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Multi Level Measurement and Evaluation Method of the TOD

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Abstract: Two evaluation methods of indicators and visualization platform are investigated at the multiple levels. Combining the two methods together, the multi level measurement and evaluation method of the transit oriented development (TOD) is proposed. Obtaining the primary indicators and applying them on the visualization platform, the comprehensively quantitative and visual evaluating methods are built. The results indicate that this evaluation system can solve effectively the urban problems, utilize the urban land intensively and realize the sustainable urban development.

Keywords: transit oriented development; evaluation system; factor; visualization; multiple levels; measure criterion

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Transit oriented development (TOD) was proposed as a planning tool to face these challenges, which integrated the land use and the transport system to create sustainable, livable, and pedestrian friendly neighborhoods^[1-2]. A TOD community or neighborhood should have the characteristics with high density, mixed and diverse land use, walking distance to the transit stations, and the friendly walking environment^[1,3]. Concerning with the area of a TOD neighborhood or community, centered with the transit station, quarter mile (400 m) to half mile (800 m) buffer area is widely accepted as a TOD neighborhood or community^[4-5].

During the past two decades of practices in the United States, many studies have demonstrated the remarkable effects on the increasing transit ridership and reducing driving from the TOD policies. As many researchers stated, the TOD neighborhoods or TOD communities not only increased the transit ridership, but improved the revival of the old communities through the economic interests from the commercial development^[5-6]. There have been many successful TOD cases worldwide, such as Stockholm in Sweden, Copenhagen in Denmark, Madrid in Spain, Hong Kong in China and Seoul in South Korea^[7-9]. The TOD concept was introduced to China in year 2000 and has been under hot discussions with the appeal of low carbon development and mass construction of the rapid transit lines in many Chinese cities.

The traditional TOD areas are often in the high density areas, such as central business district (CBD), however, with the monocentric urban pattern transferring to the polycentric urban pattern, the urban form has been re-configured^[10-11]. Up to date, there is no unanimous criteria to evaluate the TOD areas or projects. To fill the gap, this paper is trying to review and conclude the indicators that

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might be useful for evaluating the TOD projects.

1 Review of Existing Multiple Criteria of TOD

1.1 Classical 3D/5D Principle in United States and the 5D2 Principle in China

The famous transportation researchers Cervero and Kockelman concluded the characteristics of the TOD areas as “3D” principle, and then they extend the “3D” to “5D”: density, diversity, design, distance to transit and destination accessibility,see table 1^[12].

For design, it was given the priority to walking and cycling, but limited the parking space around the transit stations. Concerning with the diversity, Cervero and colleagues explained that it would be better if there are diverse land uses along the transit lines, which could avoid the heavy transportation flow^[12]. Other “3Ds” represent the core idea of TOD concept: increasing the density, walking distance to the transit station, and good accessibility to various destinations.

Tab.1 3D/5D principle^[12]

表 1 3D/5D 原则^[12]

Principle	Measurement	Explanation
3D	Density	High density could shorten the travel distance and encourage people taking transit, walking or cycling
	Diversity	It measures the number of different land uses in a given area and the degree to which they are represented. Different land uses could be arranged along the transit lines to avoid the heavy transportation flow
	Design	The design of transportation hub could meet both the function requirement and safety requirement
5D	Distance to transit Destination accessibility	The average distance from home or work places to the transit stations The accessibility from home or the transit station to various daily destinations

Through survey in Hong Kong and Taipei, references [13-14] have concluded five aspects of TOD characteristics in the two cities: differentiated density, dockized district, deluxe design, diverse destination and distributed dividends, see table 2.

Since the five aspects are all two words beginning with “D”, they are also called as “5D2” principle. The “metro+property” mode of Hong Kong MTR is the most successful case of “Distributed Dividends”, whose goal is to combine the subway construction with property development along the subway lines,using the interests from the property development to pay for the fees of the rail construction and operation^[13-14]. The TOD community area in “5D2” principle is planned or considered at the city or region level and the balance of land use could be solved across the communities, not only limited in one community^[13-14].

Tab.2 5D2 principles^[13-14]

表 2 5D2 原则^[13-14]

5D2	Explanation
Differentiated density	The density in the TOD community is higher than that in other areas
Dockized district	Refer to the water or air harbor design principle
Deluxe design	Emphasize the high standards and details of TOD principles
Diverse destination	At the regional level, diversity means that residents could access to various destinations by taking rapid rails or buses
Distributed dividends	The public service sector takes back part or all of the economic interests from the increasing land value and then redistributes to different sectors

1.2 TOD Index/Indicators

Renne and Wells the proposed “TOD Index” and they did a national survey^[15], in which they hired 30 professionals to evaluate all the indicators listed. Then, they screened 15 indicators that were at least 50% professionals marked “very useful”. Later, they posted these indicators online to get further evaluation from the public.

In the result, the transit ridership was supported as the most important indicator for evaluating a TOD area. The following important indicators: density, the quality of environment design, land use mixture, and others are listed in the Table 3. This TOD index includes the socio-economic characteristics and residents activities, which are important as the characteristics of the built environment^[15].

Tab. 3 TOD index^[15]

表 3 TOD 指标^[15]

Indicator	Category	Percentage identifying by professionals as “very useful”	Secondary ranking (by the web evaluation)
Transit ridership	Travel behavior	70	1
Population density	Built environment	67	2
Housing density	Built environment	67	2
Employment density	Economic/ built environment	53	2
Qualitative rating of streetscape	Built environment	77	3
Mixed-use structure	Built environment	60	4
Pedestrian activity counts	Built environment	77	5
Number of intersections or street crossings improved for pedestrian safety	Built environment	60	5
Estimated increase in property value	Economic	63	6
Public perception	Social diversity	63	7
Number of bus, ferry, shuttle connecting to transit station	Travel behavior	63	8
Number of parking space	Travel behavior	53	9
Estimated amount of private investment	Economic	57	—
Number of convenience or service retail service	Economic	53	—
Estimate amount of private investment by type of land use	Economic	52	—

Loo and colleagues investigated the built environment surrounding the subway stations in New York and Hong Kong^[16]. They also the proposed indicators for evaluating TOD and divided them into five categories: ridership, land use, station characteristics, socio-economic characteristics and inter-modal competition (Table 4).

Tab. 4 TOD indicators^[16]

表 4 TOD 因子^[16]

Dimension	Variable	Measurement
Ridership	R	Total number of daily riders
Land use	C/R	Total commercial/Residential floor area in square meter
	COM	Total commercial floor area in square meter
	GAR	Total garage floor area in square meter
	GAR_DUM	Garage area smaller than cumulative 90th percentile (dummy variable)
	MIXED	Mixed land use (dummy variable)
	PARK	Total off-street parking floor area in square meter
Station Characteristics	CBD_DUM	Central business district (dummy variable)
	DIST_MID	Generalized travel cost from station to middle town in United States dollars
	INTER	Major interchange station (dummy variable)
	YRS_OP	Years of operation
Socio-economic Demographic Characteristics	CARS	Car ownership per household
	POP_S	Population size
	POP_D	Population size per residential floor area
	EMPOVERPOP	Employment over population
Inter-modal competition	Bus	Number of bus stops

This evaluation placed an emphasis on the socio-economic, demographic and station characteristics rather than only focused on the built environment characteristics. In their survey and analysis results, more commercial area (COM) increased the ridership; years of operation of the station (YRS_OP) was proportional to the ridership; bigger population size (POP_S) increased the ridership; the number of the bus stops was proportional to the ridership.

In their study results, there was an interesting conclusion that more vehicles one household owned more possibility to take the transit since the residents might take their vehicles to the transit stations. The result was different with other studies, such as the studies in Los Angeles and other cities. We should pay attention that the TOD principles encourage people to walk or cycle to the transit stations and limit the parking spaces around the stations.

1.3 Visual Evaluation Methods from the Walkability Indicators to the Spatial Multiple Criteria Analysis

Schlossberg and colleagues used walkability indicators to evaluate 11 TOD areas in Portland, Oregon through ArcGIS platform^[17]. This is a great case to evaluate TOD by using GIS spatial analysis platform, however, only used one indicator. “Walkability” as a popular indicator refers to the walking ability in built environment. Although there had been various definitions, several ones were accepted as below. Abley’s^[18] group defined “walkability” as the ability to provide friendly walking environment for people’s daily life. Gebel’s group^[19] pointed out that “walkability” means compact, mixed land use, good connectivity and accessibility. Frank’s group^[20] gave the quantitative method to measure the walkability and it has been accepted widely now. The formula is as follow;

$$\text{Walkability} = (2 \times Z_I + Z_N + Z_R + Z_L).$$

Here, Z_I , Z_N , Z_R , Z_L respectively expressed variable of intersection density of street, variable of net residential density, variable of retail floor area ratio and variable of land use mix; Frank’s group makes sure that intersection density of street is important than other three indicators after many evidence studies^[20]; $Z_L = -[\sum_1^n (p_i) \ln p_i] / \ln n$, here p_i represents the proportion of the i category land use; n refers to the number of land use categories.

ArcGIS used the formula above to calculate the “walkability” and reflected different level of walkability of all the TOD areas on the GIS map, which could more readable than the numbers or tables. However, only using “walkability” is not enough to evaluate TOD areas comprehensively since many socio-economic and other factors have been ignored. Depending on GIS platform and using spatial multiple criteria analysis (SMCA) is more reasonable to evaluate the TOD areas. SMCA is a multiple evaluation criteria, whose indicators are evaluated and decided through the ILWIS platform^[13].

These indicators consist of a comprehensive target system to evaluate the TOD areas, which also reflects the results on the GIS maps. The policy makers and other stakeholders could help decide the weight for each indicator. The following researches are the primary ones that successfully employed the SMCA to evaluate the TOD projects. Keshkamat’s group^[21], Beukes’s group^[22] and Singh’s group^[23] concluded the indicators in the SMCA: 1) density; 2) diverse land use; 3) friendly walking environment; 4) economic development.

2 Conclusions and Suggestions

The TOD concept was proposed and has developed over two decades in the States United, and there has been an accumulated abundant practice experience. This concept has been introduced to our country for almost 15 years and based on the characteristics of our cities, we are exploring the proper mode of the TOD in China. Hong Kong and Taiwan introduced TOD concept earlier than us and both of them developed their own successful TOD styles. However, until now, there is no standard criteria

to evaluate the TOD projects or areas and the related literature is quite limited. This study is trying to fill this gap through concluding the existing multiple criteria, which has focused on the characteristics of built environment and socio-economic indicators in the TOD neighborhoods.

Firstly, it is widely accepted that the area of TOD community is often centered by the transit station with 400 m (quarter mile) to 800 m (half mile) radius, which is decided by the walking time (5 to 10 minutes) from any point in the TOD community to the transit station.

Secondly, the following criteria (including indicators) are suggested by this study to measure the TOD projects:

1) Built environment characteristics around transit stations (including residential density, block size, intersection density of street, the size of business/service, walking facilities, good accessibility to various destinations, diverse land use and mixture, the parking spaces around stations, etc.);

2) Socio-economic characteristics (including population density, employment density, vehicle number per household, housing value, etc.);

3) Station characteristics (including station type, seamless transportation connection, years of station operation, etc.).

Sometimes, the population density and employment density are also included into the categories of built environment characteristics. Meanwhile, according to the released data from center of transit oriented development (CTOD), it should consider the activities of residents as the important indicators to evaluate the effect of the TOD projects^[3]. The aim of TOD is to encourage residents taking transit and reducing driving, thus the following indicators of residential activities should include: transit ridership, household vehicle miles traveled (VMT) per month, and household vehicle hours traveled (VHT) per month. These indicators could verify the real effect of TOD projects and test if the projects achieve their final goal.

Finally, the visual evaluation method has many advantages compared with the traditional methods, such as readable. In the GIS maps, it is convenient to identify the levels of TOD communities from the best to the worst and locate which communities should be improved based on the evaluation criteria.

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公共交通导向型城市发展模式的多层次测量评估方法

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摘要: 对因子类评估方法和可视化评估方法进行多层面的对比,提出结合两种评估方法,建立公共交通导向的城市发展模式(TOD)多层次测量评估模型.即提炼出因子类评估方法中的主要因子,然后通过可在可视化平台上的实例应用,提出基于可视化平台的评估因子,从而建立综合定量的可视化评价体系.结果表明:该评价体系能够有效地解决城市弊病,集约利用土地,实现城市的可持续发展.

关键词: 公共交通导向型城市发展模式; 评价体系; 因子类; 可视化; 多层次; 测度标准

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