Analysis of transportation accessibility in China Shanghai Pilot Free Trade Zone Lin-Gang Special Area

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Abstract. In the field of territory spatial planning, transportation accessibility is an important index to measure regional transportation networks. It represents how easy it is for regions to communicate with each other. As a new area of Shanghai Pilot Free Trade Zone, Lin-Gang special area will carry a huge trade market. Therefore, high demands have been put forward on both passengers and freight transport in this region. Based on GIS spatial analysis technology, this paper analyses two types of factors affecting traffic accessibility in the Lin-Gang special area. The first type is road attributes, like road length, road area, road density and road accessibility index. The second type is the spatial pattern of construction land. The results show that the transportation network in Lin-Gang special area is extremely developed, especially the southern area of Pudong International Airport, where the proportion of highway is more than half. The transportation accessibility time to Lin-Gang special area is less than two hours all over Shanghai.

1. Introduction
Transportation carries the function of passengers and cargoes. It is an important industry that supports the national economy. In modern society, the way of transportation includes railways, highways, waterways, air roads, pipelines and so on. An excellent transportation planning program must take into account the population movements and land use spatial pattern which represents the social functions of every spot area.

In recent years, transportation supports the development of the whole society like blood methodically along with reform in national's territory spatial planning. Scholars in various fields have also done extensive research on transportation accessibility. Chen analyses the influence of traffic accessibility on rural living patterns through spatial distribution characteristics [1]. Rao monitors the changes in remote sensing images of Tianfu New Area Chengdu to analyze the traffic accessibility [2]. A raster distance calculation model is constructed by Zhang to analyze changes in spatial accessibility in the Xinjiekou district of Nanjing before and after the establishment of Metro Line Two [3]. A study of the urban compound traffic network carried by Wei shows that superposition of highway sub-network and rail sub-network can increase the accessibility of any point [4]. GIS technology is used to analyze the spatial layout characteristics, influencing factors and commercial central system of large commercial facilities in Pudong New Area [5].

The State Council has issued an overall plan for a new area of the Shanghai Free Trade Zone in August this year. This new area has been established mainly in Pudong named China Shanghai Pilot Free Trade Zone Lin-Gang Special Area [6-7]. Regulation in this document specifies that a highly
opened international transport management must be implemented in the FTZ. This paper analyses the transportation accessibility based on its influencing factors in Lin-Gang special area.

2. Factors Affecting Transportation Accessibility
Factors affecting traffic accessibility include road attributes and spatial patterns of land use.

2.1. Road Attributes
Differ from the traffic index, the road attributes are not conceptual values that comprehensively reflect the smoothness or congestion of road network but inherent properties of roads.

This paper selects road length, road area, road density and road accessibility index as the attribute factors of roads (table 1). There are large differences in the attribute factors of different levels of roads.

Table 1. Index of Road Attributes.

| Index Name               | Equation | Meaning                                                                 |
|-------------------------|----------|-------------------------------------------------------------------------|
| Road Length              | Constant \( l \) | It refers to the length of roads in a district. The units are kilometers. |
| Road Area                | Constant \( s \) | It refers to the area of roads in a district. The units are hectares.   |
| Road Density             | \( P_i = \frac{s_i}{S} \) | It refers to an average road length in a unit area. The units are meters per square kilometers. |
| Road Accessibility Time  | \( t_i \) | It refers to the average time each location reaches a specified destination via a transportation network. The units are minutes. |

Road accessibility time means the general time it takes to reach a specified destination via a transportation network in the study area based on ArcGIS tools. Different from general areas, the freight flow in the free trade zone will be larger than that in most other areas of the city. Therefore, the road accessibility time to the study area needs to be calculated based on freights and passengers.

2.2. Spatial Pattern of Land Use
The spatial pattern of land use refers to the spatial distribution of different land spots in the study area. Spatial distribution and spatial relationships reflect the spatial pattern of different types of land use and reveal the influence on industrial structure changes and land use policies [8]. The spatial pattern of land use is also an important basis for measuring urban ecological and environmental effects and formulating regional development strategies.

According to the guidelines of "National Land Classification (Trial)", this paper mainly takes three main types of land as objects of analysis, which include construction land, agricultural land and unused land. Then, using the method of spatial analysis, the characteristics of construction land are analyzed. In this paper, spatial statistics methods are used to analyze the aggregate distributions of different land use types and calculate the least accumulative cost distance for each point to the nearest source over a road system.

3. Transportation Accessibility of Lin-Gang Special Area

3.1. General Situation of the Study Area
China Shanghai pilot free trade zone Lin-Gang special area is composed of three areas which contain south of Dazhi River, south of Xiaoyangshan Island, east of Jinhui Port and south of Pudong International Airport, shown in figure 1. As an important node in the coastal channel of Shanghai, locating between Pudong International Airport and Yangshan International Hub Port constitutes very convenient transportation advantages.
In this paper, the area of 800 square kilometers of Lin-Gang special area and 24.7 square kilometers of the south side of Pudong International Airport are selected as research areas. Above all, this paper focuses on the priority start-up area.

3.2. Road Attributes in Lin-Gang Special Area

This paper selects some types of roads and calculates their attributes which include expressway, national highway, provincial highway and county roads. The results of road length, road area and road density are distributed in the following tables and figures.

| District                  | South Area of Lin-Gang (Kilometers) | South Area of Pudong International Airport (Hectares) |
|---------------------------|-------------------------------------|-------------------------------------------------------|
| Road Type                 | Road Length | Road Area | Road Length | Road Area |
| Expressway                | 176.61      | 616.91    | 25.04       | 104.36    |
| National and Provincial Highway | 266.46      | 597.82    | -           | -         |
| County Roads              | 630.37      | 1120.25   | 20.82       | 33.99     |

The table above shows road length and road area of two different parts in the free trade zone. The south area of Lin-Gang is three times the size of the south area of Pudong International Airport. So as can be seen from the table, the south area of Lin-Gang has more quantities of all types of roads than the south area of Pudong International Airport. There are 176.61 kilometers of city expressway and 266.46 kilometers of national and provincial highway in the south area of Lin-Gang while county roads account for the largest proportion of all roads. Closing to an important international airport, the types of roads in the southern area of Pudong International Airport are relatively single. There's almost no national and provincial highway there. The main roads are expressway with a proportion of fifty-five percent.

In terms of road density attribute, the county road density in two regions is close while the highway density in the southern area of Pudong International Airport is much higher. It proves that the southern
area of Pudong International Airport may have a more convenient transportation advantage than the south area of Lin-Gang.

3.3. Spatial Pattern of Land Use in Lin-Gang Priority Start-up Area
According to the land use division criteria, the land use distribution situation in Lin-Gang special area is shown in the following figure 3 and figure 4.

![Figure 3. Summation Area of Different Land Use Types in Lin-Gang Priority Start-up Area.](image1)

![Figure 4. Distribution of Different Land Use Types in Lin-Gang Priority Start-up Area.](image2)
As can be seen from the figures above, the construction of the Lin-Gang priority start-up area is not that high. Most of the land is agricultural land. The proportion of agricultural land in both regions is more than 40 percent and the southern area of Pudong International Airport has reached 66 percent. The overall proportion of construction land is extremely close to 30 percent and most of the construction land is located in the Lin-Gang equipment industry zone while a small amount of construction land is located in the southern of Pudong International Airport. In the southern part of Lin-Gang, there are more than 2000 hectares of unused land, indicating that the protection of the ecological environment here is well done.

According to the methods of calculating the closest distance, the arrival time from every spot of Shanghai to Lin-Gang priority start-up area via existing freights transportation network is calculated. According to the access time, the whole area of shanghai is divided into five levels. All levels are separated by half an hour.

![Figure 5. Estimated Values of Road Accessibility Time to Lin-Gang Special Area.](image)

As shown in figure 5, the traffic network around Lin-Gang Special Area is relatively developed. The area within an hour of arrival time can cover the whole territory of Pudong New Area and inner rings of Shanghai. It is less than two hours to get to Lin-Gang special area from most spots of Shanghai in addition to partial regions of Chongming island and Qingpu district. However, it is worth mentioning that the transportation networks for freights and passengers are not fully coincident. The subway in Shanghai is well developed and leading the world. However, passenger traffic can be transported by subway while the freight cannot. So, more targeted research is needed for freight networks.

4. Conclusions
The density of expressways, national highways and county roads in Lin-Gang special area is relatively large. In particular, the proportion of highway and expressway in the southern area of Pudong International Airport is much larger than half of the total roads in that region. In terms of traffic access time, it can be reached within two hours for the whole of Shanghai. The developed transportation network is very wide of trade radiation for the whole of Shanghai and even the Yangtze River Delta.
regions. As a newly established area of Shanghai Pilot Free Trade Zone, Lin-Gang special area has a perfect development prospect. The high internationalized trade model has given birth to the rapid development of transportation networks.

The spatial analysis effectively shows the traffic situation in Lin-Gang special area and provides objective data support for the traffic planning and design work in China Shanghai Pilot Free Trade Zone. However, this paper still needs further research on some issues. Taking into consideration that Lin-Gang special area contains an oceanic island, Xiaoyangshan island, this paper lacks analysing the maritime traffic accessibility of the Lin-Gang special area.

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