# Research on the Impact of Transit-Oriented Development Method on Urban Transport

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Keywords: Transit-Oriented Development, Urban Transport, Traffic Congestion, Transport Equity.

Abstract: In recent years, transit-oriented development (TOD) has gained popularity in urban development practice because it is thought to have an impact on urban transport. This paper is targeted at researching TOD's impact on urban traffic congestion and transport equity as they are the cause of many other developing problems. The purpose of this paper is to figure out the effectiveness of TOD on tackling traffic congestion and transport equity and find out the potential develop problems of TOD. This paper concludes that TOD reduce traffic congestion by changing the travel behaviour of residents. What is more, TOD might affect transport equity positively because it makes traffic transport affordable and accessible for everyone. However, TOD might also affect transport equity negatively as it could cause the regional gentrification which is not friendly for the low-income household. Finally, TOD is expected to be integrated into other concepts to keep up with the trend of urban transport system. This research helps to clarify the important impacts of TOD and enhance the sustainable growth of cities.

# **1 INTRODUCTION**

Since the industrial revolution, mechanized vehicles such as trains, motor vehicles and so on have conquered the urban transport methods and effected the urban development. On the one hand, these transport methods promote and shape the urban development, on the other hand, it can also cause several urban development problems, thus transport is called "a maker and breaker" of cities by Clark (Clark Colin, 1958).

During the process of urbanization, X-oriented methods (XOD) have been generated to optimize and enhance the pattern of urban development and promote the healthy growth and development of cities, such as Service-oriented development (SOD), industry-oriented development (IOD) and so on. Among them, transit-oriented development (TOD) has gained popularity and become an important method in urban development because it is thought to encourage public transport usage and benefit the ecosystem. Besides, TOD is also argued to be efficient in tackling urban development problems such as traffic congestion, energy consumption and so on.

A number of research studies covering different aspects of TOD have been conducted. Concerning the land management of TOD, in a case study in Shanghai, Zekun Li et al. extended the classic "node (traffic) place (land use)" model by integrating directional features that represent the morphological and functional links between transport and land use. (Li et al., 2019). Besides, Xiaolei Ma et al. designed an improved immune-genetic based algorithm to optimize the land use methods of metro stations (Ma et al., 2018). Regarding the impact of TOD, Tamakloe et al. analyzed the TOD efficiency of bus stops and found that the increase in population, the diversity of land use, and the number of bus stops around subway stations all improved TOD efficiency, while the transfer distance was negatively correlated with the performance of the stations. (Tamakloe and Hong, 2020). As for the success factors of TOD, Kelly C. Strong et al. developed a decision-making framework for the decision-makers by applying analytic hierarchy process (Strong et al., 2017).

This paper aims to provide a summary of the literature researching the impact of TOD method on urban transport. The structure of this paper is organized as follows: First, the background

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Research on the Impact of Transit-Oriented Development Method on Urban Transport. DOI: 10.5220/0013234000004558 Paper published under CC license (CC BY-NC-ND 4.0) In Proceedings of the 1st International Conference on Modern Logistics and Supply Chain Management (MLSCM 2024), pages 86-92 ISBN: 978-989-758-738-2 Proceedings Copyright © 2025 by SCITEPRESS – Science and Technology Publications, Lda. information of TOD including the definition and the classification of TOD is presented. Second, some problems of current urban transportation including traffic congestion are introduced. After that, the impact of TOD on urban transport is indicated. Finally, this paper concludes the impacts in the conclusion part, the future of TOD is also discussed.

# 2 BACKGROUND INFORMATION OF TOD

#### 2.1 The Concept of TOD

Since 1960s, with the acceleration of industrialization and economic growth, the family income increased so cars become affordable for most of the families. With the widespread application of private cars, caroriented development dominates urban development. The feature of this development method is scattered forms of settlement. In these settlements, functional separation can usually be seen, and each functional area such as residential area, business area and so on is interconnected by road. This development method can cause some problems including urban sprawl, traffic congestion and depopulation of the less accessible areas. In contrast, TOD set transport infrastructure as the center of each neighborhood and try to make an area less busy, congested and chaotic.

The original definition of TOD is concluded by Peter Calthorpe. In his book, Calthorpe described TOD as a relatively small-scaled and multi-functional community including a transit stop and a core commercial area (Newman et al., 2021). As shown in Figure 1, a TOD area should include a station, and the commercial area is supposed to place near the station. After that, the remaining area of the land is the residential zone. Even if the word TOD is totally new at that time, however, its concept has begun to develop and some similar developing concepts have inspired and influenced the concept of TOD such as Ebenezer Howard's satellite city model which was enabled by intermunicipal railway, Clarence Perry's "neighborhood unit" concept and so on.

In recent years, the concept of TOD has been widely used in urban planning practice, and in some cases, TOD concept has even been further developed. Janet Rodriguez et al. compared and contrasted different definitions of TOD and categorized them into 2 main focus: urban development outcomes (e.g., land development, real estate development) and develop process or principle (e.g., sustainable development) (Jamme et al., 2019). Apart from that, Liwei Bai et al. tried to combine TOD with the concept smart city (SC) and developed a new conceptual framework named 'smart TOD' including cloud layer, tactile layer and foundational layer. The fundamental layer is composed of 3 zones: traffic core zone, supporting zone and covering zone (Bai et al., 2023).

To conclude, TOD can be seen as a large concept covering different sections such as urbanization, public transport, lifestyle, etc. Different definitions of TOD have different focuses. Generally, it can be seen as a coordination of urban structure around public transport network. Behind all the definition of TOD stands the assumption that the travel behavior can be affected by proper spatial organization.



Figure 1: The concept map of TOD (Wheeler, n.d.).

#### 2.2 TOD Classification

To evaluate and optimize the effect of TOD stations, various researchers have attempted to classify TOD according to various features of stations and nearby areas. Some aspects are usually involved when conducting the assessment such as density, accessibility, traffic connection and so on. Among them, the most widely accepted method is probably the node-place model Betolini developed. As shown in Figure 2, this approach can be transformed into a coordinate system. The horizontal axis represents the characteristics of a place (the 'place index', describing the land use of the station area) while the vertical axis represents the accessibility of a node (the 'node index', describing the capacity of the transit station).



Figure 2: Node-place typology model (Bertolini, 1999).

According to Figure 2, all the transit stations can be divided into 5 parts theoretically: 1. Stress (S area); 2. Unsustained node (U-N area); 3. Accessibility (Ac area); 4. Unsustained place (U-P area); 5. Dependency (D area).

An ideal TOD station is supposed to be in the Ac area, where in any place of the TOD area, the station can be reached easily and cheap.

Betolini's method has been included in a lot of research. Lyu et al. set Beijing as an example, accessed and categorized metro stations in the urban area based on the node-place model and quantified the degree of orientation of transit and development components towards each other (Lyu et al., 2016). Yang et al. found that the node-place model may not be suitable for cities experiencing rapid development in both rail transit and urban infrastructure. Therefore, they incorporated a metric of residents' intentions and integrated traditional statistical analysis with GIS and machine learning techniques to establish a new approach for delineating and identifying site areas. (Yang and Song, 2021).

## 3 CURRENT URBAN TRANSPORT PROBLEMS

There are many urban transport problems, such as traffic pollution, shortage of parking spaces, etc. In this part, traffic congestion and transport equity are discussed. Traffic congestion not only lengthens travel time and increases the rate of traffic accident, but also effects citizens' life quality and has a negative impact on their mental health. Traffic inequality exacerbates social inequality and restricts the popularity and development of low-carbon travel modes, which is not conducive to the sustainable development of urban transport. Traffic congestion and transport equity could be the cause of many other urban transport problems, so they are discussed in this part.

## 3.1 Traffic Congestion

With the rapid development of cities, the urban population have continuously increased over the past few decades. This has directly caused the increase of the demand for travel in cities; thus, traffic congestion usually occurs. In fact, it is stated that road traffic congestion has been a major urban transport problem. Many problems can be caused by traffic congestion, such as increase in travelling cost, high accident rate, higher vehicular emissions that leads to air pollution and so on.

To solve these problems, researchers have been trying to find the cause of traffic congestion and categorize them. Isa et al. divided traffic congestions into 2 parts (Isa et al., 2014). One is non-recurrent congestion caused by various factors including natural disasters, traffic accidents and so on, while the other one is recurrent congestion, which is regular, caused by traffic flow during peak hour. Pi et al. found that excessive traffic volume, unexpected events (e.g., bad weather, special events), and improperly-set traffic signal systems are the main causes of traffic congestion (Pi et al., 2021). A deeper understanding of these factors can help urban planners to alleviate traffic congestion more effectively.

#### **3.2 Transport Equity**

As public transport is designed for all the residents, transport equity is the factor that cannot be ignored when researching the public transport. Transport equity means the fairness with which benefits and costs of transportation are distributed (Litman, 2002). Residents hope that the transit stations are accessible, and the transports are affordable; decision-makers hope that the city's transport system will benefit all the stakeholders. In contrast, when costs paid are not proportional to benefits received, transport inequity occurs. Even if equality and urban transport have been discussed a lot, transportation planning practice today still rarely take equity into account.

Currently, there is no standard equity analyzing method for transport system. Fortunately, Guo et al. concluded a three-step framework after doing a comprehensive literature review (Guo et al., 2020). As shown in Figure 3, population measurement (measures the targeted population group of public transport), cost/benefit measurement (quantifies the cost and accessibility for each population group) and inequality measurement (compares the outcomes among the population living in different places or population in different classes) are included.



Figure 3: Three-step framework of equity assessment (Guo et al., 2020).

# 4 IMPACT OF TOD ON URBAN TRANSPORT

#### 4.1 Effect Traffic Congestion

Although part 3.2 has introduced some causes of traffic congestion, fundamentally, a lot of past research have concluded that urban sprawl could lead to a high demand for private cars and a low investment to public transport, as a result, traffic congestion occurs and even become worse. Newman et al. has proved that in a more sprawl city, the ownership of private vehicles and accident rates are grown while walking rate and the use rate of public transport are decreased (Newman and Kenworthy, 1998). To avoid urban sprawl, people have been working to achieve urban compactness. As shown in Figure 4, TOD is one of the approaches.



Figure 4: Urban Compactness Approaches (Mirzahossein, 2020).

As Figure 1 shows, TOD integrate multiple function areas including office, residential, and retail areas into a walkable space, decreasing the resident's reliance on cars. Besides, every TOD neighborhood is supposed to include a transit station. It means that people in that area might feel comfortable traveling transit, bicycle or foot. As a result, TOD mode was thought to be useful in reducing the use of private cars and reducing traffic congestions.

A number of past research have accessed the way or the effectiveness of TOD in tackling traffic congestions. Mahardhika at.al developed a model based on TOD concept to reduce traffic congestion (Mahardhika et al., 2021). In this study, factors that encourage the use of transit modes and improve the efficiency of the transit system are described through a system dynamics model (Causal Loop Diagram) to determine how TOD can solve traffic congestion. By using a traditional four-step travel demand model, Zhang stimulated tranaport outcomes in three TOD plans in the Austin, Texas, where a metro line is under construction (Zhang, 2010). In this research, he targeted at the traffic flow in peak hour and founded that TOD reduces the traffic congestion, however, the non-TOD area benefits more than the TOD area. Finally, he concluded that promoting walking or cycling is important to the success of TOD. Xie did a comparative case study concerning the TOD development in Beijing and Shenzhen (Xie, n.d.) and found that the number of private automobiles in both Beijing and Shenzhen increased. However, that cannot prove that the TOD mode in the two cities did not make sense because Beijing and Shenzhen have been facing the pressure from population growth for a long time. Finally, the author concluded that the TOD model is still useful in solving urban development problems such as urban sprawl and traffic congestion.

To summarize, TOD has been theoretically proved to be efficient to solve the traffic congestion issues. However, in urban development practice, whether TOD makes sense depends on its effect on discouraging the residents to travel on private cars. If the citizens living in TOD area stick to travelling by car, the TOD mode may not be as effective as the theory have predicted. In conclusion, when studying TOD effect, travel behavior is certainly discussed most.

## 4.2 Effect Transport Equity

Ideally, people expect TOD could bring equity to the urban area. In a city facing the problem of urban sprawl, people may rely more on private cars to travel, so a family who cannot afford a car might have difficulties living in cities so that the social exclusion appears. In comparison, people living in the TOD area have a good accessibility to the public transport, so they rely less on the private cars. It seems that people of all classes can enjoy equal service in the TOD area; however, various research studies have shown that it may not be true.

Some previous studies have demonstrated the impact of TOD on housing prices. Xu et al. utilized a spatial autoregressive model to examine the influence of rail transit on the value of commercial real estate in Wuhan City, and determined that the value of commercial real estate would experience an increase within a 400-meter radius from the subway station. (Xu et al., 2016). As land values rise, low-income households that rely on public transport may be replaced by middle- and high-income households, leading to increased socio-economic stratification. Finally, gentrification resulted from the introduction of TOD might appear.

Some researchers have found the evidence of this gentrification. Turbe conducted a case study in Curitiba and discovered that despite the international recognition gained by its TOD-based Bus Rapid Transit (BRT) system, an unequal distribution of benefits was found in that area. The affluent classes secured prime real estate along the BRT corridor, while low-income communities were displaced to the suburbs. (Turbay et al., 2024). Appleyard et al. evaluate over 350 light rail stations throughout the US and found that the livability of the stations is associated with the quality of life for the residents (Appleyard et al., 2019). Zhao et al. assessed 133 future TOD sites in the Austin, Texas area using Node-Place-People (NPP) model and discovered that even in the TOD stations of relatively balanced NodePlace attributes, the People-Node and People-Place dimensions remains imbalanced (Zhao et al., 2024).

In conclusion, TOD is expected to bring equality to urban transport, however, the gentrification caused by TOD might increase the inequality. To solve this problem, more policies targeted at the low-income residents are supposed to be included during the process of TOD development practice.

## 5 FUTURE TOD DEVELOPMENT AND APPLICATION

Ceder mentioned a research conducted by Morrise in 2016 (Ceder, 2021). In this research, Morise analyzed three kinds of data and found that cars are parked about 95% of the time on average. Judging from this data, private cars might not be an efficient solution of the urban transport problems. In contrast, public transport might be the mainstream of urban transport solutions thanks to its high use rate, relatively cheaper price, low greenhouse gas emissions, etc. To promote public transport in future urban planning, TOD might be the most suitable choice.

To discuss future public transport, its definition cannot be ignored. In the future, the definition of public transport might be extended. As Ceder argued, any form of the travel system available for public use, including traditional forms such as bus, metro and so on, and new forms such as autonomous vehicles, is called public transport. From this perspective of view, the future TOD have to integrate new technologies or new concept to keep up the pace of the development of public transport.

To further improve the interaction between TOD and public transport, the new concept of smart TOD which is the integration of TOD and smart city might be a useful future research direction (Bai et al., 2023). However, TOD is not all about transport, research is also done in other perspectives of TOD. As for the relationship between TOD and land use, Xia et al. found a new random forest (RF) algorithm to effectively figure out the potential TOD areas in Hong Kong (Xia and Zhang, 2022). Such algorithm is a prospective tool in studying land use for TOD and promoting sustainable urban development. Concerning TOD and policy, Newman et al. raised a notion called 'Transit Activated Corridor (TAC)' (Newman et al., 2021). TAC can be seen as the connection between each TOD area placed along urban main roads. This research introduces 5 design principles for designing TAC for the decision makers to improve the urban transit quality.

## 6 CONCLUSION

This paper has studied the impact of TOD method on urban transport by doing literature review. The focus of this paper is the TOD's impact on traffic congestion and transport equity as they are the cause of many other problems. Concerning traffic congestion, this paper found that TOD concept is similar to urban compactness, whose aim is to reduce traffic congestion through optimal planning, so TOD could have positive effects in reducing traffic congestion. However, if TOD planning cannot change the residents' travel behavior, its impact will be greatly diminished. As for transport equity, this paper found that TOD might have positive or appositive impact on the equity. On the one hand, TOD reduces the price and increases the accessibility of public transport, so people belonging to different classes can travel equally. On the other hand, the introduction of TOD could cause regional gentrification, so actually, only people in the upper class will enjoy the benefits that TOD brings. In contrast, low-income households may face more difficulties in commuting.

In the future, public transport could be the mainstream of urban transport, and some new public transport method such as autonomous vehicles will be integrated into the urban public transport system. To keep up with this trend, the TOD concept should also be extended. The future research can focus on the integration of TOD and other concepts, such as smart TOD. What is more, the reason why TOD could cause gentrification needs further research because in some case studies, gentrification did not appear in the TOD area.

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