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China's regional transport dominance: Density, proximity, and accessibility

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Abstract: Transport infrastructure plays an important role in shaping the configuration of spatial socio-economic structures and influences regional accessibility. This paper defines *transport dominance* from three aspects: *quality*, *quantity,* and *advantage,* measured by *density*, *proximity,* and *accessibility* indices. County is the basic unit for analysis. The results reveal: (1) *Transport dominance* statistically follows a partial normal distribution. A very few counties, 1.4% of the total, have extremely high *transport dominance* which strongly supports the socio-economic development in these areas. In contrast, one eighth of all counties have poor *transport dominance* which impedes local socio-economic development to some extent. The remaining areas, about 70% of the counties, have median *transport dominance*. (2) *Transport dominance* is spatially unevenly distributed, with values decreasing gradually from the coastal area to the inland area. Areas in the first-highest level of *transport dominance* are mainly concentrated in the Yangtze River Delta, the Greater Beijing area, and the Pearl River Delta. Areas in the second-highest level are focused in Chengdu, Chongqing, and Wuhan metropolitan areas. Provincial capitals and a few other counties belong to the third-highest level.

Keywords: transport dominance; density; proximity; accessibility; China

1 Introduction

Transport, which guides and supports the socio-economic development, is an important indicator to evaluate the development conditions for a region. Also, transport plays a crucial role to shape a region's spatial structure and affects its accessibility. With long construction and development, China's transport network has been gradually improved and regional disparity appeared. First, the line length of transport network has reached a considerable scale. By the end of 2005, the total mileage of China's transport network had reached 2.1×10^6 km, with 7.54×10^4 km of railway and 1.93×10^6 km of highway. Meanwhile, China operated over 1000 ports and 135 civil airports. The gap of transport between China and developed countries has been declined. Today, China's freeway mileage ranked the second in the world, only surpassed by the United States. Second, the backbone of modernized transport network

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has formed. Over the past few decades, the technical level and equipment of transport system in China has been greatly improved (Table 1). By the end of 2005, the electrified railways and double-track railways accounted for 34% and 26% of all railways in operation. After five times "speed up" in the railway, the highest speed for most railways reached 160 km/h. Meanwhile, three speed-up circles centered in Beijing, Shanghai, and Guangzhou respectively has formed. The airports, Beijing, Shanghai, and Guangzhou, the hubs of China, are gradually becoming the hubs of East Asia. Third, the capacity of transport network has reached a certain level. Table 2 summarizes the hinterlands of railway, highway and air in 30 minutes by ground transport. In 2003, 50.2% area in China could reach railway in 30 minutes. The ratio for freeway and air is 25.6% and 20.6%, respectively. In terms of population, the ratio changed to 83.6% for railway, 71.7% for freeway, and 41% for air. To GDP, the ratio was higher than area and population, reaching 92.5% for railway, 87.3% for freeway, and 63.3% for air.

Table 1 Various modes of transportation, 1995–2005 (unit: 10^4 km)

Year	Railway in operation	Of which: electrified	Highway	Of which: freeway	Inland waterway	Air route	Of which: International	Pipeline
1995	5.97	0.97	115.70	0.21	11.06	112.90	34.82	1.72
2000	6.87	1.49	140.27	1.63	11.93	150.29	50.84	2.47
2005	7.54	1.94	193.05	4.10	12.33	199.85	85.59	4.40
2005/1995 Increment	1.57	0.97	77.35	3.89	1.27	86.95	50.77	2.68
2005/1995 %	126.3	200	166.9	1952	111.5	177	245.8	255.8

Source: China Transportation Yearbook, 1996, 2001, 2006.

Table 2 Hinterlands of China's transport network in 30 minutes

Mode	Area (10^4 km^2)	Ratio (%)	Population (10^4)	Ratio (%)	GDP (10^9 yuan)	Ratio (%)
Railway	481.8	50.19	107963	83.55	12803.0	92.52
Freeway	246.2	25.6	92605.9	71.66	12077.7	87.3
Airport	198.1	20.64	52921.2	40.95	8763.7	63.33

Since great success has been obtained for the development of transport network in the past few decades, there are several questions concerned by geographers and other scholars. How to evaluate the transport condition of a region compared with others? How to measure the effects of transport on socio-economic development? In regional economics, the effects of transport are abstracted as transport cost or infrastructure service cost, used in location analysis and market assessment for enterprises (Isard, 1956, 1967; Weber, 1909; Lösch, 1954). In economic geography, monetary cost, distance cost, time cost and frequency are used to evaluate transport system (Edward, 1996; Jin, 2004, 2003; Han *et al.*, 2002; Wang *et al.*, 2003; Cao *et al.*, 2005; Wang *et al.*, 2005). Besides, spatial flows and structures are utilized to verify the location of transport nodes (Jin, 2001; Cao, 1999; Cao *et al.*, 2003; Wang *et al.*, 2006; Wang *et al.*, 2006; Wang, 2007; Zhang, 1990). Some studies employed graph theory and relative methods to analyze the location of individual nodes in transport networks (Edward, 1996; Leung, 1980). On the other hand, regional transport infrastructure in terms of supportive capacity and assurance level is frequently analyzed and evaluated by economic geographers. For example, some scholars studied how transport construction directed industrial distribution (Wu *et al.*, 1955; Hang, 1981; Wang *et al.*, 1986). Some researched transport economic belts based on the spatial structure theory, analyzed the spatial coupling relationship between transport infrastructure and industry distributions, and classified the infrastructure categories (Han *et al.*, 2000; Zhang *et al.*, 2002; Yang *et al.*, 1983; Jin *et al.*, 1998). All these studies evaluated the advantages of transport and its spatial effects from different perspectives, but the analysis of spatially disparity led by transport mainly focused on only one single factor or perspective. Therefore, the integrated system for evaluating transport advantages still needs in-depth discussion. This paper will put forward the concept of *transport dominance*, illustrate its basic components, and design models to evaluate it. Using the case study of China, this paper will further explore the spatial structure of *transport dominance* and supply scientific supports for spatial cognition.

2 Definition

Transport dominance

Transport dominance is used to measure the development level of transport infrastructure network in a region, to reflect its supportive capacity for its socio-economic activities. This index is a ratio, namely it is evaluated comparing with a larger system or referring to its adjacent or target areas. For example, the *transport dominance* of a province or a city is calculated based on the whole country system, the *transport dominance* of China is referred to the United States, and the *transport dominance* of cities in the Yangtze River Delta is obtained based on the target area of Shanghai. All these are the basic meaning of *transport dominance*. The higher *transport dominance*, the better the condition for economic development is.

Dimension

Transport facilities have different types. Each type has its own technical and economic characteristics and spatial distribution. Also, each mode of transport has unique quality and capacity according to technical rules. The effects of transport network on regional development are represented by individual nodes and transport corridors, which influence the regional transport dominance. Regional *transport dominance* here is defined from three aspects: *quality*, *quantity* and *advantage*. *Quantity* reflects network scale, *quality* reflects technical level, and *advantage* reflects relative priority. Regional *transport dominance* shows three dimensions spatially: *point*, *line*, and *area*. *Point* stands for a transport node's spatial influence, *line* refers to a transport route's spatial influence and its capability for linking two nodes/areas, and *area* denotes a region's transport development.

Component

Transport dominance is an integrated indicator for evaluating regional transport conditions, and includes three components: *transport network density*, *proximity to transport hubs or trunk roads,* and *accessibility*. The core is evaluating the relative development level of a place based on quantitative methods and in the context of a larger region. The higher transport dominance, the better the location is.

Transport network density is an important indicator to evaluate transport networks. It is usually represented as the ratio of transport length or point number to area in a region. The greater the ratio, the denser the transport network is. As such, the transport capacity for regional development is stronger, and the potential for future development is higher. *Density* index is mainly used for linear infrastructure (highways, railways, pipelines, and inland waterways), especially for highway.

Transport hubs or trunk roads mainly refer to large or important transport facilities. They play important roles for transporting passengers/cargoes and support socio-economic development. Ports and airports are typical examples of transport hubs, and railways and freeways are those of trunk roads. *Proximity* is designed to evaluate how a place is close to these important transport facilities. Specifically, this index can be evaluated by whether a place owns large transports or its ground distance to them. The greater proximity, the better transport condition is. However, it should be noted that how to identify trunk roads has to be considered with their technical and economic attributes.

Key nodes (i.e., national or regional socio-economic centers) always play important roles in affecting the development of its surrounding areas. Transport infrastructure networks are major carriers/connectors for socio-economic elements transferring. *Accessibility* mainly denotes how easily a place can reach key spatial nodes. This index can be measured by Euclidean distance, transport distance or time. *Accessibility* also illustrates the probability of a place to accept influences from key spatial nodes, reflecting its economic development potential. Usually, *accessibility* is often evaluated by the shortest path or the minimum time model. According to GDP and population, key nodes are classified into several groups and are given different weight values.

3 Methods

According to the definition of *transport dominance*, this paper employs the logistic method and spatial model to analyze each transport mode, and finally designs an integrated model for evaluating *transport dominance*. County is the basic unit for *transport dominance* evaluation.

3.1 Single-indicator measure

3.1.1 Density

Density is written as,

$$D_i = L_i / A_i, \quad i \in (1,2,3,\ldots,n), \tag{1}$$

where D_i is the transport network density of region i, L_i is the length or point number of transport facilities, and A_i is the area of region i.

3.1.2 Proximity

According to technical and economic characteristics of transport facilities, trunk roads or point infrastructures here are scored by their technical classes and spatial importance. If the territory of a place contains significant or large-scale transport facilities, then the distance equals 0 and its *proximity* is scored depending on the transport mode as shown in Table 3. Otherwise the distance needs to be calculated from the administrative center of the area to the nearest trunk road or point infrastructure; and then its *proximity* is given according to the weight value of the infrastructure and the distance (see Table 1). The *proximity* of a place is the sum of its proximity to all transport modes, written as,

Table 3 Weight value for various transport modes

Mode	Technical level	Distance (km)	Score	Mode	Technical level	Distance (km)	Score
Railway	Double-track	0	2	Waterway	Hub	0	1.5
		≤30	1.5			≤30	1
		30–60	1			30–60	0.5
		> 60	0			> 60	0
	Single-track	0	1		Feeder	0	0.5
		≤30	0.5			> 0	0
		> 30	0	Airport	Hub	0	1
Highway	Freeway	0	1.5			≤30	0.5
		≤30	1			> 30	0
		30–60	0.5		Feeder	0	0.5
		> 60	0			> 0	0
	National highway	0	0.5				
		> 0	0				

$$f(x_i) = \sum_{i=1,m=1}^{n,M} c_{im}, i \in (1,2,3,...,n), m \in (1,2,3,...,M), \tag{2}$$

where m means the number of transport modes in region i, and the c_{im} is the proximity of each transport mode.

3.1.3 Accessibility

First, we need to identify all key nodes. Second, we calculate the shortest distance from each county to all key nodes. Assuming the shortest distance of each pair of nodes exists in a limited transport network. Specifically, we need to calculate the transport distance l_{im} (railway or highway) from the administrative center of each county i to the key node m. $l_{im}(x)$ is written as,

$$l_{im}(x) = \sum_{u=1}^{n} l_{imu}, \tag{3}$$

where u is the specific route from county i to the key node m. According to the statistics in 2006, China's average transport distance of highway is 55–65 km. Nowadays, major cities in China are almost connected by highway, and the average transport distance increased. As such, if $l_{im} \leq 100$ km, highway is selected as the transport mode; otherwise railway is the transport mode. According to this rule, $f_{im}(x)$ is defined as the shortest path from county i to the key node m, written as,

$$f_{im}(x) = Min(l_{im}) = Min\left(\sum_{u=1}^{n} l_{imu}\right), (i = 1,2,3,...,n), \tag{4}$$

Based on the equation (4), we calculate the shortest distances from county i to all hubs m respectively, and $f_i(x)$ is the shortest one of them. As such, i is the catchment of the nearest key node, and the latter is i's center city. Thus,

$$f_i(x) = Min_i f_{im}(x) = Min_i (Min(\sum_{u=1}^{n} l_{imu})), (i = 1,2,3,...,n), \tag{5}$$

$$H_i \in \{H_m\},\tag{6}$$

$$H_i \in \{0,1\},\tag{7}$$

where H_j varies from 0 to 1. If the equations 5–7 are true, $H_j = 1$; otherwise $H_j = 0$. According to the equations, we calculate the catchment areas for all key nodes using GIS. Physical distance to the key node will influence the degree of spatial interaction and linkage. According to the shortest distance from node *i* to the nearest key node, we value *i*'s score referring to the distance-decay law. As a result, we attain the transport dominance for all basic units.

3.2 Integrated transport dominance

First, the *density*, *proximity* and *accessibility* indices are standardized, and then are summed up with certain weight values. The transport dominance $F(x)$ of node *i* is written as,

$$F(x_i) = \sum_{i=1}^{e} (D_i^{\backslash} \times \vartheta_1 + C_i^{\backslash} \times \vartheta_2 + S_i^{\backslash} \times \vartheta_3), i \in (1,2,3,...,n),\tag{8}$$

where $D_i^{\backslash}$ is the transport network density, $C_i^{\backslash}$ is the proximity to transport hubs or trunk roads, and $S_i^{\backslash}$ is accessibility. ϑ_1, ϑ_2, and ϑ_3 are control variables.

3.3 The study area and data processing

Study area and data source. GIS data is derived from a remote sensing map at 1:250,000 scale. The map is supplied by the National Fundamental Geographical Information Center. All national trunk roads in 2006 are obtained from map, statistical data, and transport planning promulgated by the Chinese central government. The study area consists of 2365 basic units including counties, county-level cities and suburban areas of some cities. In the following part of the paper, they are all called counties for simplification.

Data for *density* calculation. National trunk roads, provincial roads, and county roads constitute the framework of road system and support regional development. As such, they are adopted in this paper to calculate the *transport network density*.

Data for *proximity* calculation. The values of railways, trunk roads, ports and airports, are identified first in order to analyze the *proximity to transport hubs or trunk roads*. Transport hubs include railway stations, road nodes, ports and airports. According to the provisions of the Ministry of Railways, 22 cities are regarded as railway hub stations. Forty-five road hubs are specified by the Ministry of Communications. Eight-six ports are divided into 23 hub ports and 65 feeder ports based on port size, function and development potential. Besides, 135 airports in operation are grouped into 33 hub airports and 102 feeder airports according to the "11th Five-year Plan of the National Civil Aviation Transport" (Table 4). Trunk roads only include railways, freeways and national trunk roads. Railways are categorized as single-track and double-track to score. Then, each county is valued according to its distance to transport hubs and trunk roads.

Data for *accessibility* calculation. Identifying *key nodes* is the prerequisite to analyze *accessibility*. Considering the socio-economic and geo-political factors, 36 cities are selected including 27 provincial capitals, 4 municipalities directly under the central government, and 5 cities with independent planning. Besides, 14 important land ports also join in the list.

Table 4 Transport hubs and feeders

Classification		Number	City
Railway hub		22	Harbin, Shenyang, Beijing, Tianjin, Shijiazhuang, Taiyuan, Zhengzhou, Wuhan, Xi’an, Jinan, Xuzhou, Shanghai, Nanchang, Guangzhou, Changsha, Shenzhen, Liuzhou, Chengdu, Chongqing, Guiyang, Lanzhou, Urumqi
Highway hub		45	Beijing, Tianjin, Shijiazhuang, Tangshan, Taiyuan, Huhhot, Shenyang, Dalian, Changchun, Harbin, Shanghai, Nanjing, Xuzhou, Lianyungang, Hangzhou, Ningbo, Wenzhou, Hefei, Fuzhou, Xiamen, Nanchang, Jinan, Qingdao, Yantai, Zhengzhou, Wuhan, Changsha, Hengyang, Guangzhou, Shenzhen, Shantou, Zhanjiang, Nanning, Liuzhou, Haikou, Chengdu, Chongqing, Guiyang, Kunming, Lhasa, Xi’an, Lanzhou, Xining, Yinchuan, Urumqi
Port	Hub	23	Dalian, Yingkou, Qinhuangdao, Tianjin, Yantai, Qingdao, Rizhao, Lianyungang, Shanghai, Ningbo, Wenzhou, Fuzhou, Xiamen, Shantou, Shenzhen, Guangzhou, Zhuhai, Zhanjiang, Fangcheng, Haikou, Nanjing, Wuhan, Chongqing
	Feeder	65	Zhoushan, Zhangjiagang, Nantong, Huanghua, Zhenjiang, Hangzhou, Jiangyin, Quanzhou, Huzhou, Jingtang, Jinzhou, Lanshan, Haikou, Zhangzhou, Zhongshan, Taizhou, Changshu, Maanshan, Wuhu, Anqing, Chizhou, Shantou, Jiaxing, Xuzhou, Longkou, Deqing, Haian, Taicang, Guigang, Dandong, Yueyang, Maoming, Huizhou, Yangzhou, Xinhui, Meizhou, Weihai, Huangshi, Jiujiang, Changzhou, Luzhou, Penglai, Huaiyin, Jiangmen, Qinzhou, Wanxian, Basuo, Changsha, Nanchang, Beihai, Yangpu, Wuxi, Wuzhou, Tongling, Zhuzhou, Feiling, Zhicheng, Yichang, Shashi, Yangjiang, Zhaoqing, Shanwei, Harbin, Nanning, Jiamusi
Airport	Hub	33	Beijing, Shanghai, Guangzhou, Shenzhen, Chengdu, Kunming, Hangzhou, Xi’an, Haikou, Chongqing, Xiamen, Qingdao, Dalian, Nanjing, Changsha, Wuhan, Shenyang, Urumqi, Fuzhou, Guilin, Harbin, Guiyang, Zhengzhou, Jinan, Tianjin, Taiyuan, Nanning, Nanchang, Changchun, Hefei, Lanzhou, Huhhot, Lhasa
	Feeder	102	Sanya, Wenzhou, Ningbo, Zhangjiajie, Xishuangbanna, Yantai, Jinjiang, Lijiang, Jiuzhaigou, Shantou, Yinchuan, Zhuhai, Yanji, Wuxi, Xining, Wuyishan, Shijiazhuang, Yichang, Zhoushan, Kashi, Huangshan, Baotou, Dali, Changzhou, Zhanjiang, Mangshi, Yining, Weihai, Dunhuang, Huangyan, Diqing, Xuzhou, Yiwu, Beihai, Korla, Altay, Panzhihua, Luoyang, Xichang, Yibin, Mudanjiang, Mianyang, Hailar, Linyi, Changzhi, Lianyungang, Yulin, Hotan, Nantong, Baoshan, Aksu, Jingdezhen, Lincang, Liuzhou, Wanxian, Changde, Enshi, Jilin, Qiqihar, Yuncheng, Xiangfan, Jiamusi, Manzhouli, Tongren, Bangda, Simao, Nanchong, Weifang, Luzhou, Hanzhong, Dandong, Yancheng, Nanyang, Yan’an, Zhaotong, Xilinhot, Meixian, Chifeng, Ganzhou, Jingangshan, Jiayuguan, Tongliao, Kuqa, Dongying, Qinhuangdao, Jinzhou, Xingyi, Heihe, Ulanhot, Liancheng, Tacheng, Wuhai, Quzhou, Anshun, Golmud, Anqing, Yongzhou, Qiemo, Zhijiang, Qingyang, Datong, Wuzhou
Key nodes	Central city	36	Beijing, Shanghai, Tianjin, Chongqing, Shijiazhuang, Taiyuan, Huhhot, Shenyang, Changchun, Harbin, Nanjing, Hangzhou, Hefei, Fuzhou, Nanchang, Jinan, Zhengzhou, Wuhan, Changsha, Guangzhou, Nanning, Chengdu, Guiyang, Kunming, Lhasa, Xi’an, Lanzhou, Xining, Yinchuan, Urumqi, Dalian, Ningbo, Xiamen, Qingdao, Shenzhen
	Important land port	14	Heihe, Suifenhe, Hunchun, Manzhouli, Erenhot, Yining, Tacheng, Fule, Ruili, Wanding, Hekou, Pingxiang and Dongxing, Dandong

Other indices. According to the equations 3–5, the shortest transport distances are calculated from the counties to key nodes. Transport distance is an indicator to represent spatial friction, while traffic flows reflect the real intercity interactions. According to the statistical distribution of China's passenger flows in 1991 and 2000 (see Figure 1), it is easily observed that railway passenger flows decreased dramatically with the increase of distance. Based on this rule, experts value the weight values for various distance ranges as in Table 5. Besides, indices of *density, proximity, and accessibility* are considered the same important to calculate *transport dominance* in this study. Therefore, ϑ_1, ϑ_2, and ϑ_3 all equal to 1.

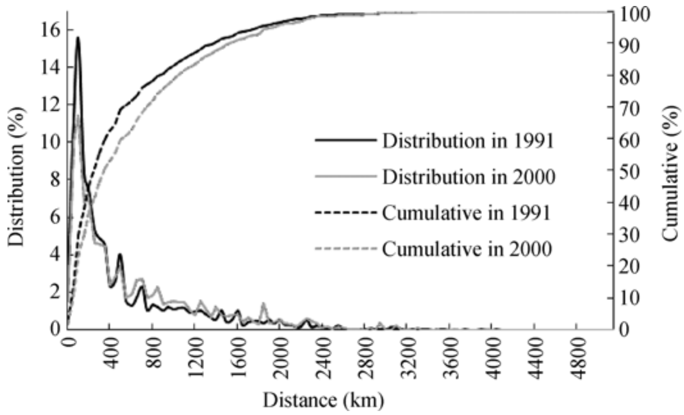

Figure 1 Characteristic of railway passenger flow distribution, 1991 vs 2000

Table 5 Weight values for various distance ranges from key nodes

Level	Distance (km)	Score
1	0–100	2.00
2	100–300	1.50
3	300–600	1.00
4	600–1000	0.50
5	L>1000	0.00

4 Results

4.1 *Density*: uneven spatial distribution

Figure 2 shows the transport network density of China based on national trunk roads, provincial roads, and county roads. Major characteristics are observed as follows: (1) Most areas have low density. According to its statistical distribution, the 2365 counties can be divided into four levels: *poor*, *fair*, *good*, and *excellent*. Level I, *poor*, includes 505 counties (21.4% of all counties) with a density of 0–10 km/100km^2; Level II, *fair*, includes 764 counties (32.3%) with a density of 10–20 km/100km^2; Level III, *good*, includes 807 counties (34.1%) with a density of 20–30 km/100km^2, higher than the national average; and Level IV, *excellent*, 289 counties (12.2%) with a density of 30–40 km/100km^2. Moreover, about 5.4% counties have road density far higher than the national average. To some extent, road transport will block economic development in counties with *poor* density and conversely speed up economic development in counties with *excellent* density. (2) Road density is unevenly distributed based on the natural condition. Density is much higher in the eastern and central regions than in the western region. Meanwhile, density disparity also exists between northern and southern China. In northern China, particularly in North China, road density is much higher than the southern. (3) High density areas mainly are concentrated in metropolitan areas, such as the Beijing-Tianjin area, the Yangtze River Delta, the Pearl River Delta, Wuhan metropolitan area, etc. These areas are spatially overlapped with economically developed regions, reflecting the spatial coupling of transport and economy. (4) A few inland areas have relatively high road *density*, such as the Huang-Huai-Hai Plain, Shandong Peninsula, southeastern Fujian, and central Liaoning. However, the covering areas are comparatively small. Therefore, road transport supplies development potentials for these areas. (5) Disparity exists between metropolitan areas and their surrounding areas, such as Chengdu-Chongqing metropolitan area, Changsha-Zhuzhou-Xiangtan urban agglomeration, and Guanzhong urban agglomeration. (6) The road density around provincial capitals such as Harbin, Changchun, Lanzhou, and Kunming is relatively high.

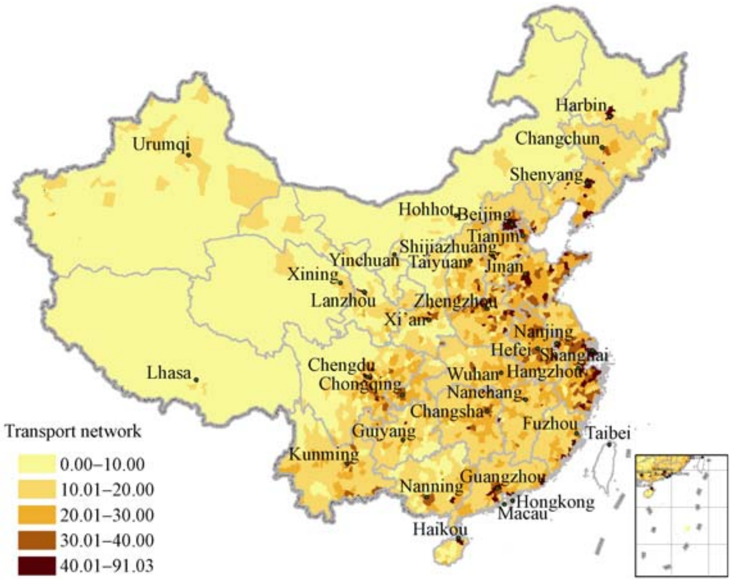

Figure 2 Spatial distribution of transport network density

4.2 *Proximity*: linear spatial distribution

Proximity is influenced by the closeness to trunk roads and transport hubs. In calculation, we need to integrate various transport modes and consider the technical level of transport facilities. Figure 3 displays the spatial distribution of *proximity.* Several points are summarized as follows. (1) The majority of counties have low *proximity*. The 2365 counties are classified into four levels: *poor*, *fair*, *good*, and *excellent*. Noticeably, the *proximity* of 223 counties (9.4%) is zero, and they belong to Level I. Level II, 1173 counties (49.4%) with a proximity of 1–3; Level III, 933 counties (39.5%) with a proximity of 4–10; Level IV, 36 counties (1.5%) with a proximity over 10, have the highest supportive capacity for regional development. (2) High *proximity* is distributed linearly and continuously mainly along with trunk railways and roads, such as Beijing-Shanghai, Beijing-Guangzhou, Beijing-Harbin, and Beijing-Urumqi. This is due to the spatial coupling distribution of railway and freeway. (3) The spatial distribution of *proximity* is also uneven, similar to road density. The proximity in the eastern and central regions is much higher than that in the western region, and northern China (including the North China Plain, Shandong Peninsula and the Central Plains) is higher than southern China. The areas with high proximity are distributed along railway belts in southern China. Unsurprisingly, the proximity in southeastern coast area is low. (4) Major metropolitan areas have high values of proximity, such as the Jing-Jin-Ji (Beijing-Tianjin-Hebei) area, the Yangtze River Delta, the Pearl River Delta, the central and southern Liaoning, Shandong Peninsula, and the Central Plains. Besides, Wuhan metropolitan area, Changsha-Zhuzhou-Xiangtan urban agglomeration, Nanchang-Jiujiang area, and Guanzhong urban aggregation, also have moderately high proximity value. Most urban areas are overlapped by favorable transport infrastructures. (5) In the western region, areas near provincial capitals have relatively high proximity values, including Chengdu-Chongqing, Kunming, Nanning, Guiyang, and Yinchuan. In the northeastern and northwestern regions, some developed regions, such as "Dalian→Shenyang→Changchun→Harbin" and "Lanzhou→Hexi Corridor→Urumqi", have high proximity and good transportation facilities. (6) Most cities in the central and eastern regions, especially in North China and the Yangtze River Delta, have high proximity values. Conversely, the majority of cities in the western and southern regions except provincial capitals have low proximity values. Hub cities undoubtedly have high proximity values, such as Shenyang, Tianjin, Xi'an, Nanjing, Guangzhou, Chengdu, Chongqing, Beijing, Harbin, Zhengzhou, Hangzhou, Nanchang, Shanghai, Changsha, and Hefei.

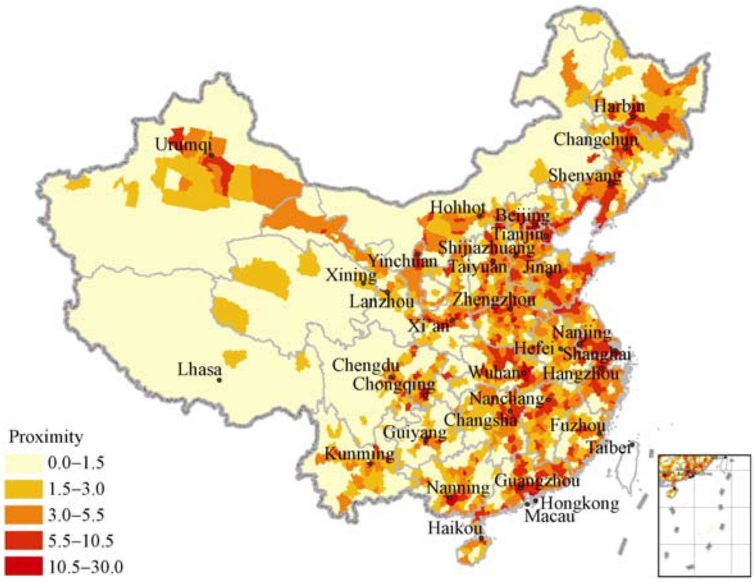

Figure 3 Spatial distribution of proximity

4.3 *Accessibility*: decreasing from metropolises to the periphery

Metropolises play important roles in regional development and dominate regional spatial socio-economic structures. Distance to metropolises is an important factor to influence a node's accessibility and socio-economic development potential. Figure 4 shows the spatial distribution of accessibility, and its characteristics are summarized as: (1) Low accessibility still exists in most counties. Only a few areas have pretty high accessibility. All the 2365 counties can be divided into five levels: *very poor*, *poor*, *fair*, *good*, and *excellent*. Level I, *very poor*, 216 counties (9.1%) with an accessibility of 0 or 0.5, of which 62 counties (2.6%) with the value of 0; Level II, *poor*, 354 counties (15.0%) with accessibility 1.0; Level III, *fair*, 1237 counties (52.3%) with an accessibility of 1.0–2.0; Level IV, *good*, 507 counties with an accessibility of 2.0–3.0; Level V, *excellent*, 51 counties with an accessibility over 3.0; and counties in levels I and II may only receive relatively low radiation from central cities. Meanwhile, counties in group III and IV may receive high radiation from central cities. Counties in group V are metropolises themselves or have strong linkages with them. (2) Accessibility is also unevenly distributed in space, decreasing continuously from metropolises to the periphery. Meanwhile, the eastern region has better accessibility than the western region. Particularly, areas near the national boundaries have accessibility below the national average. (3) The highest accessibility areas are located in the Jing-Jin-Ji area, the Yangtze River Delta and the Pearl River Delta. Also, their surrounding areas have relatively high accessibility. Shijiazhuang, Jinan, and Taiyuan have high accessibility due to closeness to Beijing and Tianjin. In the Yangtze River Delta, Nanjing, Hangzhou, Hefei, and Ningbo are close to Shanghai and also have high accessibility. The Pearl River Delta is affected by Guangzhou and Shenzhen. However, the high accessibility area in the Pearl River Delta is smaller than the Jing-Jin-Ji area and the Yangtze River Delta. Undoubtedly, the three major metropolitan areas with the highest accessibility are also the most economically developed areas in China. (4) Other areas with high accessibility. Chengdu-Chongqing metropolitan area has high accessibility. However, its catchment area is small and discontinuously distributed. Liaodong Peninsula, the south of Fujian Province, the Beibu Gulf (Guangxi), Wuhan metropolitan area, Changsha-Zhuzhou-Xiangtan area, and Guanzhong urban agglomeration all have relatively high accessibility but cover small geographical areas. Besides, provincial capitals and surrounding areas have fairly high accessibility as well. Although their coverage areas are small, they are the socio-economic centers of various provinces and regions. (5) Some land ports have slightly high accessibility, such as Manzhouli, Alashankou, Dandong, Ruili, Pingxiang etc. Some ports and central cities are spatially close to each other and thus form high accessibility and continuous areas, such as Urumqi-Alashankou, Shenyang-Dandong, Nanning-Pingxiang and Dongxing etc.

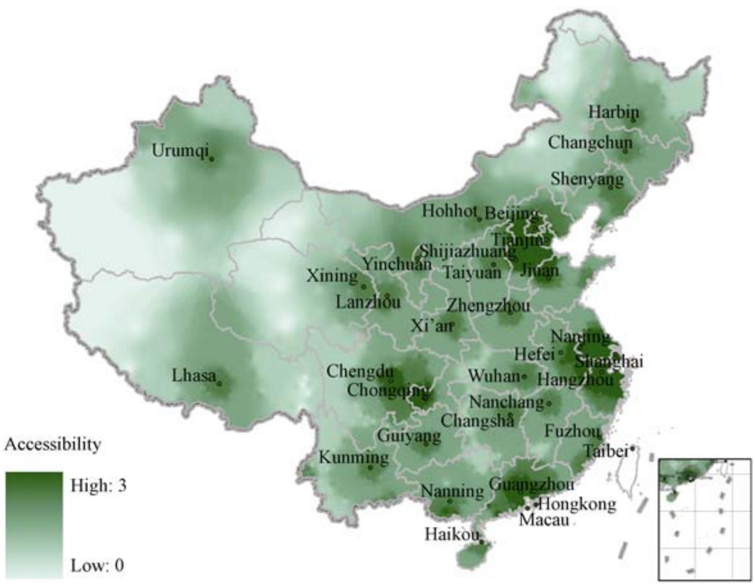

Figure 4 Spatial distribution of accessibility in 2006

4.4 *Transport dominance*: high values strongly concentrated in metropolitan areas

From different perspectives, *density*, *proximity*, and *accessibility* reflect transport facilities' supportive capacity to regional development and demonstrate the developmental potential of each node (county). *Transport dominance* is integrated from the three indices and the location advantage of a node is fully interpreted. The results are shown in Figures 5 and 6 and areas with high *transport dominance* are summarized in Table 3.

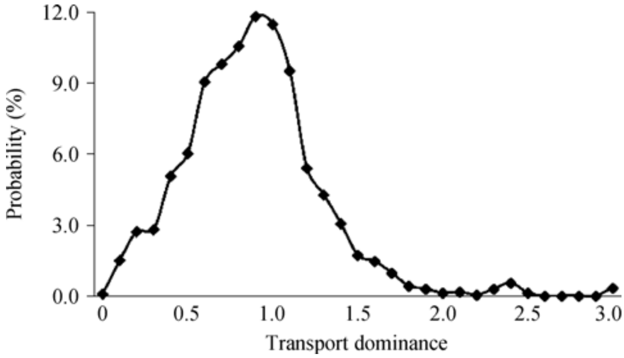

Figure 5 Probability distribution of transport dominance

The distribution of *transport dominance* has the following characteristics. (1) The majority of counties have low *transport dominance* values. Transport facilities in a few areas have strong supportive capacity for economic development. According to the statistical distribution of *transport dominance* values, the 2365 counties can be classified into five levels: *very poor*, *poor*, *fair*, *good* and *excellent*. Level I, *very poor*, 295 counties (12.4%) with extremely low values (less than 0.4); Level II, *poor*, 856 counties (36%) with values ranging 0.4–0.8; Level III, *fair*, 900 counties (38.2%) with values ranging 0.8–1.2; Level IV, *good*, 281 counties (11.8%) with values ranging 1.2–1.8; and Level V, *excellent,* 33 counties (1.4%) with a value more than 1.8. Counties in *very poor* and *poor* levels have rather inconvenient locations and low development potential. Conversely, counties in *good* and *excellent* levels are coupling with developed economy and high development potential. (2) *Transport dominance* is unevenly distributed in space with values roughly decreasing from the coastal area to the inland (Table 6). In other words, most of the coastal area has *excellent* or *good transport dominance*, while only part areas in the central region have *good transport dominance.* The remaining areas in the central region and the whole western region are in *poor* or *very poor* level of *transport dominance*. This spatial pattern basically coincides with the overall economic distribution of China, indicating the close relationship between transport facilities distribution and economic development. (3) The Yangtze River Delta, the Jing-Jin-Ji area, and the Pearl River Delta and their surrounding areas have the highest *transport dominance*. The Jing-Jin-Ji area includes 45 counties and the regional average *transport dominance* is 1.65, which is 2.25 times of the national average. The Yangtze River Delta covers 112 counties and the regional average is 1.43, which is 1.95 times of the national average. The Pearl River Delta consists of 28 counties and the regional average is 1.48, which is 2.02 times of the national average. These areas are also aggregated a considerable number of GDP and population and have the best development potential. (4) A few inland areas have relatively high *transport dominance*, such as Chengdu-Chongqing and Wuhan metropolitan areas. The Chengdu-Chongqing area contains 46 counties and the average *transport dominance* is 1.32, but the values are not distributed evenly. The average *transport dominance* in Wuhan metropolitan area is 1.4, much higher than the national average. However, the coverage area is small and only includes Wuhan urban districts and two counties. Therefore, the development potential in the two areas is higher than the national average; transport facilities could supply high supportive capacity for economic development. (5) Some areas in the eastern and central regions have *good transport dominance*, including the Central Plain urban agglomeration, Changsha-Zhuzhou-Xiangtan, Xiamen-Zhangzhou-Quanzhou and surrounding areas of provincial capitals, such as Shenyang, Harbin, Jinan, Shijiazhuang, Nanning etc. The Central Plain urban agglomeration covers 12 counties, and the average *transport dominance* is 1.24. The Changsha-Zhuzhou-Xiangtan area contains 8 counties with an average value of 1.32. These areas are located good transport facilities and thus have high development

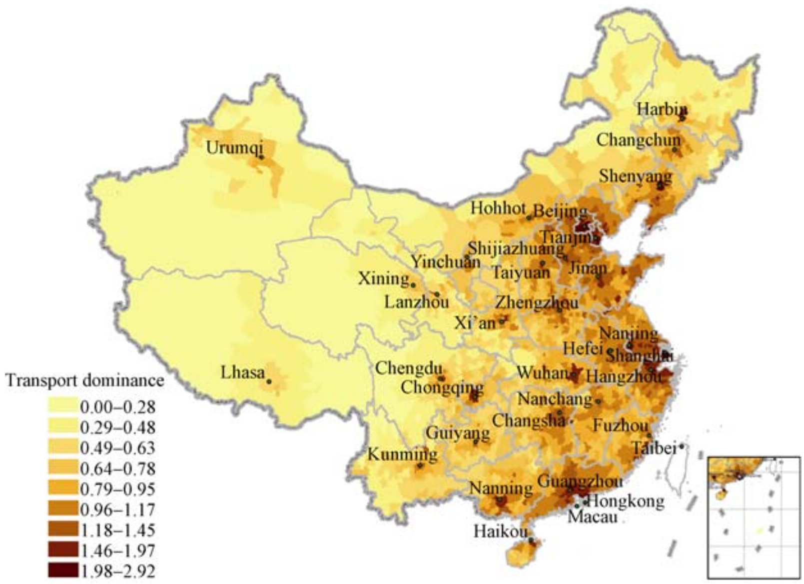

Figure 6 Spatial distribution of transport dominance

Table 6 Transport dominance of metropolitan areas in China

Region	No. of counties	Transport dominance	Ratio to national average
Jing-Jin-Ji metropolitan area	45	1.6532	2.25
The Yangtze River Delta	112	1.4331	1.95
The Pearl River Delta	28	1.4825	2.02
Chengdu-Chongqing area	46	1.3215	1.80
Shijiazhuang area	32	1.2162	1.66
Wuhan metropolitan area	3	1.4016	1.91
The central and southern Liaoning	5	1.3267	1.81
Jinan area	7	1.2045	1.64
Central Plain area	12	1.241	1.69
Guanzhong area	4	1.2931	1.76
Nanning area	2	1.1986	1.63
Xiamen-Zhangzhou-Quanzhou area	6	1.3154	1.79
Changsha-Zhuzhou-Xiangtan area	8	1.3168	1.79

potential. (6) In the western region, provincial capitals and their surrounding areas have slightly high accessibility, such as Kunming, Guiyang, Lanzhou, and Urumqi. The *transport dominance* in Guanzhong area is fairly high and the average *transport dominance* is 1.29. However, the coverage area is small with only 4 counties.

5 Conclusions and discussion

Regional *transportation dominance* in this paper is examined from three aspects: “quality”, “quantity” and “advantage”, indicating different characteristics of regional transportation development. The three aspects all play important roles in socio-economic development and their integration can fully interpret regional transportation condition. “Quality” and “quantity” denote the supportive capacity and technological capability of transport facilities; “advantage” reflects a node’s location status in a larger region context or in the whole country. *Transport dominance* represents how important a node’s location and condition to its economic development potentially. The higher *transport dominance*, the more favorable development environment. The results show that *density*, *proximity* and *accessibility* indices and the integrated *transport dominance* completely reflect a node’s transport condition. *Transport dominance* in a region is reflected from three dimensions: “point”, “line”, and “area”. Unsurprisingly, the spatial pattern of *transport dominance* is unevenly distributed and only a small part of counties have high values.

The 2365 counties are chosen as basic units to evaluate *transport dominance*. This study reveals that the 2365 units follow the *partial normal distribution* statistically. A very few counties (1.4%) have *excellent transport dominance* and superior transport condition for socio-economic development. In contrast, one eighth of all counties have *poor transport dominance* and inferior transport condition and thus impedes local socio-economic development. The remaining areas, about 70% of the total countries, have the average level or a little bit better than the national average *transport dominance*. Therefore, the spatial distribution of transport facilities is basically coupling with socio-economic development.

Transport dominance is spatially unevenly distributed with the values gradually decreasing from the coastal area to the inland area. The areas in the first-highest level of *transport dominance* are mainly concentrated in the Yangtze River Delta, the Jing-Jin-Ji area, and the Pearl River Delta. The areas in the second-highest level are basically focused on Chengdu, Chongqing, and Wuhan metropolitan areas, spatially discontinuous and with smaller coverage areas than the first-highest level. Provincial capitals and some high-density counties belong to the third-highest level.

Transportation is an important factor to influence the locations of economic activities and industries. How to make use of the advantages and avoid the disadvantages is the key to decision makers. The coastal areas, especially for gateway cities, should make advantage of their favorable locations, actively participate in international competition, and raise China’s globalization level. However, the inland areas with relatively high *transport dominance* mainly lie in large cities. These areas are economic centers in the western region and will lead the surrounding areas’ development by transportation linkages.

Transport dominance is a new concept. This paper tries to interpret its definition and design the measuring method. A lot of work still needs to improve and perfect it.

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