ISSN 2616-7433 Vol. 3, Issue 7: 68-76, DOI: 10.25236/FSST.2021.030713

The Evolution of Built Environment through Transit Oriented Development in the East Africa

Yi Guo[1*], Lixuan Min[2], Huize Yang[3], Lujian Yang[4]

[1]Shenzhen University, Shenzhen, China
[2]Planning Center, Shenzhen Metro Group Co., Ltd, Shenzhen, China
[3]Planning Institute, Shenzhen Municipal Design & Research Institute Co., Ltd, Shenzhen, China
[4]Shenzhen Metro International Investment & Consulting Co., Ltd, Shenzhen, China

Abstract: *With the rapid advancement of urbanization, "big city diseases" such as traffic congestion, environmental pollution, and land shortage have become increasingly notable. Specifically, transit-oriented development (TOD) has emerged as one possible solution to sustainable urban development and the key to promoting green transportation. Consequently, many cities and regions have embraced the concept of transit-oriented development. At present, the researches on the TOD built environment mainly focus on the cross-sectional analysis of the built environment. Although these researches reveal the impact of TOD mode on the built environment, it is difficult to determine the evolution of the built environment. Furthermore, the current research concentrated on the TOD model in Americas, Europe, and Asia, while there is little discussion on that in Africa. In view of this, this study analyses the evolution of the TOD Built Environment based on the built environment data of Addis Ababa, Ethiopia. This study verifies that the rail transit infrastructure with the TOD mode does have an impact on the built environment along the route, including the density and diversity of commercial, residential, medical, and educational facilities within the pedestrian range of the station.*

Keywords: *TOD, Urban rail, Built environment, Land use*

1. Introduction

During the Han Dynasty, 2,000 years ago, several cultural and trade routes were established between major cities in Asia and Europe, known as the Silk Road. In the new 21st century, the General Secretary Xi Jinping launched an ambitious programme called the Belt and Road Initiative (BRI) to revive the ancient Silk Road and the Maritime Silk Road.[1] The Belt and Road Initiative aims to integrate the regional connection between Asia, Africa and Europe through six main corridors of land and maritime networks to promote regional communications and regional trade economic growth (European Bank). The Belt and Road Economic Belt, which has expanded geographically to more than 70 countries, is made up of two parts: one is a land route connecting Russia, Central Asia, South Asia, East Asia and Europe; the other is the sea route connecting Southeast Asia, South Asia, the South Pacific, the Middle East and Eastern Africa.[2]

The initiative identifies five major priorities, including policy coordination; infrastructure connectivity; unimpeded trade; financial integration and connecting people.[1] Transportation connectivity is the priority and basement for the implementation of the Belt and Road Initiative and transportation is the basis for cooperation and development of key channels, cities, and projects.

At present, studies on the TOD built environment are mainly aimed at the cross-sectional analysis of the built environment. Although these studies draw conclusions about the impact of TOD mode on built environment, it is difficult to determine the evolution of the built environment, which requires further longitudinal studies. The current researches focus on the TOD model in Americas, Europe, and Asia, but few have discussed that in Africa.

This study takes Light Rail in Addis Ababa, Ethiopia as the research object. The project is the top and first urban rail infrastructure project by China's "Belt and Road" Initiative, with Chinese loan, design, equipment and management, and is a typical example of Transportation Connectivity project in countries along the Belt and Road. This study is structured as follows. The first part is literature review; The second part introduces the research context of the Belt and Road Initiative; The third part deals with the methodology and data collection; the fourth part involves the finding and discussion; and the last part is

ISSN 2616-7433 Vol. 3, Issue 7: 68-76, DOI: 10.25236/FSST.2021.030713

the conclusion.

2. Literature review

2.1. The infrastructure connectivity

According to the Action Plan of the China-proposed Belt and Road Initiative (2015), in the five major implementation areas, the infrastructure construction is the priority for corporation with the cities along the Belt and Road Economic Belt. Over the past half century, the infrastructure along the trade route between Asia and Europe has been underinvested, leaving much of it decrepit and a barrier to trade.[1]

Therefore, the Belt and Road Initiative proposes that cities along the Belt and Road should strengthen cooperation and communication in infrastructure construction planning[2] and promote major intercontinental corridor and urban transportation in Asia, Africa and Europe.[3]

2.2. The big city diseases and TOD mode

With the rapid urbanization worldwide, "big city diseases" have become increasingly prominent, such as traffic congestion, environmental pollution, land shortage.[4] Transit-oriented development (TOD) has been widely acknowledged as a suitable method for sustainable urban transportation, and an important means to promote green transportation.[5]

The TOD communities can be built along the transit lines, which are called TOD cities.[6][7] Past researches have proved that TOD mode can improve city accessibility and mobility, making the pedestrian area around public transport station area more friendly.[8]

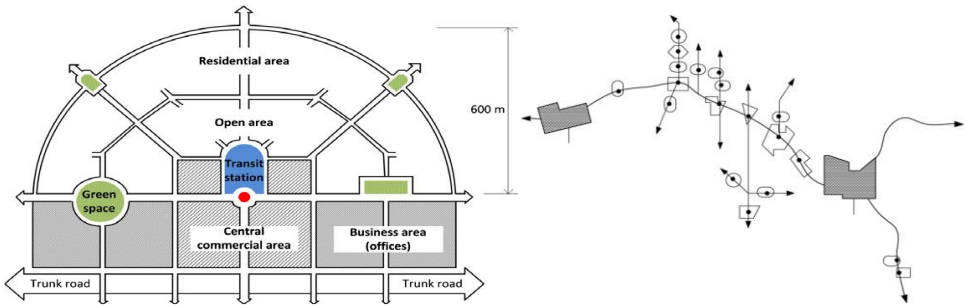

Figure 1: TOD city (Jiang and Han, 2009)

The TOD mode aims to decrease private car use, increase the land use efficacy and diversity, reduce the transportation costs and so on.[6] Cervero classifies the built environment that affects residents' mobility to 5 "D", namely Density, Diversity, Design, Destination accessibility, Distance to transit.[4] High-density development can control the urban sprawl which is the Auto-oriented development (AOD) mode.[9] The higher employment density in the TOD area can also reduce the travel of private cars for shopping and non-work purposes, and promote slow traffic such as walking mode. In the case of high land use mixing degree in the TOD area, residents' leisure travel will be dominated by non-motor vehicle travel and the car travel rate is relatively low. The main reason is that higher land mix provides people with local shopping and leisure options, which is an opportunity to help reduce travel distances.[10] The high density and diversity of land use in the TOD region have a greater impact on residents' travel. The higher population and employment density attracts more people to choose to live and work in the TOD region, which may shorten the commuting distance and encourage the choice of green travel (public transport, walking, cycling, etc.).

2.3. TOD practice in the worldwide

The concept of transport-oriented development (TOD) has achieved worldwide success for the sustainable city development. However, previous studies have also found different applications in different countries. For example, in North America and Australia using in the re-centering sub city with the public transit[4][6][11]; Europe countries focus on redevelopment of old stations[12]; the Asia counties adopt mass rapid transit to extend their mega-cities. South America countries focus on reducing the use of private cars and strengthening public transport.

ISSN 2616-7433 Vol. 3, Issue 7: 68-76, DOI: 10.25236/FSST.2021.030713

3. Conceptual framework and research context

3.1. Conceptual framework

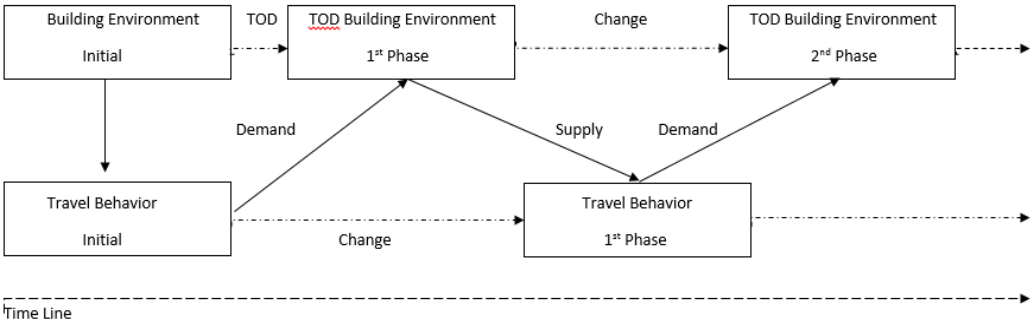

Figure 2: A theoretical framework is proposed to solve the evolution of the TOD built environment

3.2. Research context

Most major cities in sub-Saharan Africa have almost no public transportation systems. Research by the World Bank (2018) shows that the lack of mobility has devastating consequences and is a key constraint on economic growth in African cities.

Addis Ababa is the capital of the Federal Democratic Republic of Ethiopia. Addis Ababa extends over 540 square kilometers at an altitude of 2,700 meters above the level of the Sea, currently including 10 sub-cities and 116 woredas. According to UN-HABITAT, the city has a population of approximately 3.4 million.[13] The population is expected to grow at an annual rate of 3.8%, and this growth will continue for the coming 15 years.

Thus, it can be seen that 2.2 million people in Addis Ababa are taking public transport and 3.6 million trips are made daily in the city. Currently the public transport in Addis Ababa is limited to the road transport that mainly comprises 10, 000 white and blue Minibus taxis that accommodate up to 12 people. As a result, residents of Addis Ababa have had to face great inconveniences, as well as extra charges for daily trips to their destinations. This study attempts to identify the major factors that contribute to the high demand for public transport system in cities.

Generally, access to motorised transport in sub-Saharan Africa is limited. Walking is the most common mode of transport. This study based on household surveys shows that a minority of city dwellers (10 to 20%) own a vehicle and for many of them, travel is more restricted. They can travel by public transport and walking (for one-third of the residents on a given day) or only by walking (30 to 40% depending on the city). Another 10 to 20% of residents do not leave their homes on weekdays. According to the last assessment of the modal split in Addis Ababa in 2006, 45% of trips are made on foot, 46% by public transport and 9% by private transport. The matter of the existing supply, along with its accessibility, is central to the problem of mobility for a continent undergoing rapid urban changes.[14]

These buses, with a capacity of around 100 people (30 sitting and 70 standing), are mostly uncomfortable and are often considered as a means of transport for the “very poor”. The waiting time (on average 40 minutes), travel time (48 minutes on average at an average speed of 15 kilometres per hour), and the condition of the stations, buses (care and maintenance issues) make the service unattractive. Ethiopia is currently trying to find a solution. Addis Ababa Light Rail is a light rail transportation system, which is the first urban rail system in sub-Saharan Africa.

The light rail system has two lines with a total length of 33 km (17 km north-south line, 16 km east-west line) and 39 stations, and started operation at September 20, 2015. This light rail system is the top urban rail project in the Belt and Road built by the China Railway Group Limited, financed by the Export-Import Bank of China and operated by the Shenzhen Metro Group from 2015.[15]

ISSN 2616-7433 Vol. 3, Issue 7: 68-76, DOI: 10.25236/FSST.2021.030713

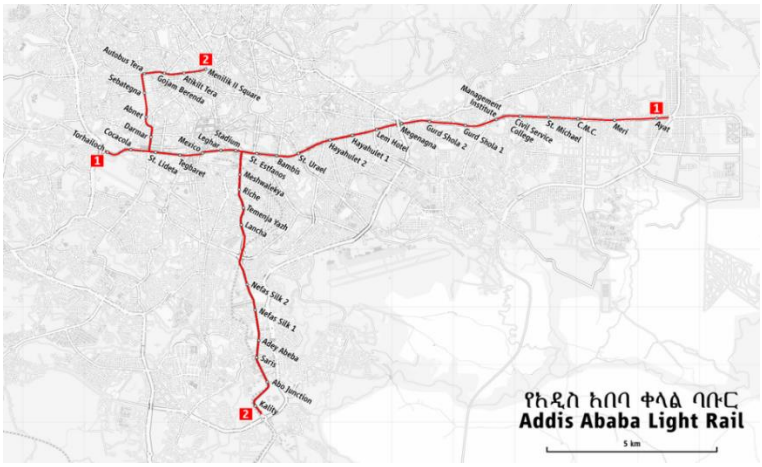

Figure 3: The line map of Addis Ababa Light Rail

4. Methodology and data collection

4.1. Methodology

This study identifies urban change and the impact of China's Belt and Road Initiative on urban rail projects by comparing the different periods of Point of Interesting (POI).

4.2. Data collection

Data from the DMSP Nighttime lights map were used for this study to analyze the city sprawl. And the built environmental data from the survey of the preliminary design of the Addis Ababa light rail in 2009 and the survey on 2016/2017/2018 after the Light Rail operation from Google POI and on site survey.

The built environment assessment uses the point of interesting (POI) density index and the land use diversity index. The POI points are classified according to the ESRI Geographic Information Public Service Platform Classification Standard. Findings of this paper are derived from 10 telephone semi-interviews and in person interviews with passengers and LRT operators.

5. Findings and discussions

5.1. Urban sprawl

According to Alexei Abrahams DMSP Night-time Lights map, the city was confined to a small area in 1985, and then, with the light rail planning, began to develop in four directions along the light rail route.

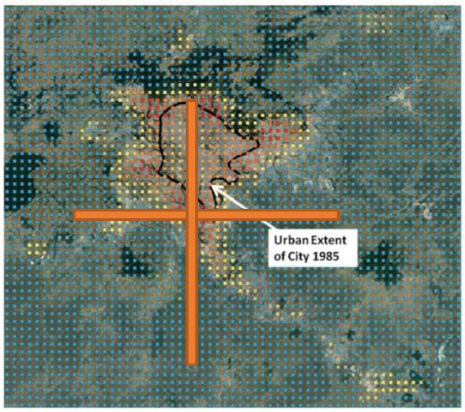

Figure 4: DMSP Night-time Lights map in Addis Ababa (Alexei Abrahams, 2018)

ISSN 2616-7433 Vol. 3, Issue 7: 68-76, DOI: 10.25236/FSST.2021.030713

As can be seen from Figure 4, although the urban population only accounts for 20% of the total population, the country is now facing very high urban growth. The country has been one of the most rapidly urbanizing in sub-Saharan Africa in recent years, with light rail transit covering its entire city. The municipality is restructuring entire neighborhoods along the LRT lines, allowing the city to expand along the light rail transit line.

5.2. City center shifting

For the time being, the central districts are the most populated. Indeed, cities are expanding faster than their populations are growing. According to Alexei Abrahams DMSP nighttime lights map in Figure 5, the lightest area is not in the old city center. And the north, east and south parts of the city, where the LRT terminal is located, are the brightest, indicating that this area has lighter at night.

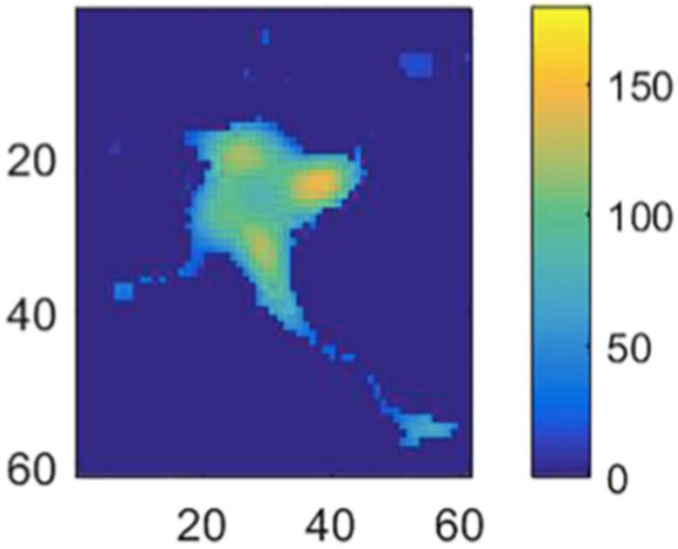

Figure 5: DMSP Night-time Lights map in Addis Ababa (Alexei Abrahams, 2018)

For instance, the extent of the metamorphosis is particularly evident at Megenagna Square, which is from a small village to the central hub of the city.

According to the Google Earth history, Figure 6 shows the overall comparison of the built environment changes from 2009 to 2018 in station Megenagna Square (r=800m).

2009 *2018*

Figure 6: An overall comparison of the changes in the built environment between 2009 and 2018 in station Megenagna Square (r=800m）

From Figure 6, we can find that the number of buildings around the station has a significant increase.

Another example is the EW 10 station. Below is the overall comparison of the built environment

ISSN 2616-7433 Vol. 3, Issue 7: 68-76, DOI: 10.25236/FSST.2021.030713

change between 2009 and 2018 in station EW10 based on the Google Earth.(r=800m).

2009 *2018*

Figure 7: An overall comparison of the built environment changes between 2009 and 2018 in station EW 10 (r=800m)

From Figure 7, we also can find that the number of buildings around the station has a significant increase.

Based on the number of POIs, we identify the regional centers of each level, most of which is around the light rail station.

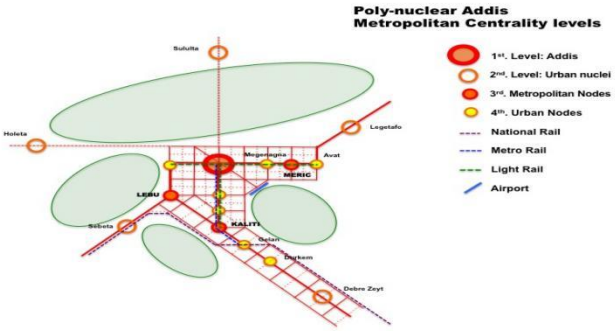

Figure 8: Poly-nuclear Addis Ababa Metropolitan Centrality Levels

5.3. Density changing

The table shows the changes of the POIs density around the main station and the small station from 2009 to 2018, the average density changes of POI before and after the light rail service in the surrounding area of the station and the comparison with other city areas.

Table 1: The average density changes in POI before and after the light rail service in the station surrounding area

POI Type	2009.9	2016.9	Increase rate	Other city area increase rate
Restaurant	4.6/km^2	15.4/km^2	234.78%	
Shopping	6.1/km^2	16.3/km^2	167.21%	
Hotel	0.4/km^2	2.1/kam^2	425.00%	120%
Finance service	0.8/km^2	3.3/km^2	312.50%	90%
Education	0.3/km^2	1.2/km^2	300.00%	120%
Medical service	0.3/km^2	0.8/kxm^2	166.67%	90%
Office (room)	25/km^2	178/km^2	612.00%	170%

From Table 1, we can find that after the planning and construction of light rail transit, the TOD model has formed agglomeration effects along the line, and the land use is more concentrated with a higher

ISSN 2616-7433 Vol. 3, Issue 7: 68-76, DOI: 10.25236/FSST.2021.030713

density.

5.4. Diversity changing

Table 2 shows the secondary changes of POIs before and after the light rail service in the area around the station. For example, restaurants can be divided into large-sized restaurants, medium-sized restaurants, small restaurants, and caf é According to the POI point classification standard, after the rail transit planning and construction, the secondary category of rail transit increases under the TOD model, indicating that land use is more diversified.

Table 2: The average changes in POI diversity before and after the light rail service in the area surrounding the station

POI Type	2009.9	2016.9	Increase rate
Restaurant	2.1	4.4	109.52%
Shopping	2.5	3.8	52.00%
Hotel	1.2	3.4	183.33%
Finance service	1.1	3.2	190.91%

5.5. The limitation of capacity

From Figure 9, we can find that the passenger flow at the terminal station is significantly higher than that at the intermediate station.

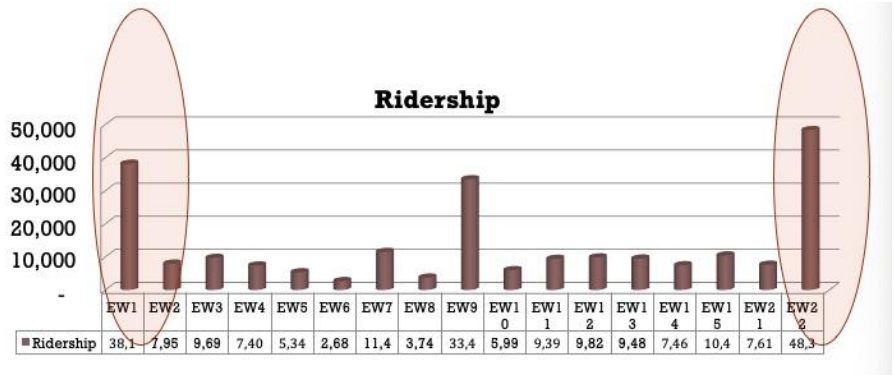

Figure 9: The ridership in each station

Officially, the passenger capacity of one tram is 370. In practice, however, it is normal to have more than 500 passengers in one tram. High demand often leads to a chaotic run of trams. The interview with local passengers confirmed this point. Endale Bogate said that the overcrowded trams are torture. When he got off, he was often drenched in sweat.[16]

There are some reasons for the high demand. One is the affordable ticket price, which makes it affordable even for low-income workers. A wide range of international experiences and user surveys[4] have shown that:

High levels of transit service qualities like Comfort Vehicles with good conditions (fresh air inside the vehicle; cleanness; good seats, etc.) and stops with good waiting facilities can give public transport system strength an edge over private automobiles, thus contributing to the TOD mode.

During periods of passenger capacity limitation, trains are fully loaded from the departure station, which not only makes it difficult for the passengers at the intermediate station to get on or off the train, but also has a negative impact on the public transport attractiveness.

ISSN 2616-7433 Vol. 3, Issue 7: 68-76, DOI: 10.25236/FSST.2021.030713

Figure 10: The congested station

5.6. Reorganize of TOD building environment

When the attractiveness of public transport is degraded due to transportation capacity limitation, the situation of passenger flow decreases, which has an impact on the built environment around the station. The built environment within 800 meters of the station is being restructured and some businesses are losing out. The interviewer, Seifu Tesfaye, owns an electronics shop. He said that his monthly rent has more than doubled after the LRT opening, so he wants to reopen in a different neighborhood.[17]

When the establishment of large-scale train stations, new stores such as restaurants and retail shops opened feverishly in a short period of time. However, due to limitations in light-rail passenger capacity, follow-up passenger flow did not continue to grow, which slightly decreased the number of restaurants and retail shops.

Around the vicinity of small stations, during the start of light-rail operations, a large number of people were attracted to the large-scale stations, leading to the closure of some small shops. However, due to the limited capacity of light-rail, a spillover effect commenced. A year later, restaurants, electronic retail shops, and other small shops within the vicinity of small stations were re-opened, continuing to reshape and rebuild the environment of those locations.

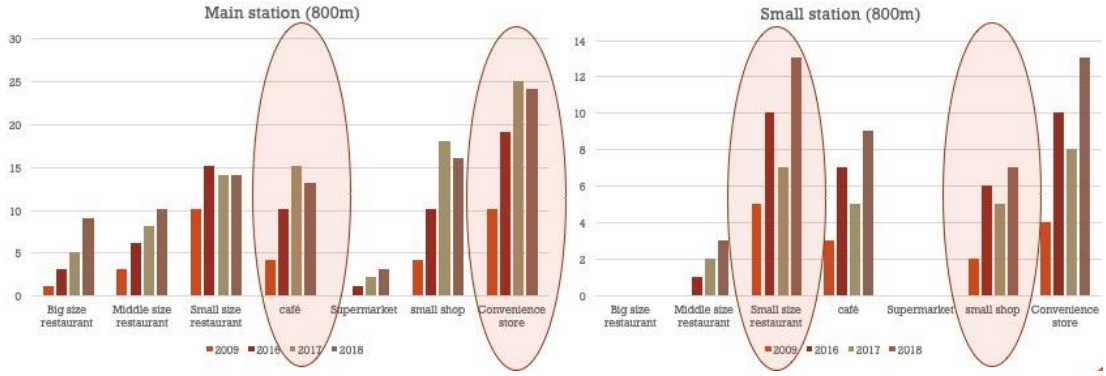

Figure 11: The changing of the POIs density around the main station and the small station from 2009 to 2018

6. Conclusion

Based on the analysis of 10 years of building environment data, this study has verified that the rail transit infrastructure built by Chinese company following the Belt and Road Initiative (BRI) has an impact on the current environment along the route, including the density of commercial, residential, medical, and educational facilities within walking distance from the station. Additionally, the land use of the area surrounding the station is also more diversified.

This study also discovered that the travel behavior of residents also affects the current TOD environment. Due to limitations of light-rail transit passenger capacity, the station passenger flow has not sustained its growth. New changes have taken place in the environment around the big and small stations after their inauguration.

The study also found that the Belt and Road Initiative still has many challenges and deficiencies. Due

ISSN 2616-7433 Vol. 3, Issue 7: 68-76, DOI: 10.25236/FSST.2021.030713

to the lack of public transportation supply, the TOD model did not achieve the desired effect from the planning stage. A large number of residents abandoned public transportation because of light-rail capacity factors, either returning to private transportation or choosing to leave the light-rail system.

At present, the 5D model of the current TOD environment is based on the supply of public transportation in developed countries. The public transportation system in developed countries can supply adequate capacity and comfortable facilities for the public, without having a greater impact on the TOD mode.

References

[1] Lobyrev, V., Tikhomirov, A., Tsukarev, T., & Vinokurov, E. (2018). Belt and road transport corridors: barriers and investments. Social Science Electronic Publishing.
[2] Qi, X., Shen, L., Jiang, Y., & Jin, Z. (2017). Multimodal transport routing problem considering transshipment and accessibility: The case of the "One Belt One Road" initiative. International Conference on Transportation Information & Safety.
[3] Vinokurov, E., & Tsukarev, T. (2017). The belt and road initiative and the transit countries: an economic assessment of land transport corridors.
[4] Cervero R. (1994) Transit-based housing in Californi: evidence on ridership impacts. Transport Policy, 1(3):174-183.
[5] Zhao P, La B, De Roo G. (2011) Impact of the jobs-housing balance on urban commuting in Beijing in the transformation era. Journal of transport geography, 19(I): 59-69.
[6] Dittmar, H., Ohland, G., (2004) The New Transit Town: Best Practices in transit oriented development. Island Press, Washington D.C.
[7] Cervero R, Day J. (2008) Suburbanization and transit-oriented development in China. Transport Policy, 15(5): 315-323.
[8] Curtis, C., Renne, J.L., et al., 2009. Transit-oriented development: Making it Happen. Ashgate, Burlington.
[9] Bernick, M., Cervero, R., (1997) Transit Villages in the 21st century. McGraw-Hill, Columbus.
[10] Handy S. (1996) Methodologies for Exploring the Link Between Urban Form and Travel Behavior. Transportation Research Part D: Transport and Environment, 1(2): 151-165.
[11] Hemsley, W., (2009) The commercial reality of TOD in Australia. In: Curtis, C., Renne, J.L., Bertolini, L. (Eds.), Transit Oriented Development: Making it Happen. Ashgate Publishing, Ltd, pp. 201-208.
[12] Bertolini, L., (1999) Spatial development patterns and public transport: the application of an analytical model in the Netherlands. Plan. Pract. Res. 14 (2), 199-210.
[13] UN-HABITAT, (2011) Condominium Housing in Ethiopia: The Integrated Housing Development Programme, Kenya: UN-HABITAT.
[14] Transportation Challenges in A Booming City: Coordination of the Mass Transit Network and Urban Development in Addis Ababa, (2012) Addis Ababa City Planning Project Office and Agence d'Urbanisme de Lyon, CODATU XV.
[15] Cao X, Fan Y. (2012) Exploring the Influences of Density on Travel Behavior Using Propensity Score Matching. Environment and Planning B: Planning and Design, 39(3): 459-470.
[16] Lund H. (2016) Reasons for living in a transit-oriented development, and associated transit use[J] . Journal of the American Planning Association, 72(3): 357-366.
[17] Schlossberg, M., Brown, N., (2004) Comparing transit-oriented development sites by walkability indicators. Transp. Res. Rec.: J. Transp. Res. Board 1887 (1), 34-42.