of Lanzhou, Vienna, and Seoul, analyze the possible connections between each urban sub-system. The third part takes two worldwide cities, Beijing and Santiago, as examples, emphatically shows the interrelationship of three urban sub-systems in the operation of the complex urban system. The conclusion of this article is that urban areas are important habitats for humans and many living things, it is important for human beings to explore and study the complex urban systems, discover and understand the various urban sub-systems, so as to better build the urban space and pursue the sustainable development of the urban systems.*

**Keywords:** *urban system, urban sub-systems, land use, environment, transportation*

## 1. Introduction of Urban Systems

### 1.1 Urban Land Use System

#### Overview of Urban Land Use System

Land can be said to be the carrier of all natural elements such as resources and environment, and the material basis for human survival, reproduction and development. Land use is the process of economic activity in which humans obtain material products and services through the combination with the land. In this process, humans exchange and transform material, energy, value, and information with the land.

For a long time, human beings have used the land to satisfy their own survival and development needs. The earliest use of land by humans was to obtain animal meat, plant fruits and other food directly from the land. With the division of labor in human society and the emergence of primitive agriculture, humans began to obtain food and other agricultural products through agricultural activities such as sowing and harvesting. With the progress of human civilization, human settlements have gradually evolved into modern cities. Due to the more effective use of urban land, a series of scientific actions on land development, utilization and protection have emerged, and urban land use systems have emerged from this.

#### Components in Urban Land Use System

Urban land use refers to the status of residential, industrial, and transportation construction land in the city, and also includes some reserved non-construction land. Urban land use reflects the basic form of urban layout and the regional differences of functional areas within the city.

The composition of the urban land use system can be roughly summarized as:

1) Residential land: including residential quarters and auxiliary shops, public facilities, roads, squares, courtyards, green spaces and other construction land.

2) Industrial land: various industrial and mining enterprises, workshops, workshops, construction bases, as well as auxiliary power, water supply, storage facilities in the factory area, special lines outside the factory area, special docks, auxiliary facilities and various slag dumping yards, etc.

3) Commercial facilities land: used for various commercial, commercial, profit-making institutions, entertainment facilities and other land.

4) Land for public service facilities: Land for administrative, cultural, educational, sports, health and other institutions and facilities that serve citizens.

5) Land for municipal facilities: land used to ensure the supply, environment, and safety of urban activities.

6) Land for transportation facilities: including railways, highways, various stations and ancillary facilities, land and ancillary facilities for port terminals and airports, automobile transportation and ancillary facilities, etc.

7) Warehousing land: the land used for material storage, transit, and distribution in the city, including land used for auxiliary roads, parking lots, and truck yards.

8) Park green land: including parks, protective green land, squares, scenic spots, historical sites and other public open space land.

9) Undeveloped reserve land

### **Importance of Urban Land Use System**

It can be seen that the urban land use system is the foundation of the formation and development of modern cities, and the carrier of urban social, economic, political, cultural and other activities. Therefore, the rational operation of the urban land use system is directly related to the rise and fall of the city and the development of the regional economy[1-3].

## **1.2 Urban Environment System**

### **Overview of Urban Environment System**

Initially, during migration, humans chose settlements with mild climate and abundant resources to establish cities and settle down. In cities, in order to improve the quality of life and production efficiency, humans have transformed the original natural environment, produced artificially managed farmland and breeding farms, and built or formed a series of new residential facilities, such as houses, Roads, parks, etc. After industrialization, various factories and trading places were born. These urban environments not only play a great role in promoting social and economic development and improving production and living standards, but also have a multi-faceted impact on various animals, plants and microorganisms living in the city, which in turn affects the quality of life and production efficiency of urban residents.

In the urban environmental system, the relationship between man and nature can be either reciprocal or competitive. A piece of land is either developed as an artificial facility or preserves the natural landscape. In the process of rapid urban development, the social and economic value of urban land continues to increase, resulting in the gradual expansion of artificial construction land and the gradual decrease of natural land, which will produce a series of consequences brought about by urbanization.

### **Components in Urban Environment System**

The urban environment is the sum of the human and natural conditions related to the city as a whole.

The composition of the urban environmental system can be roughly summarized as:

1) The natural environment is all the components in the urban ecosystem that have not been transformed by human labor, including both non-biological and biological parts. The non-biological part includes geology, landform, hydrology, climate, etc., and the biological part includes animals, plants, microorganisms, etc.

2) Artificial environment-refers to the spatial environment composed of artificially set boundary surfaces.

### **Importance of Urban Environment System**

The formation, development and layout of cities benefit from the urban environmental conditions on the one hand, and are also restricted by the local environment on the other. The quality of the urban

environment directly affects the production and living activities of urban residents. Therefore, in urban construction, efforts should be made to reduce the competitive relationship between man and nature in the urban ecosystem, and give full play to the complementary and synergistic relationship between man and nature. Only in this way can we ensure the harmony between man and nature and promote the sustainable development of the city[4-6].

### 1.3 Urban Transportation System

#### Overview of Urban Transportation System

Transportation is the realization of the displacement of people and objects and the transmission of information. The urban transportation system is developed with the needs of human life and production.

The urban transportation system is a basic part of the social, economic and material structure of the city, which connects the production and life activities scattered throughout the city.

#### Components in Urban Transportation System

The urban transportation system includes two aspects: urban passenger transportation and urban freight transportation.

1) The composition of urban passenger transportation system: Public transportation: conventional bus, rail transit, auxiliary bus, special bus, etc., Private transportation: walking, bicycle, motorcycle, car, etc.

2) The composition of the urban freight transportation system: Road transportation, railway transportation, ship transportation, air transportation, pipeline transportation, etc.

#### Importance of Urban Transportation System

The urban transportation system plays a very important role in organizing the production and life of the city, improving the efficient operation of the city's cargo flow, and promoting the development of the city's economy. The layout, scale, and lifestyle of cities all need the support of an urban transportation system.

## 2. Preliminary Exploration of Connections between Urban Systems

### 2.1 Connections between Urban Environment and Land Use System——Take Lanzhou as Example

#### Terrain and rivers guide the directions of region development

Lanzhou in China is a city built on the Yellow River. In China 2000 years ago, Lanzhou was an important ferry on the upper reaches of the Yellow River and an important node on the "Silk Road". In ancient times, the layout of urban land use in Lanzhou complied with the traditional Chinese layout of government cities. Therefore, the inner city was organized with four gates, but the outer city showed an irregular form. This irregularity was mainly caused by the restrictions of terrain and rivers.

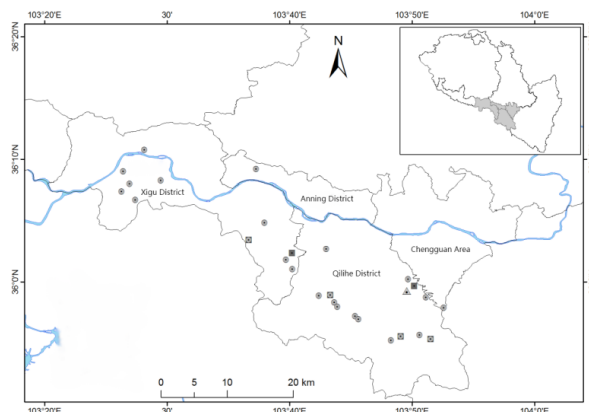


Figure 1: Distribution of Prehistoric Human Sites around Lanzhou, China

The urban spatial expansion of Lanzhou is strictly limited by the topography of the river valley. For

a long time, land use in Lanzhou, China has been built in the valley of the Yellow River(Fig.1). To today. The urban built-up area of Lanzhou has filled the entire Yellow River valley and basin. Therefore, the urban construction of Lanzhou had to spread from the river valley plains to the mountains in the restricted construction area.

### Natural elements bring inspirations for urban land use

There are many beautiful natural landscapes in the geographical environment of Lanzhou, China. In history, many poets have praised these beautiful landscapes. For example, the Tang Dynasty poet Gao Shi (704-765) described Lanzhou as "Looking west from the North Tower, the sky is clear and the mountains are like a painting."

In this way, in the urban planning of Lanzhou in recent decades, it has been emphasized to maintain the overall landscape pattern of "two mountains and one river" in Lanzhou, and to construct an urban landscape with a northwestern regional style. The development of the city is also carried out in accordance with such environmental advantages[7-9].

### Orderly development can stimulate the vitality of urban environment

Urban planners in Lanzhou have effectively used the floodplains along the Yellow River and other areas to increase urban green space and set up urban ecological corridors to bring vitality to the urban environmental system. From 1961 to 2015, the area of urban green space in Lanzhou, China increased from 1.71 km<sup>2</sup> to 12.10 km<sup>2</sup>. In the growth process of urban green space, urban built-up areas, arable land, woodland, and grassland are all sources of land for urban green space growth. Among them, the areas where water bodies and floodplains disappeared in large areas mainly occurred in the Chengguan area, and the areas where urban green space increased mainly occurred in the Chengguan area.

### Incorrect construction may seriously damage natural biosphere

Inappropriate land development will first reduce the number of ecological patches. The destruction of ecological patches first appeared in Xigu District and Anning District. Since the 1990s, the construction of large-scale "development zones" and "industrial parks" in Lanzhou, China has resulted in a significant reduction in arable land, woodland, and floodplains (Fig.2). The ecological background of Shanshui City has been severely damaged.

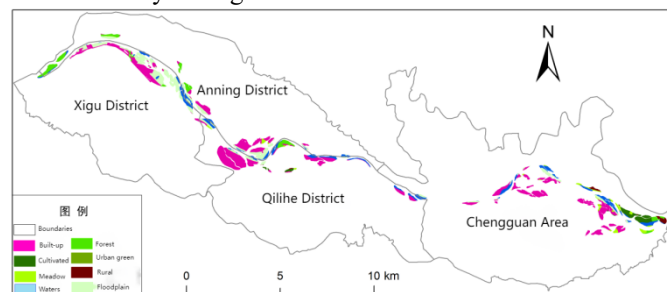


Figure 2: Spatial distribution characteristics of the evolution of floodplain structure

Scattered ecological patches have weakened the overall function of the urban environmental system. The ecological functions of the main ecological land in cities-woodland and grassland are gradually reduced due to the expansion of urban construction, and these ecological patches are difficult to exert ecological effects due to their small scale, scattered layout, and space barriers by built-up areas. With the concentration of urban population and the expansion of urban built-up areas in the future, the ecological functions of the urban landscape in Lanzhou are in a trend of continuous degradation.

## 2.2 Connections between Urban Transportation and Land Use System -Take Vienna as Example

### Products from land are the reasons for transport operation

Historically, the Danube was an important transportation route for wood and coal to Vienna, Austria. Vienna is an important industrial city in Austria. Before the 19th century, industrial production consumed a lot of wood. The Danube connects Vienna with the vast woodland hundreds of kilometers upstream of the city to the west. With the increasing demand for wood in industrial production, these woodlands have gradually become the hinterland of the Vienna market (Fig.3).



Figure 3: the west and east are forests, the angled structures in the north-east and south are agricultural areas, and the fragmented structures are settlement areas

After the 19th century, the status of coal in industrial production gradually increased. In the 1860s, when the use of coal in Vienna, Austria began to reach a significant scale, at the same time, the advantages of railways in coal transportation gradually became prominent. With the advantages of large traffic volume and faster speed, railways gradually replaced the previous waterway transportation. Vienna and its surrounding areas began to build multiple railway lines, running at the same time as the Danube[10-11].

#### Reasonable land use arrangement improve the efficiency of transportation

In order to improve the efficiency of transportation, Vienna planned and opened a canal in 1803-Wiener Neustädter Kanal, which is a 63-kilometer-long artificial waterway that connects Vienna with its southern hinterland and is used to connect wood, bricks, and coal. Transported into the city. Prior to this, the main route for supplying goods to Vienna was the Danube, a river that traverses Vienna from west to east. The opening of the canal greatly increased the capacity and speed of cargo transportation (Fig.4).

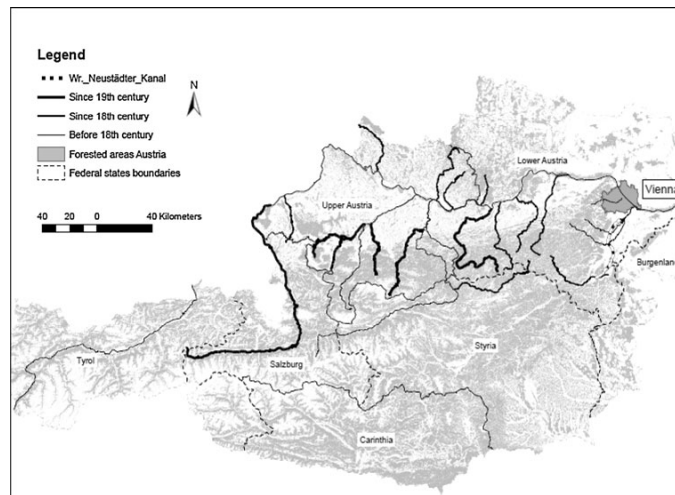


Figure 4: Danube tributaries used for wood transport to Vienna, Austria in the nineteenth century

#### Transportation system plays a "skeleton" role in land expansion

In terms of geographical location, Vienna is a strictly inland city. It is located between the high mountains and hills in the west and the Pannonian lowlands in the east. Compared with many other major urban centers in Europe, it does not have an advantage. However, the Danube connects the city with the upper Alps in the west, the Pannonian Plain in the lower east, and the Black Sea nearly 2,000 kilometers away. Due to the importance of the Danube in Europe's transportation network, Vienna has therefore become an important transportation hub city. The early land use layout of Vienna was laid out around the inland port by the Danube.

### Evolution of transport methods changes the layout of urban land use

The land use in Vienna, Austria has undergone tremendous changes during the 19th century. The main reason is that at this time, rail transport joined the freight network and played an important role at the same time as water transport. Until the beginning of the 19th century, the settlement area on the Danube Plain was limited. However, in the early 19th century, many residential and industrial areas were quickly built on the left bank of the Danube. After the 1870s, new built-up areas were also built on the right bank of the Danube. After November 1850, Vienna established a connection with the northern coal producing areas, and the layout of urban land use has since been extended along the Danube River and the railway (Fig.5).

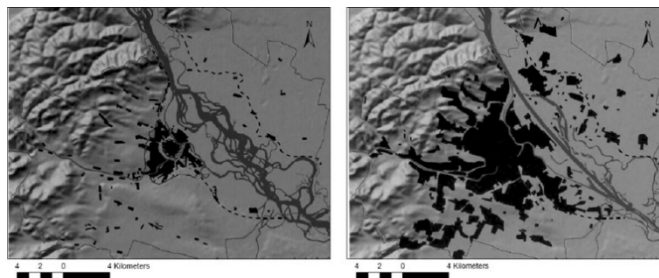


Figure 5: Land use in the Viennese Danube floodplains a 1770 and b 1913 (from Eigner and Schneider 2005)

### 2.3 Connections between Urban Transportation and environment System -Take Seoul as Example

#### Landscape factors usually be considered in transportation planning

In the "Seoul 2030 Urban Planning", the Han River's role in Seoul's urban planning is particularly emphasized. In the previous road network construction, the riverside highway made the transportation network smooth, but it isolated the interaction between the citizens and the Han River, and the advantages of the urban natural environment could not be felt by the citizens. Therefore, in the new urban planning plan, a large number of parks, green spaces, and squares are planned along the Han River. Such an approach will not damage the connection between the urban transportation system and the environmental system, but can also improve the city's outlook and increase the convenience of citizens.

#### The development of urban transportation may cause damage to the urban environment

#### Exhaust emissions from motor vehicles can cause severe air pollution

Traffic is a large part of urban air pollution emissions, such as carbon monoxide (CO), nitrogen dioxide (NO<sub>2</sub>) and volatile organic compounds (VOC), and indirectly contributes to ozone (O<sub>3</sub>) concentrations.

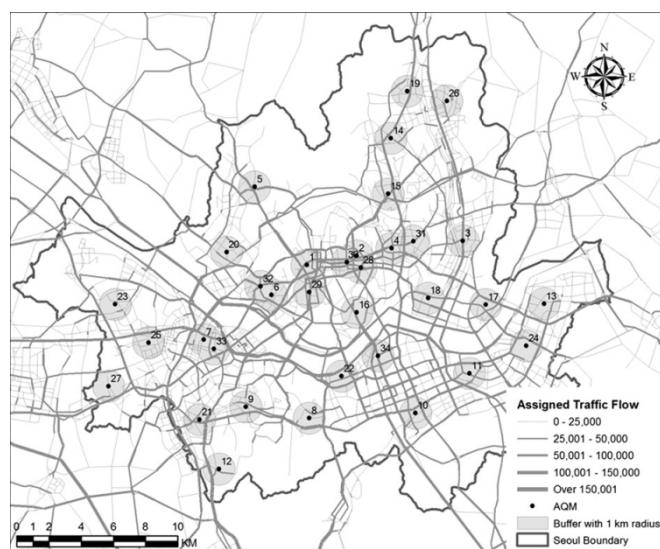


Figure 6: Location of AQMs and assigned traffic flows in Seoul, Korea

In Seoul, South Korea, automobile exhaust is the main source of direct pollutants in urban areas, and air pollution values have shown a significant increase during the morning and evening peaks. Moreover, the daily wind direction of the city also affects the air pollution concentration in different areas (Fig.6). Despite improvements in vehicle emission control technology, the recent rapid increase in vehicle ownership and average travel distance has caused unhealthy air quality in urban areas.

### 3. Further Exploration of Interactions among Urban Systems

#### 3.1 A sample of complex urban systems from 'Beijing's Sprawl'

##### Urban Sprawl, the disorderly expansion of urban space

Urban sprawl is a phenomenon in which the expansion of urbanized areas is out of control. It spreads the urban activities originally concentrated in the central area to the periphery of the city, and the urban form presents the characteristics of decentralization, low density, and single regional function.

In 1937, Draper E. of the Tennessee Valley Administration of the United States first used the term "urban sprawl". It is defined as "the process of outward extension of urban space and urbanization of agricultural land", and it is believed that urban sprawl is an unsightly and uneconomical urban space expansion phenomenon. In 1954, the French scholar Guttman called the sprawl in "Megalopolis" as "the continuous expansion of the periphery of the metropolis".

Beijing, China has experienced rapid urbanization in recent years, and the sprawl phenomenon of the urban center of the city continues to intensify. The expansion of Beijing's land use to the periphery has deviated from certain control, resulting in urban diseases such as traffic jams, encroachment of green belts, and deterioration of the environmental quality of the central city.

##### Rapid construction caused chaos transportation in the city center

The central city of Beijing, China is expanding outwards at a rapid rate. At the same time, traffic problems are increasing day by day, and problems such as traffic jams and parking are happening every day.

In 1994, the scale of land use in the central area of Beijing has expanded to the third ring road, and the number of motor vehicles and roads has begun to increase significantly. However, the growth rate of motor vehicles is 5.7 times that of roads, and many traffic problems have become prominent: traffic congestion. The average commuting time of Beijing residents in 2010 was 45 minutes, which was 18.5% higher than the 38 minutes in 2005. Difficult parking: In 2013, the total number of motor vehicles in Beijing, China was 5.312 million, with 2.172 million parking spaces, and the parking space gap was about 2.5 million.

##### Inefficient land use destroyed ecological environment in the suburbs

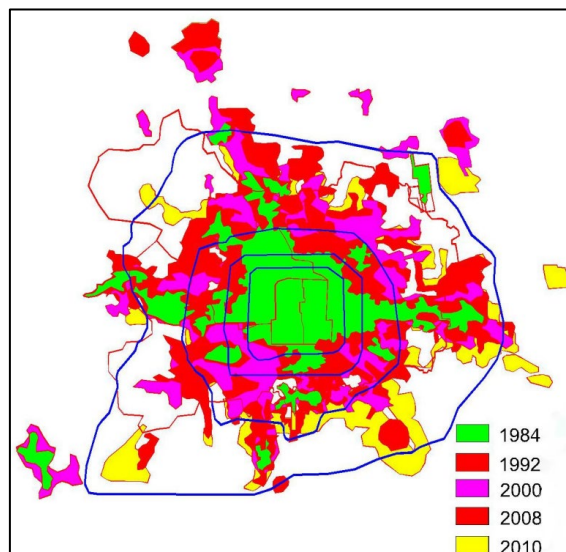


Figure 7: 2008-2010 Beijing Central City's construction land change relationship

Beijing is located in the North China Plain. The overall quality of the original ecological base is not high. The construction land development process did not pay attention to the protection of the environment, which intensified the severity of ecological damage, especially in several aspects: the reduction of ecological wetlands and the area of Beijing wetlands. It accounts for 3.13%, which is lower than the national average of 4.77%. The soil conservation ability has deteriorated, and the continuous exploitation of groundwater has caused the stratum to sink, and the dryness of rivers has increased the area of desertification, leading to flooding problems after heavy rains. In addition, the area of water and soil erosion, sandy land and barren hills in Beijing has also continued to increase (Fig.7).

### Compact City Theory—an attempt to govern the phenomenon of Urban Sprawl

The compact city theory is a countermeasure proposed against the phenomenon of urban sprawl. It emphasizes the strategy of mixed land use and intensive development. It advocates that people live closer to the workplace and the service facilities necessary for daily life. It is a land-based approach. New ideas for efficient use of resources and exquisite development of cities.

In 1973, American mathematician Dantzig G, Satty T. proposed the concept of compact city, which is a complex, interconnected and highly dynamic city system. In 1990, the Community Commission of the European Community issued the "Urban Environment Green Paper", indirectly proposing the concept of compact cities. The Green Paper pointed out that compact cities are "urban economic and social activities that rely on high-density space, convenient transportation, and "Diversified land use", "emphasis on mixed use and intensive development strategies, has led to people living closer to work places and necessary service facilities for daily life, and cars have become a choice.

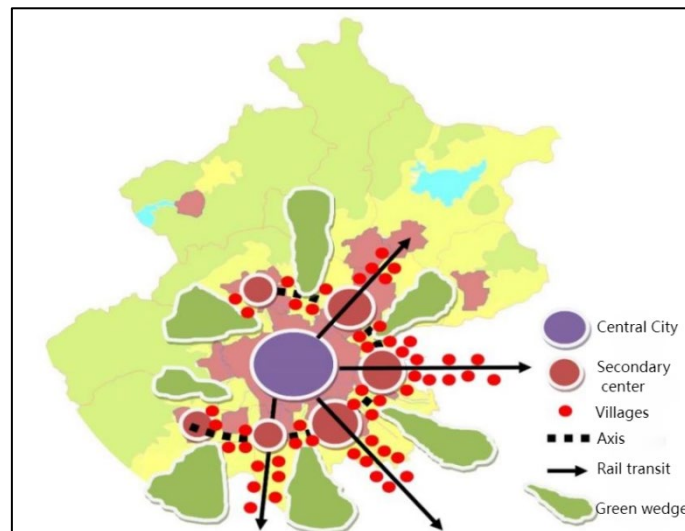


Figure 8: New Town Cluster and Circle Line TOD Planning Concept

Based on this theory, urban planners in Beijing, China have also put forward some countermeasures, such as the TOD of the ring road and the planning of the wedge-shaped green space system. The ring road TOD plan plans to establish a series of "secondary urban centers" integrating office services, commercial shopping, culture and entertainment, etc., around Beijing (Fig.8). The construction of high-volume rail transit loops between the sub-centers, and the development of rapid transit, Multi-mode transportation network for cars and bicycles. The wedge-shaped green space system plan is to connect Beijing's basic farmland, other agricultural land, mountains and lakes to form a wedge-shaped green space barrier system. These are measures to optimize the urban land use system by changing Beijing's urban transportation system and urban environmental system. It will take time to verify the effect.

### 3.2 Performance of complex urban systems in the urbanization of Santiago

#### Mediterranean climate, Western wind strip and subtropical high air pressure

Mediterranean climate, also known as subtropical dry summer climate, is formed by the alternate control of the westerly zone and the subtropical high pressure zone. It is a subtropical and temperate climate type. The summer is hot and dry, and the winter is cold and rainy. This more extreme climate is



unfavorable to the lives of urban residents.

Santiago, located in the center of Chile, on the west coast of the mainland between 30-40 degrees south latitude, has a Mediterranean climate. At the same time, because it is located in the intermountain basin of the Andes at an altitude of more than 600 meters, this steep and narrow natural environment has brought many difficulties to the development and utilization of urban land. However, in the 19th century AD, copper mines were discovered here and gradually mined on a large scale, and the city developed rapidly. In the following years, despite being damaged by natural disasters such as earthquakes and floods several times, Santiago has gradually grown into an international metropolis.

**Complex terrain brings various difficulties to urban construction**

The overlapping peaks and ravines in Santiago, Chile, and the variable elevation in elevation limit the effectiveness of land use in urban construction, but the corresponding pattern of mountains, waters and cities also injects a unique character into the city. Most of the buildable areas within the project scope of the two rivers and four banks are in hilly areas, with an elevation of 196-350 meters (Fig.9).

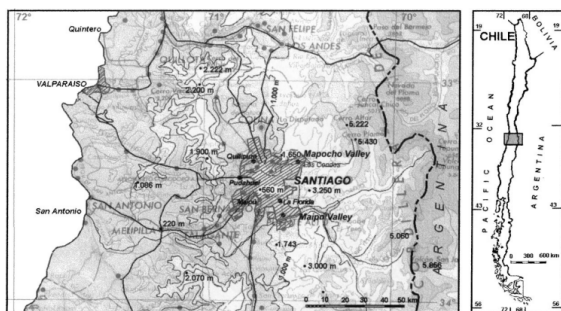


Figure 9: Rapid urban growth, land-use changes and air pollution in Santiago, Chile

The slope is an important limiting factor for the development of Santiago, Chile. Land with a slope of less than 25% is suitable for construction. However, within the scope of this study of the Two Rivers and Four Banks, the slope below 25% only accounts for 60%, making the construction land very precious and also causing the city. High construction cost and difficult problem. Inappropriate construction and development and heavy rain erosion can easily cause geological disasters, such as landslides, and aggravate the rapid development of water cities, which also affects heat islands and air pollution, reducing transpiration and air humidity.

**Pollution spread slowly under seasonal weather and slope winds**

Santiago is a typical example of environmental pollution problems in Latin America. The main causes of environmental pollution in Santiago are: air pollution caused by the burning of poor-quality diesel in motor vehicles. For cost-saving reasons, the transportation system in the city center and suburbs uses a large amount of low-quality diesel as fuel, and the number of motor vehicles has increased. This kind of pollution has been exacerbated. Copper mining damages the environment, and the acid-alkaline wastewater discharged during the mining process has caused lasting damage to the surrounding rivers and farmland pollution (Fig.10).

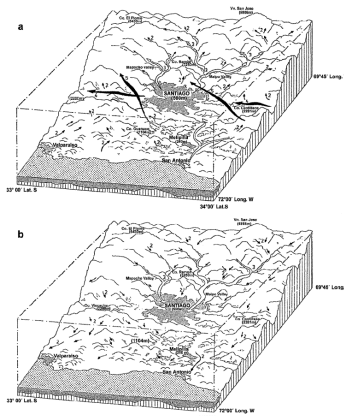


Figure 10: Daily wind systems in summer: (a) day (b) night. The numbers indicate 1, sea breeze; 2, slope winds; 3, valley winds; 4, regionalwind; 5, upper wind.

Some studies have found that the degree of these pollution is inconsistent in different geomorphic areas of Santiago, Chile. The air pollution and urban heat island effect are the most severe in the urban center and the exposed land after extensive deforestation in the southwest. However, air pollution in the foothills of the Andes is lighter, probably due to the effects of valley winds.

#### False urbanization, non-intervention led to a further deterioration

The urbanization process of Santiago is advancing rapidly, and a large number of rural people have poured into the city. However, the existing urban land has not been well developed and utilized, the road network planning is imperfect and the pollution problem caused by diesel is serious. What's more serious is that the urban planning did not take into account the unique climate characteristics of the local area, making Santiago, like many Latin American cities, trapped in a kind of "false urbanization"(Fig.11).

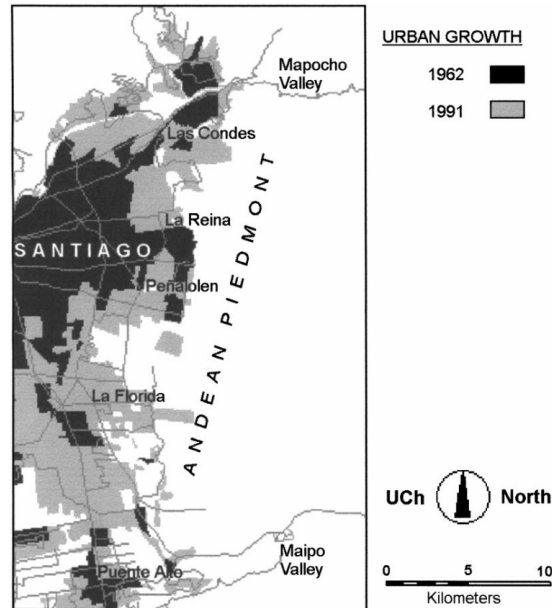


Figure 11: Urban growth to the Andean piedmont area between 1962 and 1991. Black indicates urban and grey rural areas, respectively

In such "false urbanization", the poor population in a large number of cities will be concentrated on limited residential land, thus forming huge-scale "slums". Such wild development will affect the urban land use, transportation, and environmental systems. There was a huge negative effect.

#### 4. Conclusion

This article introduces the three urban sub-systems in the complex urban systems: the urban land use system, the urban environment system and the urban transportation system. After analyzing their components and the important roles they play in the urban systems, this article shows the mutual influence of the various urban sub-systems in the operation of the urban areas by studying five cities around the world. The following conclusions are drawn: (1) The urban environment system is the cornerstone of a city, which guides the layout of the urban land use system. 2. The urban transportation system is the frame of a city, which supports the construction of the urban land use system. 3. The urban transportation system and environment system can promote each other, and can also decline each other. 4. Inappropriate land development will lead to the paralysis of the urban transportation system and the damage of the urban environment system.

In short, urban areas are important habitats for humans and many living things, and the urban sub-systems are closely related. We should explore and study the complex urban systems, discover and understand the various urban sub-systems, so as to better build the urban space and pursue the sustainable development of the urban systems.

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