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Research on Traffic Congestion Management in Xi'an City Based on Transit-Oriented Development

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Abstract: Xi'an City has developed rapidly in recent years, with a significant increase in automobiles. However, this has led to an exacerbation of traffic congestion and a decline in the city's traffic capacity, which has harmed the overall image and development of the city. Therefore, solving Xi'an's traffic congestion problem is of great significance. Although some attempts have been made in the past to address traffic congestion in Xi'an, the problem remains a challenge due to its complexity and the emphasis on increasing traffic supply rather than reducing traffic demand. Transit-oriented development (TOD) is a concept that refers to the idea of public transportation guiding urban development. It is an important theory in the "new urbanism" movement and has significant guiding significance for addressing urban problems. This paper draws on the experience of managing traffic congestion under a TOD approach in foreign countries and proposes effective strategies for solving Xi'an's traffic congestion problem, including leading transportation and urban coordinated development with a TOD approach, optimizing public transportation infrastructure, establishing a comprehensive TOD management institution, and setting up special departments and policies for funding.

Keywords: Xi'an, traffic congestion, TOD, suggestions

1. Introduction

As people's living standards continue to improve and society and the economy develop rapidly, urbanization is advancing yearly, resulting in increasingly deteriorating urban traffic conditions. Traffic congestion has caused enormous losses to various aspects of society: it leads to additional fuel consumption by motor vehicles, exacerbates air pollution and carbon emissions, and significantly increases health risks for residents; a large amount of people's time is wasted in road congestion, which also greatly reduces people's sense of well-being. The problems caused by traffic congestion, such as energy waste, environmental pollution, health risks, and time waste, have gradually become the focus of public attention, severely hindering China's urban development and urbanization process. It is evident that the problem of traffic congestion urgently needs to be addressed.

In most large and medium-sized cities in China, the common approach to alleviate traffic congestion is to continuously increase investment in traffic infrastructure construction to improve the traffic supply level. Typically, these cities choose measures such as adding urban roads, widening existing roads, expanding public transportation lines, and constructing new parking lots. However,

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relying solely on these traditional methods cannot achieve the desired effect. In the 1980s, American architect and designer Peter Calthorpe first proposed the Transit-Oriented Development (TOD) model, a comprehensive transportation mode combining public transportation with land use. It emphasizes comprehensive land use and intensive development, advocates public transportation as the primary mode of transportation, and is a development model that tightly integrates land use with public transportation systems. Currently, many large cities in China, such as Beijing and Guangzhou, have gradually launched practices related to TOD transportation planning and are striving to find TOD development models that align with China's urbanization characteristics.

Xi'an is the capital of Shaanxi Province and a mega city. The Xi'an city government has taken multiple measures to control urban traffic congestion, but the effect has been unsatisfactory. After more than twenty years of rapid development, Xi'an has begun to face the dual pressures of increasingly prominent traffic problems and extremely scarce land resources. How to combine its practical situation and innovate in the planning and construction of traffic infrastructure and transform from the traditional mode of urban infrastructure construction to a high-density, intensive, three-dimensional, all-round, and multi-angle development mode has become one of the critical solutions to solve the problem of traffic congestion and achieve sustainable development. This article analyzes the application of TOD theory in controlling traffic congestion in Xi'an by studying the current situation and governance of traffic congestion in Xi'an, summarizing relevant learning experiences by citing specific cases of applying TOD theory to control traffic congestion abroad, and finally provides feasible suggestions for controlling traffic congestion in Xi'an under the guidance of TOD.

2. TOD Model

2.1. Characteristics of the TOD Model

In general, the TOD model, which is oriented towards public transportation, mainly refers to a development model that centers around hub stations such as subways and bus rapid transit (BRT) lines, with a radius of 400-800 meters (a 5-10 minute walking distance) and integrates functions such as travel, residence, work, shopping, leisure, and entertainment, forming an efficient, intensive, comfortable, and green urban space [1]. American architect Peter Calthorpe believes that the TOD model is a development model that guides the balanced expansion of cities with convenient and efficient public transportation, such as high-capacity rail transit and BRT lines. Compact urban development can be achieved by arranging employment, culture, education, medical care, residence, and commerce near rail transit and BRT stations. Professor Huapu Lu of Tsinghua University believes that TOD is a development model that achieves public transit-oriented urban development through the intensive development and utilization of land near public transportation stations [2].

The TOD model has the following characteristics:

(1) Public transportation hubs or core business districts as central hubs.

(2) Advocacy for using high-capacity public transportation systems such as subways and light rail transit.

(3) High-density mixed land use development.

(4) Mutual promotion between land development and transportation optimization.

(5) Good pedestrian environment and quality public transportation system services.

2.2. Case Studies of TOD

2.2.1. Toyama, Japan

Toyama City is a regional core city in Japan, which became the 11th largest city in Japan in 2005 through the merger of nearby towns and villages. However, since the 1990s, this city, with a

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population of 414,000, has been struggling with the problem of population aging, which has led to the expansion of fiscal expenditures, a decrease in tax revenues, outdated urban planning, and a continuous population decline. Toyama City has adopted a compact city strategy, recognizing that the cost of uncontrolled expansion is high in construction, maintenance, and service, and city planners have attempted to make the city smaller, denser, and less reliant on cars [3].

Toyama City's TOD model mainly includes three measures: increasing public transportation, regulating and guiding urban development, and revitalizing the city center. Large-capacity public transit plays a key role in Toyama City, as it can help the city achieve efficient and equitable access and support a dense and compact development pattern. In addition, by conducting higher-density development near transfer stations, the city can maximize the gathering of people and businesses and industries, thereby activating the city [4]. Through the TOD-oriented approach, Toyama City has achieved great success in urban development policies and has even become a model of compact cities worldwide.

2.2.2. Singapore

In Singapore, the TOD model is a development from practice to theory. It was developed as a choice for urbanization to tackle urban issues in the limited land resource conditions. In 1971, the Singapore Urban Redevelopment Authority announced the first conceptual plan, which established a "ring-shaped" city form around the central business district and nature reserve, and a new town pattern linked by a high-capacity rail transit system, MRT (Mass Rapid Transit) [5]. In the 1980s, the Singapore government consciously built a public transportation system for long-term development and established a mode of using high-capacity rail transit to guide urban development. The rail transit corridors connect the new towns to the central area, and the new towns have been developed as compact transit-oriented communities that combine transportation infrastructure with land use [5]. Today, the new cities in Singapore have gradually developed into satellite towns closely integrated with transportation infrastructure, becoming a development model of transit-oriented communities based on the high-density urban context in Asia.

2.2.3. Chicago, America

The public transportation system in the Chicago metropolitan area is a model of how transportation corridors can drive urban development, bringing abundant urban vitality, convenient transportation connections, and comfortable living environments to the city. As the center of finance, culture, manufacturing, and commodity trade in the United States, the spatial structure of the Chicago metropolitan area presents a typical radial pattern, with a high degree of concentration in the core and low-density sprawl in the suburbs [6]. Based on this, the Chicago metropolitan area has constructed a public transportation system suitable for urban development. Firstly, the hand-shaped commuter railway (Metra) carries the main commuting passenger flow in the Chicago metropolitan area, with Metra stations spread throughout the city and suburbs. Secondly, the city's internal bus system, which connects to the railway, serves Chicago and 35 suburban communities, with an elevated rail system of eight high-capacity lines encircling the city center in a loop. Finally, the Chicago metropolitan area has established a diversified public transportation service based on suburban buses, providing various service modes and maintaining a high passenger transport capacity.

Overall, these TOD cases in cities provide some ideas for developing urban transportation in Xi'an. In the context of Chinese cities gradually entering the era of stock planning and urban renewal, the guiding value of the TOD model lies in alleviating multi-level ground transportation pressure and improving urban operation efficiency through systematic planning and incentive policies at the urban level. This is achieved through precise transportation station design, land use planning, and slow

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system design to enhance land asset value, reconstruct urban renewal space, and shape efficient and people-oriented living environments.

3. Data and Methodology

The main research methods employed in this article are as follows:

3.1. Data Analysis Method

A survey of data on the traffic congestion situation and management measures in Xi'an City was conducted. Data on traffic congestion were mainly sourced from the "2022 China Urban Traffic Report". Data on management measures were mainly sourced from the website of the Xi'an Municipal Transportation Bureau. Based on the data, an analysis was conducted on the causes of long-term traffic congestion in Xi'an City, as well as the measures are taken to address it, with a proposal to use the TOD theory to address the issue of traffic congestion.

3.2. Comparative Analysis Method

Regarding traffic congestion management, cities such as Toyama, Singapore, and Chicago have performed well in the TOD model. This article focuses on researching and citing relevant policies in these cities regarding the management of urban traffic congestion under the TOD approach. At the same time, a comparative analysis is conducted on the similarities and differences between Xi'an City and these cities in the field of traffic management to gain insights from them.

4. Current Situation and Causes of Traffic Congestion in Xi'an

4.1. Current Situation of Traffic Congestion in Xi'an

Xi'an, with an area of 10,752 square kilometers and a permanent population of 12.9529 million, is the largest city in Northwest China. As of the end of 2022, the total length of roads in Xi'an reached 13,500 kilometers. As of February 2023, the number of motor vehicles in Xi'an has compared to 4.93 million, with a daily increase of about 2,000. Traffic congestion in Xi'an is severe. According to the "2022 China Urban Traffic Report," Xi'an's congestion level ranked eighth in the country in 2022, up two places from the previous year.

32.9% of Xi'an residents consider private cars the primary tool for commuting on working days, while 49.57% consider private cars as the main mode of transportation on weekends, and public buses can alleviate 41.41% of the travel demand [7]. The city's population and functional layout are relatively scattered, and public transportation covers a large area, which makes private cars heavily relied upon for transport and exacerbates traffic pressure.

As of the end of March 2022, Xi'an has opened eight subway lines. The coverage rate of bus stations every 500 meters in the central urban area is as high as 100%, and buses can alleviate 41.41% of the travel demand. There are 14,749 taxis, with a daily passenger volume of 900,000, and 6,450 online ride-hailing vehicles, with a daily passenger volume of 750,000.

4.2. Causes of Traffic Congestion in Xi'an

4.2.1. Low Carrying Capacity and Sharing Rate of the Public Transportation System

Based on factors such as the large capacity of public transportation, fixed routes, and dedicated lanes, the transport capacity of public transportation is far greater than that of private cars on the same road conditions. In other words, public transportation utilizes road resources more efficiently in the same

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amount of time. However, there are issues with public transportation facilities and route construction, such as unreasonable station locations, long waiting times, and few routes. In addition, the public transportation construction in Xi'an is still focused on conventional buses, rail transit, and BRT, and these public transportation modes have fixed characteristics in terms of route setting and transport standards, which can achieve the function of connecting the city but lack targeted services for various needs of citizens[7]. To some extent, these factors affect citizens' choice to use public transportation for travel and lead to the use of private cars. Overusing private transportation fails to fully utilize the role of public transportation, wastes traffic resources, and generates negative effects of traffic congestion [8].

4.2.2. Lack of Application of Intelligent Technology

The traffic congestion problem in Xi'an is not entirely the responsibility of urban infrastructure construction. The traffic management department frequently rectifies, but the effectiveness is limited. The low traffic management efficiency and lack of effective comprehensive traffic management mechanisms and intelligent management methods are also important reasons. The government lacks the necessary intelligent technology means to conduct macroscopic regulation of traffic and grasp real-time traffic situations, which leads to the low sensitivity of the traffic management department to traffic problems and delayed response, often missing opportunities to unblock urban roads timely.

4.2.3. Road Construction Occupying the Roadway

Xi'an's metro is currently in the development planning and construction phase, and the metro fence area is relatively large and lasts for a long time, which to some extent, increases the degree of traffic congestion. At the same time, the city's infrastructure construction and service life are relatively long, and the road network infrastructure construction lags far behind the development needs of urban traffic. Excavation of road pipelines and other phenomena occur from time to time, and some manhole covers have reached the end of their service life but have not been replaced promptly, which also leads to traffic congestion.

4.2.4. Historical Reasons

As the ancient capital of 13 dynasties, Xi'an has left many cultural relics and sites. These cultural relics need to be protected when planning and constructing the city, but it also increases the difficulty of traffic planning and construction. City wall gates are the main entry and exit points for traffic construction and planning. As the traffic flow continues to increase, the number of motor vehicles passing through the city wall area shows a continuous development trend, which leads to severe traffic congestion around the city wall gates.

5. Suggestions for the Treatment of Traffic Congestion under the TOD Guidance

5.1. Guiding the Coordinated Development of Transportation and City with the TOD Model

The fundamental principle of the TOD development model is to address transportation demand at the source, promote a more balanced functional layout of the city, and foster a closer relationship between residential and work areas. This helps to reduce long-distance commuting needs and lowers the average travel distance. The governance of traffic congestion, an "urban disease," is placed within the overall urban planning framework under the guidance of the TOD development model, which adjusts the overall transportation pattern and comprehensively coordinates rail transit [9]. To implement this approach, Xi'an should strengthen the functions of transportation hubs around rail transit stations and promote balanced development of residential and work areas. This approach

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enhances transportation hub functions and creates distinctive “subway towns” and TOD eco-circles. Furthermore, Xi’an should take advantage of opportunities for organic urban renewal, consider the interconnectivity between rail transit stations and surrounding areas, strengthen connections with public transportation, shopping malls, hospitals, schools, parks, greenways, communities, office buildings, sports facilities, and cultural sites to form a strong flow of people and show the physical effects of “people following the line” and “stations attracting people”.

Looking at the practical results of Tokyo’s TOD development, TOD development improves the urban transportation network and is an important way to build a modern, multi-dimensional transportation system and enhance urban operational efficiency. The most important thing is that the TOD model changes the concept of “city development leading transportation development” to “rail transit leading urban development” [10]. The relationship and status between urban expansion and transportation development are also changing. To vigorously promote comprehensive TOD development, we must adhere to vertical coordination of investment, construction, operation, and management, and promote the integrated development of projects to the greatest extent possible. This approach aligns with the construction of supporting transportation facilities and the transformation of transportation organization methods. Integrating rail transit development into the expansion of future cities is an important measure for Xi’an to build a multi-dimensional transportation network and improve urban operational efficiency.

5.2. Optimizing Public Transportation Infrastructure

The relevant departments need to flexibly configure ordinary buses, rapid transit, community buses, and commuter buses to cover the city’s transportation network and improve the city’s public transportation share. The government needs to optimize existing public transportation, improve planned bus networks, expand coverage areas, increase the construction of intelligent bus stops, accelerate the construction of bus stops, and enhance residents’ travel experience. Fully tap the initiative and advancement of the TOD model, promote the connection between different public transportation modes, and meet various transportation needs.

In the process of building the Xi’an metro system, a guarantee system for the development of the Xi’an metro should be proposed to improve the service level of the metro system, attract more passengers, and put people first. The service level of the metro system includes the quality of metro services, frequency of train operation, reliability, and transfer times. For example, the comfort of passenger travel can be improved by optimizing relevant hardware facilities, or by reducing the train interval, the frequency of train operation can be increased. In this way, it can promote the economic development of TOD areas and relieve the burden of ground transportation.

For other public transportation facilities, the parking supply-demand conflict should be scientifically adjusted to promote the optimization and adjustment of the transportation structure. Reasonable parking supply and management measures should be determined for each area, promote the sharing of parking spaces, strictly manage illegal parking, deepen the implementation of differentiated fees, and accelerate the construction of intelligent parking management and service systems[11]. Improve the slow transportation system and end transportation, and connect the last mile of green transportation. Ensure a safe and continuous system of bicycle lanes and pedestrian paths, provide convenience for the use of shared bicycles, and plan and design a system of school access roads.

5.3. Establishing a TOD Comprehensive Management Institution

From the experience of TOD construction in foreign countries, TOD has a strong comprehensive characteristic, and its development cannot be separated from the assistance of relevant government

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departments involving transportation construction, land development, and financial management. At the same time, it also requires the cooperation of some construction units to promote joint development [3]. It indicates that the construction of TOD now requires active cooperation from various departments in the city. Any mistake in any link will affect the construction of TOD. Therefore, it is recommended that the Xi'an Municipal Government establish a TOD comprehensive management institution to systematically manage urban transportation from both the macro and micro perspectives of the transportation system.

The main contents of TOD systematic management are:

(1) Overall planning for Xi'an City. Without changing the existing system, the TOD policy should be implemented, and the relationship between transportation and land in each stage should be fully utilized to promote the development of TOD policy towards standardization and standardization.

(2) Zoning planning. Considering the factors of the common development of urban land and urban transportation, the key development areas of TOD should be listed, and the key areas suitable for TOD development should be determined [12].

(3) Establishing a professional TOD planning team, considering it as a supplement to government planning, and enhancing the management of the planning team on TOD, using TOD thinking to develop urban transportation.

5.4. Establishment of Special Financial Funds and Implementation of Financial Support Policies

To implement the planning and implementation of public transportation congestion control under the TOD guidance, a huge amount of project construction funds is required, and strong financial support is a strong guarantee for traffic congestion control [8]. To address the enormous construction funds required for TOD projects, special funds should be established from the government's financial resources to ensure the implementation of the projects. The use of special funds should guarantee the amount and timely allocation of financial subsidies. On the other hand, the supervision and evaluation system for public transportation financial subsidies should be improved, and the efficiency of financial subsidies should be enhanced by implementing reasonable financial subsidy usage methods.

Since the required amount of funding is enormous, financial support alone cannot fully cover the funding gap. To address this, a Xi'an TOD Development Fund can be established to strengthen government guidance, value market rules, provide professional management, and develop TOD projects suitable for Xi'an. This could transform the traditional construction model and creatively integrate the urban industry, transportation industry, and economic development into an organic whole. At the same time, funds can be raised for urban transportation projects to promote the healthy development of cities. Establishing a foundation allows land resources to be fully utilized for urban development.

6. Conclusion

As urbanization continues to accelerate, the traffic congestion problem in Xi'an has become increasingly severe. Traditional transportation infrastructure construction methods have become challenging to meet the rapidly growing transportation demand in the city, so it is necessary to seek more comprehensive and sustainable solutions. This article explores the application of TOD to achieve the urban traffic optimization and congestion reduction goals in Xi'an. First, by analyzing the problems of the current transportation model in Xi'an, including weak public transportation carrying capacity and insufficient application of intelligent technology. Next, this article summarizes the advantages of TOD mode and its feasibility in Xi'an through a typical case analysis of TOD mode

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both domestically and internationally. These advantages include improving urban transportation efficiency, promoting urbanization, and so on.

To use the TOD model to manage traffic congestion in Xi'an, this article proposes the following suggestions: (1) Guiding the coordinated development of transportation and the city with the TOD development model. Based on the actual situation of the city, reasonable planning of various transportation infrastructure construction should be carried out, and public transportation should be promoted as the main force. (2) Optimizing public transportation infrastructure. Strategies such as improving the public transportation network, enhancing the operational efficiency of public transportation, and strengthening the management of public transportation stations can increase the carrying capacity and utilization rate of public transportation, reduce the use of private cars, and ultimately alleviate traffic congestion. (3) Establishing a comprehensive TOD management agency. A specialized TOD comprehensive management agency should be established to coordinate cooperation among relevant departments and improve the efficiency and quality of the entire TOD project. (4) Establishing special financial funds and introducing financial support policies. Effective measures should be taken to address the difficulties and problems faced in the construction of TOD projects, such as establishing special financial funds and introducing tax incentives, to encourage more investors and developers to participate.

In summary, applying the TOD model in Xi'an could bring sustainable urban development and a more comfortable living environment and help improve urban transportation efficiency and reduce congestion. Therefore, relevant departments should seriously consider the suggestions proposed in this article and actively promote implementing the TOD model better to meet the needs of urban residents' lives.

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