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The Supply-Demand Structural Contradictions in Transportation: An Analysis of the Disparities both Temporal and Spatial in China

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Abstract: This paper delves into the intricate tapestry of transportation supply and demand, unraveling the structural contradictions that give rise to disparities both spatial and temporal. In China, these disparities are particularly pronounced—evident in the stark contrasts of congestion and idleness that mark different periods, locales, modes of transport, and service tiers (notably high-speed train versus general train). A meticulous examination of these phenomena reveals the root causes: the compressibility of time and space, along with the imbalance of distribution. To address these issues, this paper proposes a multi-faceted approach encompassing the continuous augmentation and enhancement of transportation supply, the scientific management of demand, the construction and refinement of a comprehensive transport network, the optimization of urban planning and construction, and the reforming of policy measures to alleviate high-density demand.

1. Introduction

Transportation systems are intricate lattices that straddle the axis of economic and societal functionality. One effort is to strike a delicate balance between supply and demand, aiming at ensuring the streams of passengers and cargo flow smoothly, while simultaneously trimming costs, conserving resources, and mitigating environmental impacts. However, the dynamic dance of supply and demand often teeters towards disharmony.

Existing literature has extensively explored the balance of aggregate supply and demand in transportation, the structure of transportation supply and demand, and the transportation demand forecasting and management strategies [1]-[6]. However, a comprehensive, in-depth, and specific examination of the structural contradictions in transportation supply and demand, and the corresponding resolution strategies, remains relatively scarce.

Taking the imbalance of transportation supply and demand across different times and spaces in China as a case, basing on the foundational theories of transportation science, urban planning, economics, and sociology, this paper discusses the manifestations, impacts, and root causes of the supply-demand structural contradictions in transportation and propose potential solutions.

2. The Manifestations and Impacts of the Structural Contradictions in Transportation Supply and Demand

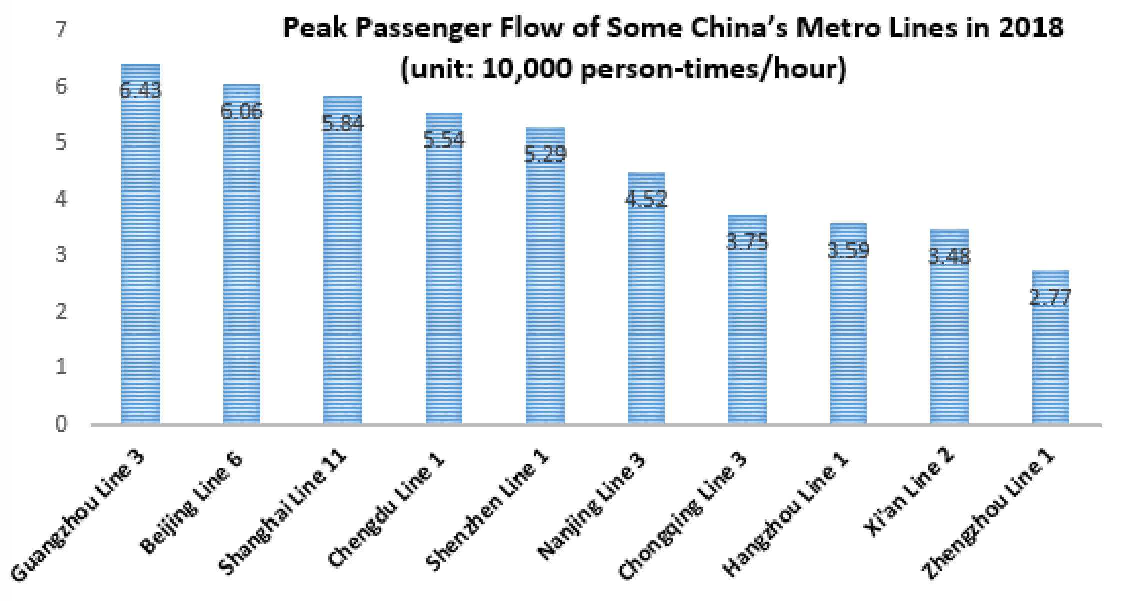
The structural contradictions in transportation supply and demand are also restricted by the balance of total supply and demand in the macro level. As the global economy continues to grow and there is vigorous investment in the construction of transportation infrastructure, the total supply and demand for transportation are basically balanced in most countries and regions. Despite this overall balance, the structural contradictions between supply and demand in transportation are very prominent.

2.1. Manifestations of the Structural Contradictions in Transportation Supply and Demand

The structural contradictions in transportation supply and demand of transportation are mainly manifested congestion and underutilization across different periods, spatial locations, modes of transport (such as road, rail, water, and air), and service standards (including high-speed and conventional trains). This paper primarily explores the disparities both temporal and spatial, which are the main aspects of the contradiction.

2.1.1. Manifestations in the Temporal Aspect

First, the daily temporal disparity is marked by peak and off-peak periods of congestion and idleness. The morning and evening rush hours are a common experience for commuting workers in China (As shown in Figure 1), characterized by crowded almost all commuting methods such as buses, subways, taxis (including online car-hailing), private cars, and bicycles. In contrast, off-peak hours are characterized by a significant number of empty seats in public transportation, a scarcity of taxi passengers, and few private cars on the road.



Data: China Association of Metros [7].

Figure 1: Peak passenger flow of some urban subway lines in 2018.

Second, the annual temporal disparity is evident in the contrast between peak travel and freight seasons and the off-season. Peak travel seasons, typically triggered by major holidays, and peak freight seasons, influenced by large-scale shopping events (such as "Double 11"), exemplify this contradiction. The Chinese Spring Festival travel rush is the most illustrative, with record-breaking cross-regional personnel flows exceeded 8.4 billion person-trips in 2024 [8]. Superimposed severe weather, such as freezing rain and heavy snow, further aggravated the traffic jam, leading to a large number of people and vehicles trapped on the way in Hubei and other places [9]. Conversely, during the off-season, the transportation resources are not fully utilized.

2.1.2. Manifestations in the Spatial Dimension

The spatial aspect of manifestations is characterized by a stark contrast between the bustling movement in popular areas and the relative idleness of less visited regions. These hotspots encompass economically vibrant zones, renowned tourist destinations, and trending social media spots. The Yangtze River Delta and the Pearl River Delta are two of the most economically prosperous regions in China, with the largest, densest and busiest traffic flow there. During the winter of 2023, Sanya and Harbin, two popular tourist cities in China, south and north, respectively exemplified the allure of winter sunshine and the enchantment of snow and ice, drawing numerous tourists and resulting in overwhelmed transportation systems [9]. In the first half of 2023, Zibo barbecue unexpectedly gained traction through the Internet, enticing visitors from all over the country and significantly increasing traffic flow. However, in contrast to these hotspots, many less popular areas face the opposite reality.

Furthermore, the discrepancy is evident between popular and underutilized transportation lines. Only few high-speed rail lines such as the Beijing-Shanghai and Beijing-Guangzhou routes achieve a passenger carrying rate of 80%, while many others can not even reach 50%. During peak travel seasons, some lines may approach full capacity, yet during the off-season, these same lines may see passenger numbers plummet to as low as 40%. [10] The Guangzhou-Shenzhen Expressway, known as “China's busiest expressway”, experienced an average daily mixed traffic flow of 636,000 vehicles in the first three quarters of 2023, reaching the basic saturation state [11]. In stark contrast, the traffic flow on lines in remote areas such as the northwest region is relatively low.

2.2. Impacts of the Structural Contradictions in Transportation Supply and Demand

Transportation systems are not only the lifeblood of economic development and social activities but also a mirror reflecting the structural imbalances of economic and social operation. The structural contradictions in transportation supply and demand will inevitably bring multiple impacts.

2.2.1. Restrictions on Economic Development

The structural contradictions between supply and demand cause different degrees of impact on the stability and reliability of the supply chain, making the flow of economic factors not smooth, hindering the optimal allocation of various resources, and limiting the efficiency of economic development.

2.2.2. Suppression of Demand

Unmet direct mobility needs lead to cancellations and subsequent dampening of indirect tourism, consumption, and production/sales demands.

2.2.3. Impact on the Consumer Experience

Even fulfillment of mobility needs does not guarantee a satisfactory experience. Overcrowding can lead to a decline in service quality and compromise the physical and mental well-being of travelers.

2.2.4. Reduction of Operating Resource Economy

Operational resources under excessive load may consume beyond their capacity, leading to increased costs. Conversely, in underutilized resources, the revenue-to-cost ratio may fall, even potentially resulting in negative economic outcomes.

3. Analyzing the Root Causes of Structural Contradictions in Transportation Supply and Demand

Through a meticulous examination of the diverse manifestations and underlying principles governing the structural contradictions in transportation supply and demand, this paper delineates the root causes of these imbalances:

3.1. Causes for Time Compressibility

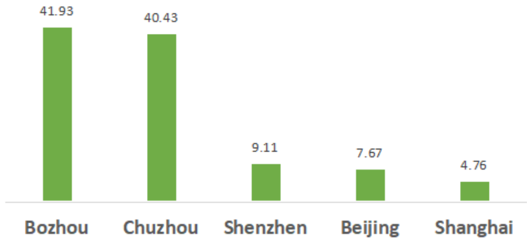
Within a specific short time, an extraordinary volume of mobility demand is highly concentrated, far exceeding the supply capacity; while during the rest of the time, there exists an oversupply, resulting in a waste of transportation resources to various degrees. This high concentration of demand in time ranges leads to conflicts between supply and demand in different time periods and seasons.

3.2. Causes for Space Compressibility

Within a specific limited space, an extraordinary volume of mobility demand is highly concentrated, resulting in an extreme shortage of local transportation resources; while other local resources remain useless. This high concentration of demand in the spatial range leads to conflicts between supply and demand in different areas and lines.

3.3. Causes for distribution disequilibrium

The level of economic development and population density in different regions are positively correlated with the distribution of mobility demand, but there is some negative correlation with the actual distribution of per capita transportation supply. Taking per capita road area as an example, the two highest cities in China in 2020 are Bozhou and Chuzhou, medium-sized cities in Anhui Province, while the three lowest cities are Beijing, Shanghai and Shenzhen with leading development level in China (As shown in Figure 2). This phenomenon is also more fully confirmed by the statistical data of 31 provincial administrative regions in Chinese mainland in 2018 [12] (The results are shown in Table 1). As can be seen from Table 1, Beijing, Shanghai and Tianjin ranked the top 3 in per capita GDP and population density, while the per capita road area ranked the last 3. Except for Shandong and Jiangsu, the top 10 provincial administrative regions in per capita road area are ranked low in per capita GDP or population density. This has formed the structural contradiction between supply and demand manifested in the interweaving of time and space. This inversion between supply and economic level leads to an imbalance between supply density and demand density.



Data source: The Standard Ranking and Monitoring Data.

Figure 2: In 2020, the two cities with the highest per capita road area and the lowest three cities in China (unit: square meters).

Table 1: Per capita GDP, population density and per capita road area for some of 31 provincial administrative regions in Chinese mainland in 2018.

Provincial Administrative Region	Per Capita GDP		Population Density		Per Capita Road Area	
	Amount (RMB: Yuan)	Ranking	Person / Km^2	Ranking	Square Meters	Ranking
Beijing	140211	1	1322.74	2	7.57	30
Shanghai	134982	2	3814	1	4.58	31
Tianjin	120711	3	1306	3	11.67	29
Jiangsu	115168	4	742	4	25.20	2
Zhejiang	98643	5	460	8	18.05	11
Fujian	91197	6	285	15	20.59	6
Guangdong	86412	7	481	7	13.39	27
Shandong	76267	8	579	5	25.28	1
Nei Monggol	68302	9	20	28	22.75	5
Hubei	66616	10	325	12	17.00	13
Chongqing	65933	11	374	10	13.52	25
Shaanxi	63477	12	185	21	16.47	17
Liaoning	58008	13	291	14	14.93	19
Jilin	55611	14	151	23	13.81	24
Ningxia	54094	15	85	25	22.94	4
Hunan	52949	16	304	13	16.96	14
Hainan	51955	17	224	17	16.81	15
Henan	50152	18	553	6	14.57	22
Sichuan	48883	20	172	22	14.63	21
Hebei	47772	21	355	11	19.76	8
Anhui	47712	22	429	9	22.95	3
Qinghai	47689	23	7.2	30	16.19	18
Jiangxi	47434	24	247	16	19.37	10
Shanxi	45328	25	212	18	16.81	15
Heilongjiang	43274	27	81	26	14.86	20
Guangxi	41489	28	190	20	19.42	9
Guizhou	41244	29	200	19	13.51	26
Yunnan	37136	30	109	24	14.11	23
Gansu	31336	31	57	27	17.91	12

Data source: According to China's National Bureau of Statistics, statistics bureau of the provincial administrative regions and 21st Century Business Herald.

4. Exploring Strategies to Address the Structural Contradiction in Transportation Supply and Demand

In view of the manifestations and causes of the structural contradictions in transportation supply and demand, this paper discusses the following resolution strategies.

4.1. Continuous Augmentation and Enhancement of Transportation Supply

Although the total supply and demand of transportation in most countries and regions are basically balanced, there is an ongoing need to augment and refine transportation supply. This encompasses:

4.1.1. Increasing High-Quality Transportation Supply

With the continuous economic development, social progress and scientific and technological innovation, human beings increasingly need high-quality services supply for transportation. Amidst a shift from high speed to high quality of economic development, the development model of China's transportation is transitioning from aggregate scale driven to structural adaptation oriented, and public demand for transportation is also transitioning from “have” to both “have” and “good”. Moreover, there is still a large gap between China's per capita supply and developed nations. Therefore, the continuous increase of high-quality supply is an important prerequisite to solve the structural contradiction between the supply and demand of transportation.

4.1.2. Boosting the Flexibility of Transport Resources

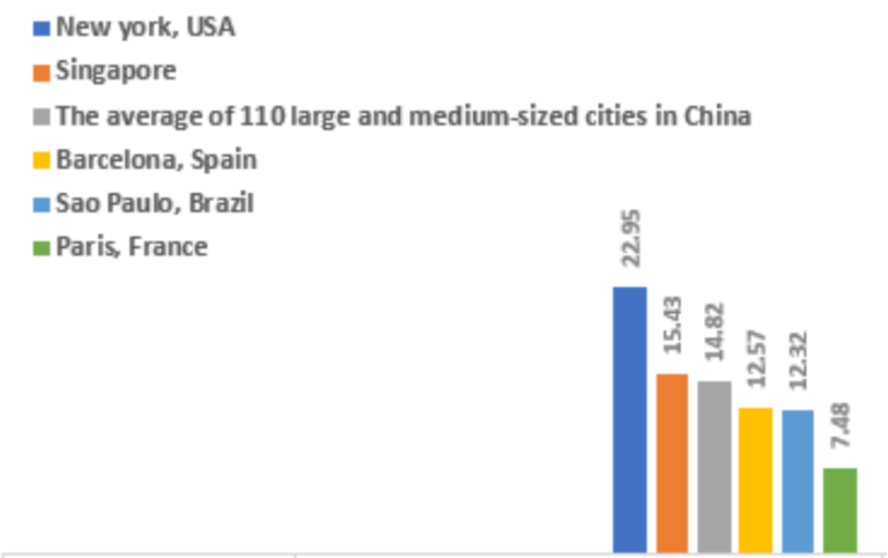
From the design, construction, operation, scheduling, coordination and other links, to boost the flexibility of transportation resources. In these ways, the demanders can access to a variety of options to avoid having to focus on choosing a certain point in time, location or route. According to the dynamic changes in demand, the allocation of operating resources is flexibly adjusted, especially the redundant resources are fully utilized, so as to adapt to the demand dynamics and reduce the uneven busy and idle and waste of resources as far as possible. Using intelligent technology, help travelers or shippers to flexibly get the optimal options based on constraints. Modular and adaptive solutions such as variable-capacity vehicles or on-demand transportation services are employed to ensure that demands are met as much as possible, and to reduce the inefficiencies associated with fixed capacity systems.

4.1.3. Optimizing the Supply Structure

This involves two pivotal considerations:

4.1.3.1. Balancing Road Area and Length

Road length is road network density. Compared with cities in developed countries, one of the important reasons for the greater traffic congestion in Chinese cities is not only the lower per capita road area, but also the lower per capita road length (As shown in Figure 3). For example, Tokyo metropolitan area and Beijing are close in size, the former has more people and cars than the latter, but the traffic is much smoother, one of the root causes is the much more dense road network [13] [14] (As shown in Table 2). The efficiency of traffic is influenced not only by road width but also by its length, which determines the number of access function points along the route. Pedestrians and vehicles aim to arrive at their destinations, rather than merely passing through. A wider road does not necessarily increase the probability of arrival but only increases the section traffic flow. The sparse road network means poor traffic capillaries, reducing access between any two places, leading to detour. [15] Therefore, the length should not be sacrificed by the width, but should greatly increase road network density to enhance accessibility.



Data source: The Report of China Sustainable Development Evaluation Report (2023).

Figure 3: Per capita road area in some cities around the world in 2021 (square meters).

Table 2: Compare some traffic indicators in Tokyo metropolitan area and Beijing in 2017.

	Tokyo Metropolitan Area	Beijing	Tokyo Metropolitan Area / Beijing
Area (10 thousand km²)	1.36	1.64	0.82
Population (10 thousand people)	3643.9	2171	1.68
Population density (person / km²)	2679	1323	2.02
Car ownership (10 thousand units)	1491	590.9	2.52
Car ownership per capita (vehicle)	0.41	0.27	1.52
Total road mileage (km)	116276	30662	3.79
Road network density (km / km²)	8.5	1.9	4.47

Data source: China International Engineering Consulting Corporation [13].

4.1.3.2. Aligning Transportation Supply with Economic level and Population Density

As China continues to urbanize, there will be an increased concentration of population and resources in areas with suitable conditions. The inverted phenomenon between the transportation supply volume and the degree of economic development and population concentration should be restructured to form a supply structure commensurate with the flow demand of economic factors and population. This is mainly to accelerate the increase of transportation supply in areas with high economic level or population density. Meanwhile, the transportation supply in areas with relatively low economic level or population density can moderately control the growth rate rather than stopping or reducing, because the sufficient transportation resources in these areas have positive externalities for the local development and progress and the unified governance of the country, although their benefit-cost is relatively low or even negative.

4.2. Scientific Management of Transportation Demand

The planning, construction and service of transportation must aim to fulfill demand to the greatest extent possible. However, demand is endless and varies randomly, while supply is constrained by various objective factors. Hence, one of the keys to mitigating the structural imbalance between supply and demand lies in the scientific management of transportation demand.

4.2.1. Predicting and Guiding Traffic Flow

Scientific prediction methods, especially big data analysis, are used to assess traffic trends and forecast the flow volume and direction of mobile demand in different periods. At present, the big data resources are rich and can be fully utilized. For example, by summarizing the page visits, bookings and successful booking volume of the major booking system (including network and artificial), the potential demand, actual demand and met demand of a train, flight and passenger bus can be calculated respectively; the search quantity and simulated navigation quantity of each navigation system can calculate the possible demand of private car travel. Therefore, the load of a station, airport, line and city can be calculated. On the basis of prediction, through public communication, adjustment of resource allocation, enhancing the substitutability of supply options, optimization of pricing strategies and other ways, timely guide the corresponding adjustment of demand in terms of time, space, route, mobile mode and more, so as to close to a dynamic fit between supply and demand.

4.2.2. Implementing Tailored Management and Control

Transportation demands are varied and subject to dynamic changes, including regular, random, necessary, and unnecessary patterns. Supply and demand also influence each other. Demand drives supply, and supply can also stimulate demand. For instance, opening new high-speed rail, expressway or air route in a certain area will boost travel demand. Measures should be taken to judiciously manage and control different types of demands, so that the distribution of these demands can be staggered peak, and adapt to the supply capacity and supply rhythm as closely as possible.

4.2.3. Fostering Green Travel

Enhance the convenience and attractiveness of green travel options, such as shared transport, cycling and walking, to alleviate the pressure on transportation operations, and conserve resources and protect the environment.

4.3. Building and Enhancing the Comprehensive Transportation System

Through comprehensive transportation system planning, construction, operation, and the improvement of relevant policies and measures, interest barriers and "solo" mode is broken down, and continue to promote interconnected and smoothly coordinated multimodal transport, to make different transportation modes reasonably share the pressure caused by time and space compressibility and layout imbalances of resources, collectively mitigating the structural contradictions between supply and demand.

4.4. Optimizing Urban Planning and Construction

A city is a complex giant system with a high concentration of various economic resources and social life elements, such as population, industry and public service. Fundamentally, the structural contradictions in transportation supply and demand originates from the layout of the city and the combination mechanism of various functions within the city. The tidal morning and evening traffic peak originates from long-distance commuting demands, which result from the separation of employment and residential areas [16] [17]. The reason behind the high compression of mobile demand in a specific short time and in a specific small space in China, is the concentrated construction of large residential and commercial areas, which not only limit road network density but also greatly increasing population density, inevitably leading to heightened demand saturation at specific times and places.

Therefore, optimizing the urban planning and construction is one of the fundamental ways to resolving the structural contradictions in transportation supply and demand. Some strategies such as mixed-function planning, small-block regulation and TOD mode (Transit-Oriented Development) should be implemented to balance employment and residence, and to form narrow roads and dense road networks, enabling most daily work and activities to be easily completed within a small radius. For example, in Chengdu, China, small block planning has been explored and implemented to improve the urban microcirculation capacity and crack big city disease by reducing the block scale and increasing the road network density [18].

4.5. Optimizing the Policies and Measures to Disperse High-Density Demand

To solve the structural contradictions in transportation supply and demand, it is impossible to complete only by the transportation system alone. It also needs decision-making and policy-making agencies to optimize policy and measures to disperse high-density transportation demand. During the Golden Week holiday and the Spring Festival holiday in China, hundreds of millions of people travel within a few days, forming a large scale and dense amount of movement. The overload and intensive operation of transportation resources still cannot fully meet the demand. It is impossible to increase the supply capacity to a level that can meet such colossal demands at any given moment, while for the rest of the time vacancy rates are very high, which will add to the staggering social marginal costs, causing serious negative externalities. It should be an option worth considering about dispersing the high-density mobility demands concentrated over a short period by reforming and improving the vacation system.

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