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A Comparative Study on Land Use and Spatial form of TOD Models in The United States and Japan, from a City-Scale Perspective

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Abstract The transit-oriented development (TOD) model can effectively help to solve urban problems and promote sustainable urban development. The United States and Japan are widely considered the earliest two countries to start TOD practices; however, the origins of TOD models in the two countries were different. The TOD practices in the two countries formed distinct characteristics, yet their differences have been underexplored. This study aims to grasp the characteristics of the TOD model in the two countries through a systematic comparative analysis of 10 typical cities in the United States and Japan that have adopted the TOD model. This paper compares the case cities' three key aspects of the TOD model: public transit system, spatial form, and land use, and summarizes the characteristics of TOD models in the two countries from a city-level perspective, to help deepen the global understanding of TOD.

Keywords Land Use, Public Transportation, Spatial Form, Transit-Oriented Development

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1. Introduction

TOD (Transit-Oriented Development) is an urban planning and development model centered around urban public transport and emphasizes the combination of urban compactness and land use. First proposed by the American architect Peter Calthorpe(Calthorpe, 1993), it is one of the most representative models of new urbanism, focusing on land use, urban transportation, public space quality, pedestrian environment quality, and urban growth boundaries(Wang et al., 2007).

The United States and Japan are widely considered as the earliest two countries to start TOD practices. However, the TOD model has very different origins in these two countries. The idea of TOD in the United States was originated from the "pedestrian pocket concept" and further shaped by New Urbanism and "smart growth" concepts, aiming to alleviate urban problems brought by urban sprawl and suburbanization(Hu and Tao, 2018). The TOD model in the United States emphasizes the control of city boundaries, advocating the promotion of compact spatial form within the boundary, predominant development of transit, highly mixed land use, a walkable environment, livable neighborhoods, and vibrant public spaces(Calthorpe, 1993). The origin of the U.S. TOD was to overcome automobile and highway dependence of American cities, whereas the origin of TOD in Japan can be traced back to the integration of the railway extension and suburban development in metropolitan and medium-sized cities, executed by Japanese private railway companies since the mid-19th century. The TOD model in Japan focuses on property development around hub stations in the city centers(Takayama et al., 2020). The private railway companies integrated the joint transit-property development with railway construction to form a market-led TOD model(Liu et al., 2022). They invest the revenue from the joint transit-property development in railway construction and operation to improve the railway's operational efficiency, which further encouraged them to promote the TOD model to other joint transit-property development projects(Suzuki et al., 2015). In this way, the railway construction and joint transit-property development formed a mutual-promotion relationship(Lu, 2017).

Due to the contrast in the origins of TOD model, practices in the United States and Japan have formed distinct characteristics, leading to differences in the public transit systems, land use, and spatial patterns at the city level. However, the difference between two countries' TODs still lacks serious discussion. The purpose of this paper is to compare the TOD practices at the city level in the United States and Japan and to clarify the characteristics of two countries' TOD models from a city-scale perspective, to help deepen the global understanding of TOD.

2. Data Sources and Research Methods

2.1 Research Framework

To grasp the characteristics of the TOD model in the United States and Japan, this study comparatively analyzed 10 typical TOD cities from the two countries. In this paper, TOD cities refer to cities advanced in TOD practices.

In the development of theory and practices, the TOD model formed three key characteristics: a supportive public transit system, compact and mixed land use, and high-quality open space, which have become primary criteria for qualitative examinations of TOD practices. In practice, the TOD principles can be applied on three scales: neighborhood scale, city scale, and corridor scale (Thorne-Lyman et al., 2011). This study focuses on the city-level perspective; specifically, it investigates the public transit system, urban spatial form, and compactness of land use within the administrative boundary of each case city based on statistics and cartographies, and summarizes the characteristics of the TOD model in the United States and Japan from a city-scale perspective.

For the public transit system, this study analyzed 10 specific indices, as shown in Table 1, by investigating the statistical information to comprehensively grasp the development situation of the public transit system in each case city.

As to the urban spatial form, this study analyzed the spatial distribution of rail stations, road and rail networks, open spaces, and static traffic space through kernel density analysis and visual interpretation of geographic map information.

As to the land use, this study assumes that a 500-meter area around a mass transit station is the core area for the TOD model at the station level, and generally has a higher development intensity than the peripheral area. Therefore, this study investigates the land-use intensity in the 500-meter station area around each subway station and examines the spatial relation between the land development intensity and the station's location in the city.

Considering that the urban scale can influence the implementation of TOD principles, this study classifies the case cities into three classes in terms of the city population size, and compares the cities in the same class.

The remainder of this paper is arranged as follows: Chapter 3 introduces the basic information of the case cities and the grouping situation; chapters 4, 5, and 6 successively summarize the commonalities and differences of the TOD models in two countries' megacities, large-sized cities, and medium-sized cities, with statistics and cartographies; the last chapter is the conclusion.

2.2. Data Sources

Data used in this study are generally open-source data from the internet. Specifically, the basic geographic data such as the road network, rail network, and location of public transit stations are from Open Street Map (OSM) and calibrated based on the Google Maps and Baidu Street View tools. Other statistical information, such as

Table 1. Indices for analyzing TOD model from a city-scale perspective

Criteria	Index	Unit
Public Transit System	Total rail network length	km
	Rail network density	km/km^2
	Rail length per capita	Km/10000 person
	The number of rail transit stations	No. of stations
	Rail transit station density	No. of stations /km^2
	The number of rail transit stations per capita	No. of stations /10000 persons
	The number of rail transit routes	No. of routes
	Rail route density	No. of routes/ km^2
	Average daily passengers in the rail transit system	10000 persons/day
	Average daily passengers per station	10000 persons/day·station
	Year of the first subway operation	-
Urban Spatial Form	Distribution of rail stations	-
	Spatial form of road network	-
	Spatial form of rail networks	-
	Distribution of public space	-
	Distribution of static traffic share	-
Land Use	Spatial relation between land development intensity of the 500-meter station areas and the position in the city	-

the number of passengers and population, are from the official government website or reports and documents published by related government departments.

Additionally, this study used ArcGIS, the Space Syntax tool, and Microsoft Excel to generate maps and plots. Mainly, the line-density and kernel-density tools in ArcGIS were used to help explore the spatial form of the TOD models.

3. Basic Information of Case Cities

As the leading country in TOD practices, currently, the United States has 21 cities that have adopted the TOD model(Cervero et al., 2004; Lin et al., 2020), and it was estimated that by 2030 approximately a quarter of the American population would choose to live in TOD communities. Also, the TOD model in Japan has been well-developed, with excellent practices in the central cities of the major metropolitan regions, especially the Tokyo metropolitan area (Hu, 2016). This research selected 10 typical TOD cities from the U.S. and Japan as case studies. Specifically, the U.S. TOD cities include New York, Chicago, San Diego, Seattle, and Portland; the Japanese TOD cities are Tokyo, Osaka, Sapporo, Sendai, and Chiba.

This study divides the case cities into three classes regarding their population. Considering the different demographic situations in the U.S. and Japan, the classification of city sizes is based on an integrative consideration of an international city-size classification standard, Japanese city-size classification standards, and each case city's domestic city index ranking (the U.S. Census Bureau,2021; the Statistics Bureau of Japan, 2020). Accordingly, New York and Tokyo are classified as megacities; Chicago, San Diego, Osaka, and Sapporo are large-sized cities; and Seattle, Portland, Sendai, and Chiba are medium-sized cities, as Table 2 shown. Besides, although the population of Chicago, San Diego, Osaka, and Sapporo is between 1-3 million, given their population and the comprehensive city power reflected by the domestic city index ranking, this paper further divides these four cities into two sub-classes: Chicago and Osaka

Table 2. City-size classification of 10 U.S. and Japanese case cities

Class	Country	City	Population	Domestic ranking
Megacity	U.S.A.	New York	8,804,190	1
	Japan	Tokyo (23 Wards)	9,733,276	1
Large-sized city	U.S.A.	Chicago	2,747,231	3
		San Diego	1,385,922	17
	Japan	Osaka	2,752,412	2
		Sapporo	1,973,395	8
Medium-sized city	U.S.A.	Seattle	735,157	11
		Portland	652,089	21
	Japan	Sendai	1,096,704	11
		Chiba	974,951	13



Figure 1. Locations of Case Cities in Japan (left) and the U.S. (right).

Table 3. Public Transit System Indicators between New York and Tokyo

Index / Cities	Area (km^2)	Population (person)	Total rail network length (km)	The number of rail transit stations (No. of stations)	Average daily passengers in the rail transit system (10,000 persons/day)	The number of rail transit routes (No. of routes)	Year of the first rail transit operation
New York	788.18	8,804,190	394	472	560	36	1904
Tokyo	627.53	9,733,276	777.9	497	1,591	85	1927

Index / Cities	Rail network density (km/ km^2)	Rail route density (No. of routes/ km^2)	Population density (person/ km^2)	Rail transit station density (No. of stations)	Rail length per capita (km/10,000 persons)	The number of rail transit stations per capita (No. of stations / 10,000 persons)	Average daily passengers per rail transit station (10,000 persons/ day・station)
New York	0.51	0.05	1.05	0.607	0.45	0.54	1.19
Tokyo	1.24	0.14	1.51	0.792	0.80	0.51	3.20

another sub-class. The comparison of city public transit systems, spatial forms, and land use will be conducted among cities of the same class, so as to get a comprehensive understanding of the U.S. TOD model and Japanese TOD model in terms of different city scales.

4. Comparison of U.S. and Japanese Tod Models in Megacities

Before the discussion, we would like to explain the study area of New York and Tokyo in this part. In this study, we generally investigate the TOD development within the administrative boundary of each case city; however, the Tokyo Metropolis is a prefectural administrative subdivision in Japan, equivalent to a "state" subdivision in the U.S. Therefore, this study focuses on central Tokyo, consisting of 23 special wards located in the east of Tokyo Metropolis, which is also the area of the former Tokyo City. Besides, the total area of New York City is 1,223.59 km^2, of which 445.41 km^2 is water, which will affect the indicators related to the density. Hence, this study only considers the land area of New York City, which is about 788.18 km^2.

Comparison of Public Transit Systems in Megacities

The Tokyo metropolis is a globally renowned public transit-dependent city, and it has a radial and circular rail transit network, consisting of 882 interconnected rail stations and 121 passenger rail lines, while central Tokyo consists of 23 special wards converging 85 passenger rail lines and 497 stations in less than one-third of the metropolis area. In New York, the rail transit system, mainly composed of the New York City Subway, serves as the core mass passenger transit system, and its number of daily passengers reached 5.66 million in 2016, ranking first in the U.S. and the 7th in the world. Table 3 compares the indicators of the development situation of the public rail transit systems in New York and Tokyo.

Table 3 shows that: (1) Although New York City has a larger area than the Tokyo's 23 wards, its total railway extension is only about half of Tokyo's, suggesting that Tokyo has a much denser rail transit network. We calculated the rail network density of the two cities and found that Tokyo's railway network density is 2.45 times that of New York's. (2) The number of rail transit stations per capita in New York is slightly higher than in Tokyo. Nevertheless, the number of average daily passengers in the rail transit system of Tokyo is about three times New York's, and the number of average daily passengers at a rail transit station in Tokyo is 2.68 times higher than in New York, which indicates that both the rail transit network and the rail transit stations in Tokyo have much higher transport efficiency. (3) According to the city population and the number of daily passengers, Tokyo's rail transit system has a much higher usage rate. (4) Regarding the city population, the total extension of railways and the number of rail transit stations demonstrate that Tokyo has a more supportive public rail transit system.

Accordingly, it can be concluded that although both New York and Tokyo have a well-developed public transit system, apparently, Tokyo is more public transit-dependent with a denser rail network, higher usage rate, and higher passenger transport efficiency.

4.2. Comparison of Spatial Forms of Megacities

To clarify the TOD model's urban spatial form in New York and Tokyo, this study compared the spatial pattern of rail stations, road networks, rail networks, open spaces, and static traffic spaces in two cities based on cartographies.

4.2.1. The distribution of rail stations in Tokyo is more aggregative than in New York

Figure 2 shows the kernel density analysis of the rail stations in New York and Tokyo. It can be observed that the rail stations in New York are densely distributed in the whole city area, while the rail stations in Tokyo are more aggregative and form some significant clusters. Moreover, the peak value of kernel density in the two cities suggests Tokyo's rail stations are more intensively aggregated,

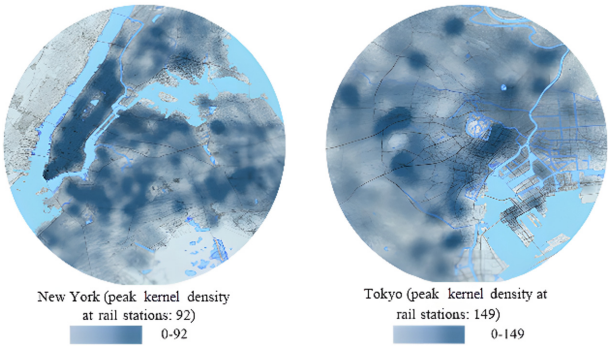


Figure 2. Kernel density of rail stations in New York and Tokyo.

whereas New York's rail stations are distributed in a relatively uniform fashion.

4.2.2. Tokyo has a denser road network than New York

The road network density of New York and Tokyo is shown in Figure 3. Tokyo's average road network density is significantly higher than in New York. Owing to the traditional small block structures, Tokyo naturally formed this high-density road network pattern, which contributed to the walkable scale and pedestrian-friendly environment in Tokyo.

In comparison, the density of New York's road network forms significant clusters in the south Bronx, north Queens, and south Manhattan, presenting an uneven spatial pattern. This results from the historical grid plan of New York City, especially the superblocks in suburban areas. Although urban renewal projects have progressed to rescale the blocks and improve the walkability of those areas, there are still disparities compared to Tokyo.

4.2.3. Tokyo has a denser rail network than New York.

Figure 4 shows the distribution of rail networks in New York and Tokyo. As is shown, Tokyo's rail network is more densely and evenly distributed, whereas New York's rail network is relatively centralized. The density of the rail network in Manhattan is significantly higher than other districts in the city, which corresponds to the central position of Manhattan in New York. Besides, we can

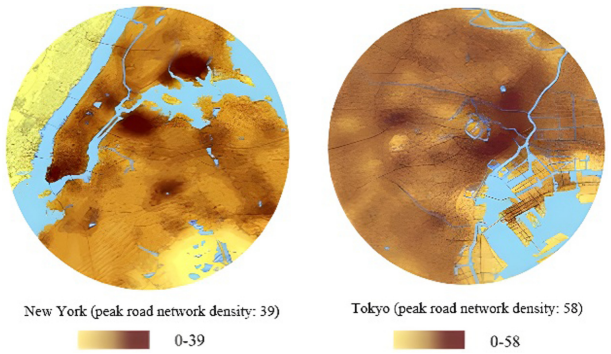


Figure 3. Road network density of New York and Tokyo.

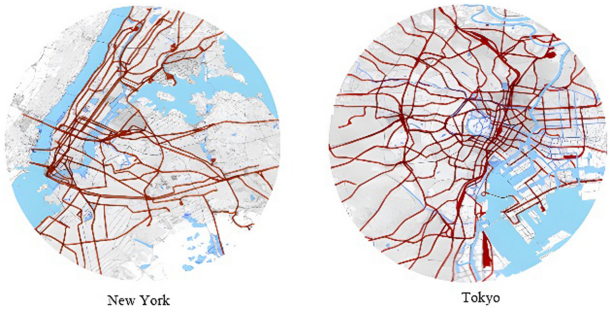


Figure 4. Rail networks in New York and Tokyo.

observe a radial and circular structure from Tokyo's rail network, which corresponds to the urban structure of Tokyo, whereas New York's rail network seems less correspondingly structured.

4.2.4. New York has a better-structuralized open space system than Tokyo

Figure 5 shows the occupancy and distribution of open spaces in New York and Tokyo. It can be seen that New York has a greater number of open spaces than Tokyo, and they are well organized along the coastline, major roads, and in the city centers, forming a systematic structure composed of the city-level central parks, neighborhood parks, and street parks. In contrast, we only observe a limited number of large-sized green patches on the map, mainly the Imperial Palace in the center of Chiyoda ward, and the artificial island in the south Chuo ward created as land reclamation from seabed fill. Instead, Tokyo's open spaces are primarily composed of numerous small neighborhood parks, temples, and shrines dispersed in the city. The differences are deeply related to the formation of the two cities. Tokyo's 23-ward central area is a historical city whose basic urban structure formed before the concept and theory of systematic open spaces planning was proposed. It is hard to build a well-structuralized open space system when the land has already been densely populated. In contrast, New York is a relatively young city, it was planned from scratch, and its open space system has been preliminarily implanted in its grid network urban structure.



Figure 5. Open spaces in New York and Tokyo.

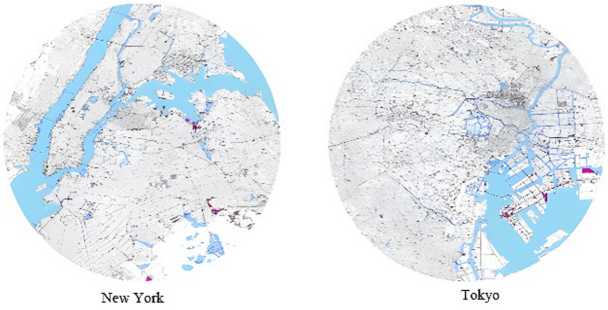


Figure 6. Static traffic distribution in New York and Tokyo.

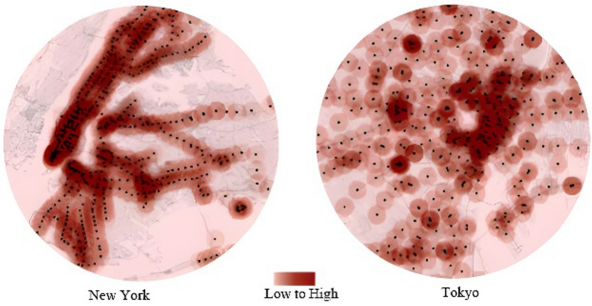


Figure 7. Land development intensity of station areas in New York and Tokyo.

4.2.5. The static traffic in Tokyo is more loosely distributed than in New York

Figure 6 shows the distribution of static traffic spaces in New York and Tokyo. Tokyo has a greater number of stated traffic spaces than New York, distributing in a dispersed form. In contrast, the static traffic spaces in New York are comprehensively uniformly distributed throughout the whole city at the global level; simultaneously, they are concentrated in each business area at the local level.

4.3. Comparison of Land Use of Megacities

A fundamental principle of the TOD model is to promote high-density land development around the transit stations. Figure 7 shows the land development intensity in the 500-meter range area around every rail transit station in New York and Tokyo. Accordingly, we observed the following similarities and differences:

(1) Similarities: The land development intensity of the 500-meter-radius station area is generally higher in both cities' central areas, presenting a single-center urban structure.

(2) Differences: The land development intensity of station areas in New York varies with different districts. Figure 7 shows stations in the Manhattan district have the highest development intensity, followed by Brooklyn and Queens. In comparison, in Tokyo, stations in the central five wards, which are Chiyoda, Chuo, Minato, Shibuya, and Shinjuku, have extremely high development intensities, while the land development intensity of stations in the periphery area is at a similarly lower level.

5. Comparison of The U.S. and Japanese Tod Model in Large-sized Cities

This part compares the public transit system, spatial form, and land use in large-sized U.S. and Japanese cities. As explained before, the comparison is between cities in the same sub-class with a similar population and city index level. In other words, Chicago is compared with Osaka, and San Diego is compared with Sapporo.

5.1. Comparison of Public Transit System in Large-sized Cities

Table 4 compares the public rail transit system indicators of large-sized cities. Consequently, this study found the following characteristics of the public transit systems in large-sized U.S. and Japanese TOD cities:

Although the area of Osaka is only about one-third of Chicago, its passenger rail length is about twice that of Chicago. The rail network density suggests that Osaka's rail network density is about five times higher than Chicago's. On the contrary, San Diego and Sapporo have similar passenger rail lengths. However, due to a greater city area, the rail network density of Sapporo is lower than San Diego. Besides, despite the larger city areas that San Diego and Sapporo have, their passenger rail length is much shorter than Chicago and Osaka, indicating that they have relatively poor rail transit service coverage compared to the larger-sized cities, which is understandable since rail transit development is highly related to a city's population and integrated power. (2) In terms of the number of daily passengers in the rail transit system, Osaka's rail network hosts 7.5 times more passengers than Chicago every day. Even though the rail network density of Osaka is about five times higher than Chicago, Osaka's rail network performed at a higher efficiency than Chicago. As to the average daily passengers per station, stations in Osaka are also superior in terms of throughput, transferring about five times (2.604/0.524) more passengers on average than Chicago.

Similarly, the rail transit system in Sapporo has a higher passenger transport efficiency than San Diego, as its rail network transit hosts about six times (62.3/10.5) more passengers every day with almost the same rail length, and the rail stations in Sapporo on average transfer 3.8 times more passengers than San Diego. According to the city population and the number of average daily passengers, the two Japanese cities both have a greater usage rate of the public rail transit system than the U.S. cities.

Consequently, it can be concluded two large-sized Japanese cities are more public transit-dependent than two large-sized U.S. cities. Specifically, the two large-sized Japanese cities have denser rail transit networks, higher passenger transport efficiency, and usage rates than the U.S. cities whose populations and integrated power are similar. However, since rail transit development is highly related

Table 4. Public Transit System Indicators of Large-Sized U.S. and Japanese Cities

City \ Index	Area (km^2)	Population (person)	Total rail network length (km)	The number of rail transit stations (No. of stations)	Average daily passengers in the rail transit system (10,000 persons/day)	The number of rail transit routes (No. of routes)	Year of the first rail transit operation
Chicago	607.44	2,747,231	165.4	145	76	8	1892
San Diego	844.02*	1,385,922	105.0	62	10.5	4	1981
Osaka	225.21	2,752,412	309.3	219	570.3	36	1933
Sapporo	1121.26	1,973,395	107.5	96	62.3	7	1971

City \ Index	Rail network density (km/ km^2)	Rail route density (No. of routes/ km^2)	Population density (10,000 persons/ km^2)	Rail transit station density (No. of stations)	Rail length per capita (km/10,000 persons)	The number of rail transit stations per capita (No. of stations /10,000 persons)	Average daily passengers per rail transit station (10,000 persons/day · station)
Chicago	0.272	0.013	0.452	0.239	0.60	0.528	0.524
San Diego	0.124	0.005	0.164	0.073	0.76	0.447	0.169
Osaka	1.373	0.160	1.222	0.972	1.12	0.796	2.604
Sapporo	0.096	0.006	0.176	0.086	0.54	0.486	0.649

to a city's integrated power, the rail transit systems in two larger-sized cities (Chicago, Osaka) are better developed than another two smaller cities (San Diego, Sapporo).

5.2. Comparison of Spatial Forms of Large-Sized Cities

5.2.1. The distribution of rail transit stations in large-size Japanese cities is more aggregative than the U.S. cities

Figure 8 shows the kernel density of the rail transit stations in four large-sized case cities. As shown, the kernel density's peak values in Osaka and Sapporo are much higher than in Chicago and San Diego, indicating that the distribution of rail stations in the two Japanese cities is more aggregative. In contrast, stations in Chicago are uniformly distributed in the city area, while stations in San Diego aggregate in the central city area. In both Chicago and Osaka, rail stations basically cover the whole city area. Nevertheless, San Diego and Sapporo have much poorer coverage in suburban regions.

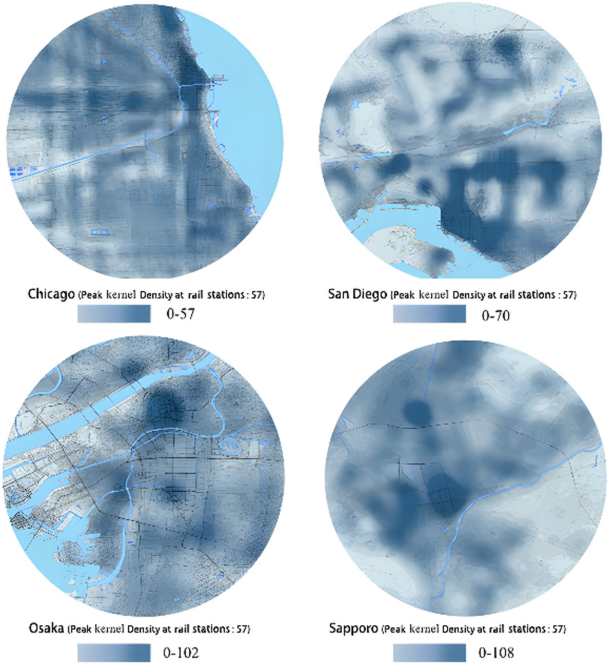


Figure 8. Kernel density of rail stations in large-sized U.S. and Japanese cities.

5.2.1. Road network in large-size Japanese cities is denser than that in the U.S. cities

Figure 9 displays the road network of four case cities. As is shown, both cities are covered by a relatively dense road network. However, Osaka has a denser road network in the central areas than Chicago, as the peak value suggests. This implies that Osaka might have a more walkable and pedestrian-friendly block size than Chicago in many regions. As to San Diego and Sapporo, distinct from the uniformly high density in Chicago and Osaka, we observe significant clusters from the road network density map. It can be found that although the road network in city centers is hugely dense, nevertheless, the peripheral area is much sparser, forming a highly clustered network structure, suggesting the road network development in the two smaller cities is regionally imbalanced. This might correlate to the two cities' demographic distribution and urban structure.

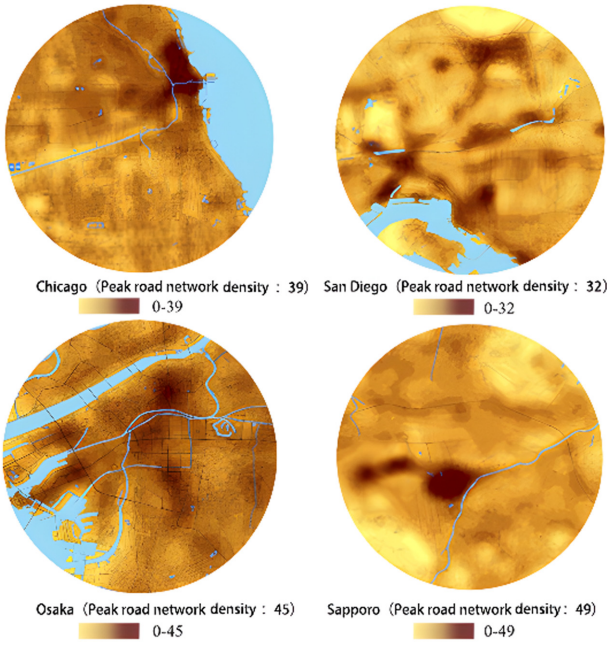


Figure 9. Road network density of large-sized U.S. and Japanese cities.

5.2.3. The density of rail network in large-sized Japanese cities is higher than in the U.S. cities

Figure 10 shows the rail network of four case cities. According to the rail network map, both Japanese cities' rail networks are denser than that of the U.S. cities of the same population and integrated city power level. Nevertheless, San Diego's and Sapporo's rail networks only cover a limited area.

5.2.4. The open spaces in large-sized U.S. cities are more systematic

Figure 11 is the spatial distribution of open spaces in four case cities. Chicago has more large-sized open spaces than Osaka. We can observe a significant open space system consisting of large-sized central parks, medium-sized neighborhood parks, tiny street parks, and coastal open spaces in Chicago. In contrast, the open spaces in Osaka are generally small and densely dispersed in cities. As to San Diego and Sapporo, there seems to be no significant difference between the two cities' open space structures.

5.2.5. The spatial distribution of static traffic of large-sized U.S. cities is more aggregated than in comparable Japanese cities.

Figure 12 shows the spatial distribution of static traffic in four case cities. As is shown, Chicago and San Diego have a greater number of static traffic spaces. In addition, we observed large-sized patches from the static traffic map of Chicago and San Diego, suggesting the static traffic spaces in the two U.S. cities have a bigger size and are distributed in a more aggregated fashion. In contrast, on average, static traffic spaces in Osaka and Sapporo have a smaller size than the two U.S. cities and are more dispersed throughout those cities.

5.3. Comparison of Land Use of Large-Sized Cities

Figure 13 shows the land development intensity in the 500-meter range area around every rail transit station in case cities. As a result, the characteristics of land development intensity in large-sized U.S. and Japanese cities are summarized as follows:

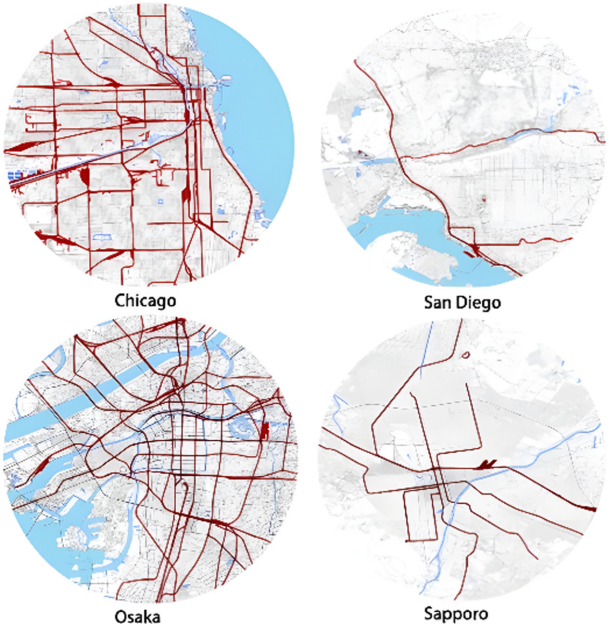


Figure 10. Rail Networks in Large-sized U.S. and Japanese Cities.

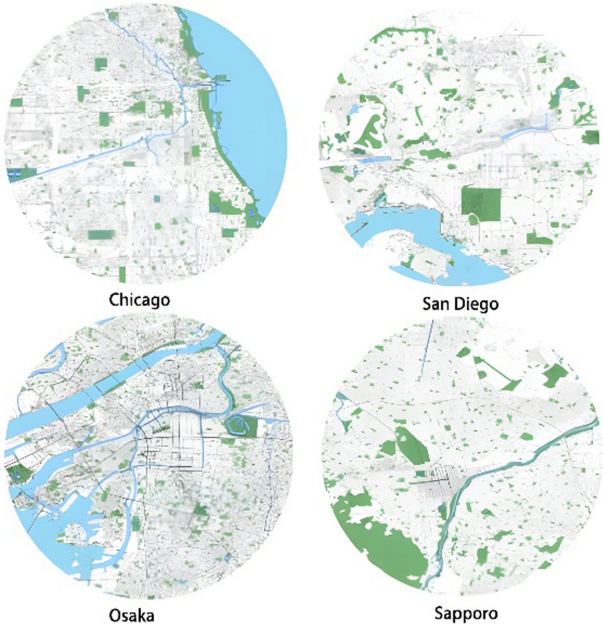


Figure 11. Open space in large-sized U.S. and Japanese cities.

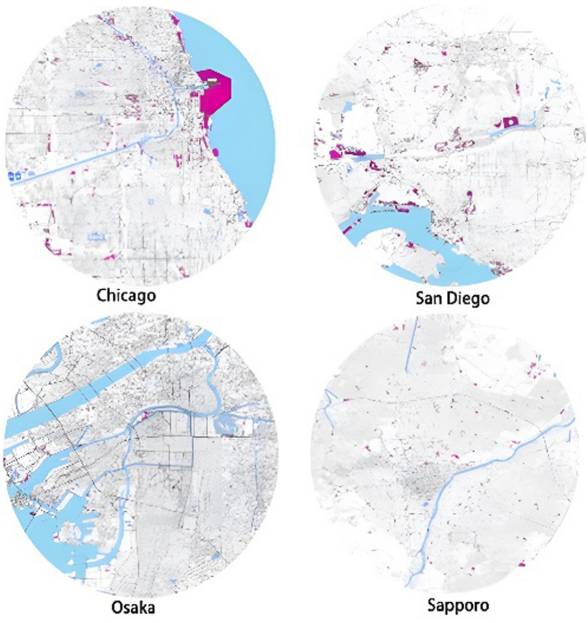


Figure 12. Static traffic distribution in the large-sized U.S. and Japanese Cities.

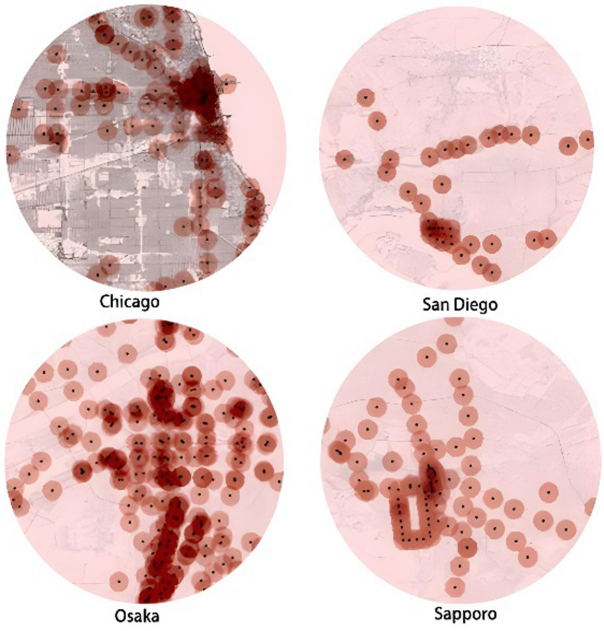


Figure 13. Land development intensity of station areas in large-sized U.S. and Japanese Cities.

5.3.1. Similarities

The land development intensity of station areas in four large-sized cities is obviously higher in the city center, suggesting an agglomerated spatial form. For example, in Chicago, the station areas with the highest land development intensity are all located in the Loop district, corresponding to the high-density development in this district. In Osaka, the majority of the intensively developed station areas are situated on the city axis along Sumiyoshi, Abeno, Tennoji, Chuo, and Buku, corresponding to Osaka's city structure.

5.3.2. Differences

For Chicago and Osaka, we can observe that Chicago has one prominent center, the station areas with high-density land development aggregate in a single center, whereas densely developed stations in Osaka are distributed along city axes and form multiple centers in the city. As to smaller-sized cities, San Diego and Sapporo, little difference was observed.

6. Comparison of The U.S. and Japanese Tod Model in Medium-sized Cities

6.1. Comparison of Public Transit Systems of Medium-Sized Cities

The major public transport systems of medium-sized cities in the United States and Japan started around the 1980s. The public transport systems of Portland and Seattle consist of light rail, tram, and bus, while the public transport systems of Sendai and Chiba only include subway (or monorail) and bus. Accordingly, the public transport system in medium-sized U.S. cities seems superior to the medium-sized Japanese cities, in terms of diversity of public transit modes. Nevertheless, the rail transit system plays a predominant role in the TOD model. Table 5 compares the public rail transit system indicators for medium-sized cities. As a result, the characteristics of the public rail transit system in the medium-sized U.S. and Japanese TOD cities are summarized as follows:

(1) In contrast to the megacities and large-sized cities, where Japanese cities always have a denser rail network than the U.S. cities of the same population size level, in medium-sized cities, the rail network density does not make a significant difference. Unconventionally, Seattle's rail network is even about 2.6 times denser than those of two medium-sized Japanese cities.

(2) Nevertheless, according to the number of daily passengers in the rail transit system measured at single stations, the rail transit system in medium-sized Japanese cities still has a much higher efficiency than two comparably-sized U.S cities. Remarkably, Sendai's rail transit system transport 3.8 times more passengers with a one-third less-dense network than Seattle, reflecting that a higher-density network does not guarantee high transport efficiency.
(3) Regarding the population and daily passengers, the rail transit system in two medium-sized Japanese cities has a significantly higher usage rate than the two U.S. cities.

6.2. Comparison of Spatial Forms of Medium-Sized Cities

6.2.1. The distribution of rail stations in medium-sized Japanese cities is more aggregative than the U.S. cities.

Figure 14 shows the kernel density of rail stations in four medium-sized cities. The peak value of kernel density

Table 5. Public transit system indicators of medium-sized U.S. and Japanese Cities

Index / City	Area (km^2)	Population (person)	Total rail network length (km)	The number of rail transit stations (No. of stations)	Average daily passengers in the rail transit system (10000 persons/ day)	The number of rail transit routes (No. of routes)	Year of the first rail transit operation
Seattle	367.97	735,157	170.6	144	75	8	1892
Portland	376.5	652,089	59.7	53	11.98	4	1981
Sendai	786.3	1,096,704	138	133	292.2	9	1933
Chiba	269.8	974,951	48	46	62.78	12	1968

Index / City	Rail network density (km/ km^2)	Rail route density (No. of routes/ km^2)	Population density (person/ km^2)	Rail transit station density (No. of stations)	Rail length per capita (km/10,000 persons)	The number of rail transit stations per capita (No. of stations /10,000 persons)	Average daily passengers per rail transit station (10,000 persons/day・station)
Seattle	0.464	0.022	0.200	0.391	2.32	1.959	0.521
Portland	0.159	0.011	0.173	0.141	0.92	0.813	0.226
Sendai	0.176	0.011	0.139	0.169	1.26	1.213	2.197
Chiba	0.178	0.044	0.361	0.170	0.49	0.472	1.365

in Sendai and Chiba is higher than in Seattle and Portland, suggesting that rail stations in two medium-sized Japanese cities are more aggregated. According to the kernel density map, the rail stations in two Japanese cities are generally concentrated in the city center, leaving the peripheral region with poor coverage. In contrast, Seattle and Portland have a relatively more balanced development, in the sense that the rail networks extend to the suburbs.

6.2.2. The road network density of medium-sized U.S. cities is higher.

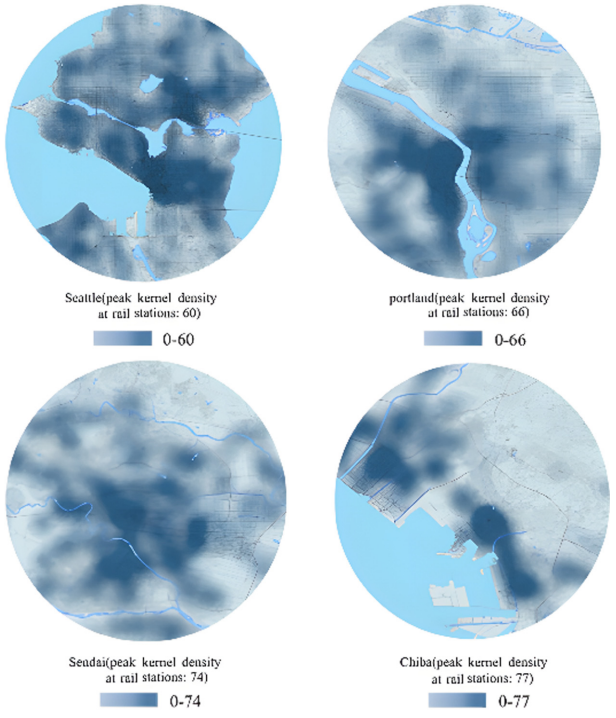


Figure 14. Kernel density of rail stations in medium-sized U.S. and Japanese cities.

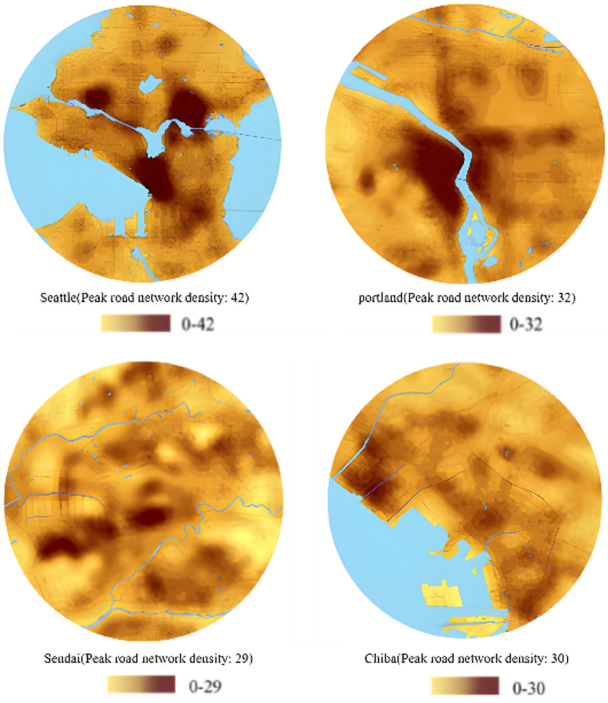


Figure 15. Road network density of medium-sized U.S. and Japanese cities.

Figure 15 shows the road network density of four medium-sized cities. The road network density of two medium-sized U.S. cities is comprehensively higher than that of the two Japanese cities, which indicates that Seattle and Portland might have smaller block sizes for better pedestrian environments. The areas with high-density road networks in both Seattle and Portland are those core business districts and subcenters. In contrast, in Sendai and Chiba, there is a minor difference between the city center's road network density and the periphery area.

6.2.3. The rail network of medium-sized U.S. cities is more systematic.

Figure 16 shows the rail network systems in four medium-sized U.S. cities. The rail networks in Seattle and Portland have a more complex structure centralized in the city center, which corresponds to the road network structure. Compared with the megacities and large-sized cities, the rail network of medium-sized cities has a limited service coverage area.

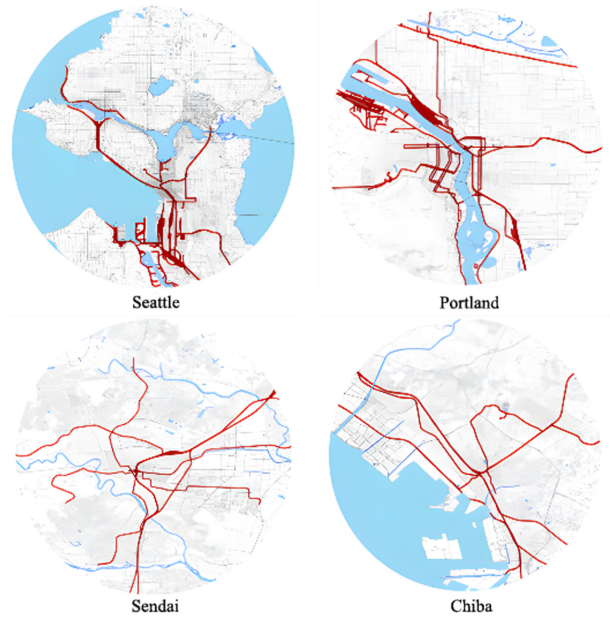


Figure 16. Rail networks in medium-sized U.S. and Japanese cities.

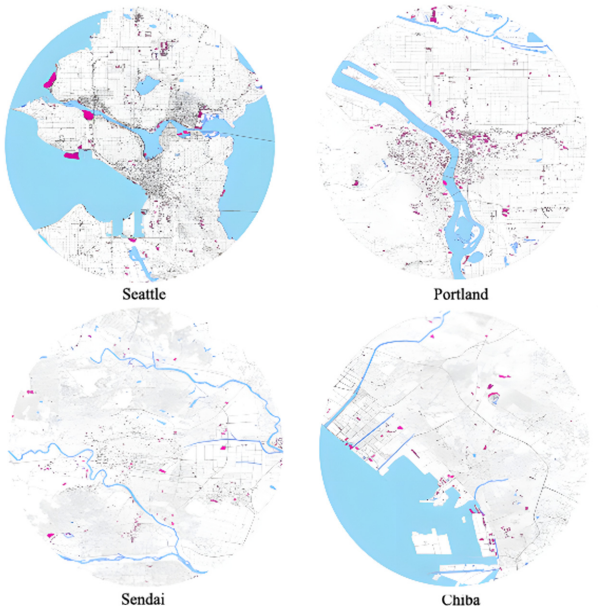


Figure 18. Static traffic distribution in medium-sized U.S. and Japanese cities.



Figure 17. Open space in medium-sized U.S. and Japanese cities.

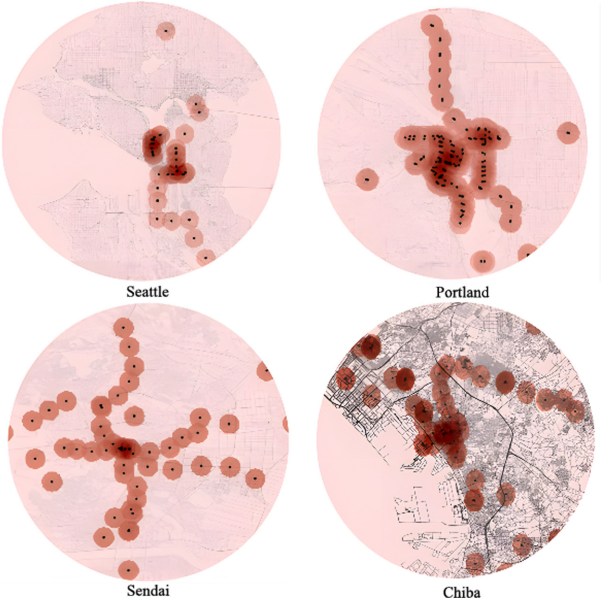


Figure 19. Land development intensity of station areas in medium-sized U.S. and Japanese cities.

Table 6. Summary of Characteristics of TOD Model in the United States and Japan from the City-scale Perspective

Criterions	The U.S. TOD model	Japanese TOD model
Public Transit Systems	◆ Usage rate, passenger transport efficiency, and operational efficiency of the public transit systems in U.S. cities are generally lower than the Japanese cities with similar populations.	◆The Japanese TOD cities generally have a high-level supportive public transit system. The usage rate, passenger transport efficiency, and operational efficiency suggest that the Japanese TOD cities are more public transit-dependent.
Urban Spatial Form	◆ In U.S. cities, open spaces and static traffic spaces generally take up larger areas and are distributed in a more aggregated form than in Japanese cities. The rail transit networks of medium-sized U.S. cities are usually more systematic, and multiple public transport modes have a better correlation in the cities.	◆ The density of rail transit stations and rail networks of Japanese megacities and large-sized cities are generally higher than the U.S. cities of the same population, and the railroad networks are more complex and more systematic. Public transit stations in medium-sized Japanese cities are more aggregated, but the rail transit networks can only serve a limited area.
Land Use	◆ Station areas in the city center have significantly higher land-use intensity, forming a single-center structure.	◆ Station areas in the city center generally have higher land development intensity; however, the difference less pronounced than in U.S. cities. The spatial distribution of station areas' land development intensity in many Japanese cities formed a multi-center structure.

6.2.4. Medium-sized U.S. cities have more open spaces, and the spaces are distributed in a more aggregated pattern.

Figure 17 shows the distribution of open spaces in four case cities. As shown, the U.S medium-sized cities have more open spaces and are distributed in a more aggregated pattern. The open spaces in Sendai and Chiba are smaller and dispersed in the city.

6.2.5. Static traffic spaces in medium-sized U.S. cities are large, and are distributed in a more aggregated pattern.

Figure 18 shows the static traffic spaces in four medium-sized case cities. Seattle and Portland have more static traffic spaces than Sendai and Chiba, and the static spaces are distributed in a more aggregated pattern throughout the city, which correlates to the Japanese cities' rail systems' higher usage rate, demonstrating that the U.S. cities are more automobile-dependent. In contrast, Japanese cities are more public transit-dependent.

6.3. Comparison of Land Use in Medium-Sized Cities

Figure 19 shows the land development intensity in the 500-meter range area around every rail transit station in four medium-sized cities. Consequently, the characteristics of land development intensity in medium-sized U.S. and Japanese cities are summarized as follows:

(1) In both medium-sized U.S. and Japanese cities, the land development intensity of station areas are higher in the city centers.

(2) In both medium-sized U.S. and Japanese cities, the disparities between the land development intensities of station areas in different regions are enormous, especially between the city center and the periphery.

7. Summary and Conclusion

This study comparatively analyzed TOD practices of 10 typical cities in the United States and Japan from a city-scale perspective, to get a comprehensive understanding of the commonalities and differences between the TOD model in the two countries. This paper separated the case cities into three groups based on population, and systematically analyzed the public transit system, spatial form, and land use of the cities in each group. In consequence, the characteristics of the U.S. TOD and Japanese TOD from the aspects of the public transit system, urban spatial form, and land use intensity are summarized in Table 6.

References

Calthorpe, P. (1993). *The Next American Metropolis: Ecology, Community, and the American Dream*. Princeton Architectural Press.

Cervero, R., Murphy, S., Ferrell, C., Goguts, N., Tsai, Y.-H., Arrington, G. B., Boroski, J., Smith-Heimer, J., Golem, R., Peninger, P., Nakajima, E., Chui, E., Dunphy, R., Myers, M., & McKay, S. (2004). *Transit-Oriented Development in the United States: Experiences, Challenges, and Prospects*. https://www.worldtransitresearch.info/research/3066

Hu A.(2016). *The Construction of HUB stations and Development of Surrounding Regions in Japan*. Sichuan University Press.

HU Y. D., TAO S.(2018) The Evolution, Classification and Enlightenment of TOD Models in the U.S.. *Urban Transport of China*, 16(4):34-42.

LU H. P.(2017). Guide of Special Topics: Transit-Oriented Development in Japan and the Experience in Tokyo. *Urban Transport of China*, 15(01):5-6.

LIN X. B., XU Y., DONG M. X., Lin Y. L., Huang Z., and Xu K.(2020). Planning and Policies for Transit-oriented Development in Megacities: A Comparative Study between Shenzhen and Seattle. *Urban Planning International*, 35(02):122-128.

Liu, Y., Nath, N., Murayama, A., & Manabe, R. (2022).

Transit-oriented development with urban sprawl? Four phases of urban growth and policy intervention in Tokyo. *Land Use Policy*, *112*, 105854.

Suzuki, H., Murakami, J., Hong, Y.-H., & Tamayose, B. (2015). *Financing Transit-Oriented Development with Land Values: Adapting Land Value Capture in Developing Countries*. World Bank Publications.

Takayama, K., Watanabe, Y., Chang, H.-C., & Morimoto, A. (2020). Study on the Characteristics of Japanese Transit Oriented Development as Seen from Long-term Land-use Changes. *Transportation Research Procedia*, *48*, 2313-2328.

Thorne-Lyman, A., Wood, J., Zimbabwe, S., Belzer, D., Breznau, S., Fogarty, N., Brennan, T., Tumlin, J., & Yake, C. (2011). *Transit-oriented development strategic plan/ metro TOD program*.

The United States Census Bureau, City and Town Population Totals: 2020-2021, https://www.census.gov/data/tables/time-series/demo/popest/2020s-total-cities-and-towns.html Accessed: Nov.26 2022

the Statistics Bureau of Japan, 2020 Population Census Report, https://www.stat.go.jp/data/kokusei/2020/kekka.html Accessed: Nov.26 2022

WANG J. E., JIN F. J., MO H. H., Chu B. (2007). Analysis and Review of Transit Oriented Development. *Traffic & Transportation*, B12(02): 19-22.