Measuring TOD Index in Jakarta with Accessibility and Land Use Function – Case Study on Three Transit Nodes

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Abstract. Accessibility increases values significantly in transit node areas. In Jakarta, there are areas that have been developed or prepared as Transit Oriented Development (TOD). TOD is city transformation concept focusing on integrated transportation and land use, with novel concept creating diversity land use in medium to high density area, so residents can walk or bike to move inside the area, and commute using public transport. TOD index is used to assess area's suitability with TOD principles and AHP system calculates TOD index in six specifics historical, social & culture different areas in one city. TOD index helps stakeholders designing TOD strategically based on potential values in each area. Differ from prior studies, this paper measures external and internal accessibility effects at transit nodes in different areas in Jakarta, so TOD index is a function of external and internal accessibility and land use, influences value added based on each area's characteristic.

Keywords: TOD index, External accessibility, Internal accessibility, Land use.

1 Introduction

Jakarta is a metropolitan city with many people have activities in it, some of them living in Jakarta and some other lives around Jakarta. The data from BPS (Central Statistics Agency) in 2018, the population in Jakarta during the day was 12 million, while at night about 10.6 million people. This means the number of commuters who lived outside Jakarta and working in Jakarta is 1.4 million people. Many commuters require a large means of the need of convenient transportation with time efficiency.

The solutions of Jakarta problem in commuters are increase the accessibility. Accessibility defined as the extent to which land use and transport systems enable a person able to reach activities or destinations using transport mode (Geurs and van Wee, 2004). According to Tamin (2000), accessibility is a concept that combines a geographic land use management system with

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a transportation network system that connects it. Meanwhile, according to Black (1981) accessibility is a measure of comfort or convenience regarding the way land use locations interact with each other and the 'easy' or 'difficult' location being reached through the transportation network system.

The important role of transportation infrastructure for spatial development, simply implies that areas which has better access to activity centres become more productive and more competitive than more remote areas (Espon Eu, 2005). The accessibility in this research will be divided into two major part: accessibility form suburban to city centre and accessibility inside the city. Most accessibility calculation, take some concern in accessibility as a node, from one transit node to another transit area (figure 1).

Fig. 1. Accessibility calculation

For accessibility from outside to city centre, DKI Jakarta government has prepared many solutions for large number of people to travel, the earlier step is toll road from suburban and megapolitan area to city centres. This policy was being answered with the raise of motorized vehicles (cars and motorcycle) in DKI Jakarta is not balanced with the construction of adequate roads, causing traffic jams every day. Other solution is the availability of public transports, such as KRL and BRT from several area to Jakarta. To accommodate accessibility around the city, the government has prepared BRT, MRT and LRT. To increase the quality of life for Jakarta's people, there's a TOD plan in Jakarta. TOD has been described as a planning approach that aims to integrate land use and transport planning (Schlossberg & Brown, 2004).

Transit Oriented Development (TOD) is the concept of city transformation that focusing on integrated transportation and land use. A novel concept of TOD is creating diversity land use in a regional area with medium to high density, so the people inside able to fulfil their activities inside the area using non-motorized transportation, and if the activity is placed outside, the resident will use public transport. Many studies states about the TOD typology in one city to another, but there's a gap to categorize many areas within the same city.

For implementation in Indonesia, the DKI Jakarta Provincial Government (Pemprov) has issued three Governor Regulations (Pergub) related to the city design with the concept of Transit Oriented Development (TOD). The regulations for developing the TOD are contained in the Governor's Regulation No. 55 of 2020, the Governor's Regulation No. 56 of 2020, and the Governor's Regulation No. 57 of 2020 as an extension of the Governor's Regulation No. 15 of 2020. In the Governor Regulation, the DKI Jakarta Provincial Government determines some TOD development areas, namely, Blok M, Lebak Bulus, and Fatmawati.

Whenever we design a program, we have some goals to have better quality of living in it. TOD big goals are to create economic development and to increase the quality of life use increasing in transportation that able to directing the mobility of people and goods (Litman, 2007 and OECD, 2018). TOD concept is to design transportation and land use diversity.

A recent review of TOD typology, both, qualitative and quantitative approaches has been demonstrated for TOD typology classification, and node-place models are applied as the most common of TOD typology [23]. More, Su stated that a novel universal conceptual model is required whose theoretical structure and practical outputs are easy to interpret and visualize [23].

Many research place TOD as a beneficial option, as the solution better city planning and transformation the city with sustainability concept. The problem in many countries, both developed and developing countries is the restriction in TOD financing. Its good if there's a method that can recognize the potential value creation in an area, so the government able to design the policy to reach the TOD ideal and perhaps financing the TOD in that area into the TOD ideal.

This paper will see the TOD criteria from accessibility and land use. We will be dividing the accessibility into two parts, internal accessibility, and external accessibility. Internal accessibility will observe how the resident in catchment area use non-motorized transportation to reach the transit node. Also observe the activities that grow up as the effect of the new transit mode station. How the lifestyle of people mobility at the area and how the transit node grown up the economic scale and enrich the diversity function in the area.

If see the picture 2 below, TOD describe as a circle in some area with many function of building inside. TOD is a concept where a multifunctional building taken into one area with many diversities and density inside. So, there must be accessibility in one region between many deferent functions of building.

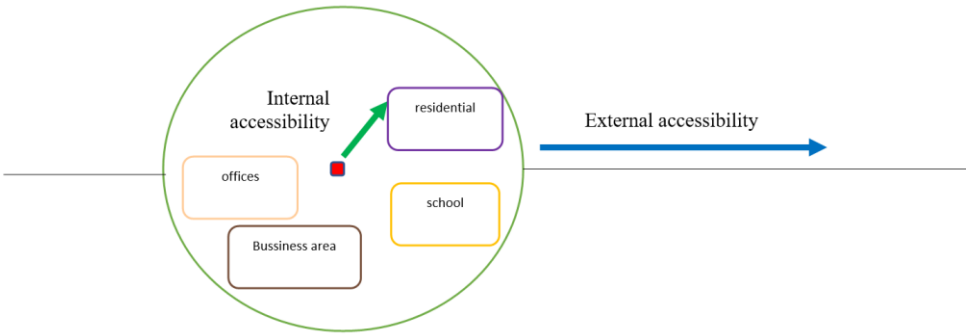

Fig. 2. Accessibility in TOD consist of external and internal accessibility.

The paper is arranged as follows: Section 2 reviews the previous literature, Section 3 is Methodology with TOD criteria inside and TOD Index measurement with Min-Max method which taken the case study in three different locations as study area, section 4 is the Results and Conclusion.

2 Literature Review

The previous literature on comprehensive assessments of TOD strategies (Arrington and Cervero, 2008; Renne, 2007); and on specific TOD impacts, such as on property values (Bowes and Ihlanfeldt, 2001; Duncan, 2011; Mathur and Ferrell, 2013) or relocation of work and residence (Cervero and Landis, 1997; Pagliara and Papa, 2011) [21] but mostly interest related to analyzing the impact of TOD on travel behavior (Cervero et al., 2002). However, none of these studies provides direct insight into the relationship between TOD with accessibility and land use.

The extent to which urban and transit network structures allow individuals to participate in activities and acquire spatially distributed resources (Geurs and van Wee, 2004; Handy, 1992; Handy and Niemeier, 1997).

3 Methodology

TOD typologies under different transport modes, such as bus rapid transit (BRT), subway, railways and combination has been studied in prior study (Case et al., 2019; Chorus and Bertolini, 2011; Kamruzaman et al., 2014; Kumar et al., 2020; Li et al., 2019; Lyu et al., 2016; Monajem and Nosratian, 2015; Nasri and Zhang, 2014; Reusser et al., 2008; Li et al., 2019; Lyu et al., 2016; Zhang et al., 2019; Vale et al., 2018) [4 & 24].

Models, such as the node-place model by (Bertolini, 1999) [21], and the Butterfly model by (Delta Metropolis Association, 2014), suggested that node should be in balance with the place for all station areas. Based on that suggestion, various stations were created depending on that balance and stations were slotted into the 'best-fitting' type.

Renne (2007) recommended two approaches : the Regional Performance Approach (RPA) and Community Performance Approach (CPA). While RPA includes comparison between two or more TODs; TOD and non-TOD; TODs and regional averages, CPA is a monitoring system specific to community that can be created to track TOD indicators towards achieving the local goals [24].

Reviewing the research of (Su et al., 2021), the TOD typology is carried out based on the criteria of node, place and functionality [23]. From the three criteria above, the TOD typology will be classified, which based on this study there are 27 typologies [23]. After that, the identification of value creation and the most appropriate strategy based on the existing TOD typology were carried out. Evans & Pratt (2007) proposed TOD index as a potential device for considering the degree to which the project is intrinsically oriented towards transit.

3.1 Focus and Discussion

The index can measure multidimensional aspects that cannot be captured by a single indicator. The index does not have units so that it can perform multi-criteria measurements that have different units (Dur et al, 2010).

For this research, the TOD index will be made in a structured manner, which is referred to as a factor for each research indicator. The index was chosen because it can measure multidimensional aspects that cannot be captured by a single indicator. The index does not have units so that it can perform multicriteria measurements that have different units (Dur et al, 2010). The index focuses on what is being measured not what indicators are available (OECD, 2008).

3.2 Indicator Selection

To identify the indicators, there are numbers of indicators proposed in the literature and as used in various TOD case studies (Curtis et al, 2009), (Lindau et al, 2010), (Balz & Schrijnen, 2009), (Bae, 2002), (Cascetta & Pagliara, 2009), (Yang & Lew, 2009), (Cervero & Murakami, 2009).

To determine the variables or research factors, previous research studies will be conducted. The variables for this study refer to previous researches related to the TOD typology, which have been widely studied by Higgins and Kanaroglou, 2016; Huang et al., 2018; Kumar et al., 2018; Li et al., 2019; Lyu et al., 2016; Song and Knaap, 2007; Vale et al., 2018, Singh (2015); Su et al. (2020); and Yang and Song (2021). (Su et al., 2021) (Singh, 2015) Taki et al (Re-Assessing TOD Index in Jakarta Metropolitan Region, 2017) took indicator from three criteria: Density, Economic and Diversity.

Sulistyaningrum & Sumabrata (2018) which studied about TOD Index at the current transit nodes in Depok City, applied 8 rules and 24 indicators from previous study (Singh YJ, 2015) [24] that consist of population density, mix-use land, access on foot and bicycle ride, economic development, capacity utilization transit, the user-friendly transit system, access and accessibility, and parking at the station.

The research criteria will be determined from literatures review where there are still gaps from previous studies where internal accessibility has not been widely used as an important element in determining the TOD index. For this research, the criteria consist of external accessibility, internal accessibility, and land use.

Table 1. Transit Oriented Development Criteria.

Criteria	Factor
External Accessibility	Capacity
Internal Accessibility	Distance to transit, pedestrian infrastructure, first and last mile connectivity, bicycle and micro mobility infrastructure and on demand micro transit
Landuse	Density, Diversity, FAR

The concept of the TOD index that will be calculated in this study is carried out based on the criteria of external accessibility, internal accessibility, and land use. The TOD index formula is as follows:

$$TOD\ Index = \sum\{f_1(external\ accessibility), f_2(internal\ accessibility), f_3(landuse)\} \quad (1)$$

Multi-criteria analysis to assess the development of the TOD index is conducted based on indicators of external accessibility, internal accessibility, and land use.For the variables that will be added in this study, previous researcher had not conduct variables from internal accessibility yet, namely those related to pedestrian infrastructure, first and last mile connectivity, bicycle and micro mobility infrastructure and on demand micro transit (ojek or angkot). The variables then adjusted to the conditions of external accessibility criteria, internal accessibility and land use.

3.3 Minimum Maximum Method

Determination of indicators consisting of external accessibility, internal accessibility and land use carried out a literature study and preliminary survey. Then, sub-factor evaluation was carried out with Minimum-Maximum analysis to build factors & sub-factors based on secondary data.

The Min-Max method is required to perform the procedure for normalizing the indicators so that they have a similar range (0 and 10) by subtracting the minimum value and dividing it by the distance from the indicator value. The Min-Max formula is as follows:

$$I_N^+ = \frac{I^+ - I_{min}^+}{I_{max}^+ - I_{min}^+} \quad (2)$$

$$I_N^- = \frac{I^- - I_{min}^-}{I_{max}^- - I_{min}^-} \quad (3)$$

where:

I_N = normalized indicator

+ = positive indicator

- = negative indicator

I = the initial value of the indicator before normalization

I_{max} = maximum indicator value

I_{min} = minimum indicator value

The minimum and maximum standards for each sub-factor are made based on applicable standards or regulations as well as previous research data. Multi-criteria analysis is needed because each research sub-factor has units and standards that are different from one another.

Determination of the TOD index will be proposed in this study, by providing an assessment for each research sub-factor which is included in the indicators of external accessibility, internal accessibility, and land use. The calculation of the assessment is as follows start by search the minimum and maximum value for each sub factor, the reference comes from the standards that usually used or from the secondary data. There are several standards from the literature regarding the assessment of each sub-factor.

Then prepare and give categorization for each sub factor which will be assessed with scoring range for each sub variable, where the score will vary from 0 to 10. This needs to be done so that the assessment process can be carried out to assess sub-variables with different units into the same unit assessment.

The calculation in case study area for this research, the reference center will be the transit node (Lebak Bulus MRT station, Dukuh Atas MRT station and Kelapa Gading LRT station), then focus on a circular area with a radius of 800 meters from the transit node as a center. The characteristics for these three areas are very different, where Dukuh Atas represent the city center with offices around, Lebak Bulus is a gate to enter Jakarta from sub urban area with residential as majority, and Kelapa Gading is residential area in the city center.

The location of the study is as follows:

Fig. 3. Maps of Three Study Areas

First, in each area there will be a center of the transit node taken as the center of the circle with 800 meters radii. Then there will be an identification into eight categories of land use in each area then measuring index TOD-ness in the area.

Lebak Bulus Condition:

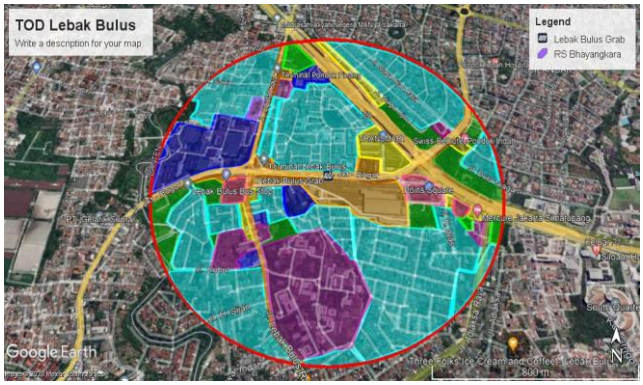

Fig. 4. Index measurement in Lebak Bulus

The categories of land use are as follow:

a. Transit node: MRT Station, BRT (Transjakarta) station, Lebak Bulus station.

b. Residential: Land use rumah tapak (Lebak Lestari Indah, Pondok Pinang, Cireundeu Permai, Niaga Hijau Pondok Indah & apartemen (Poins Square, Rusun Pasar Jumat)

c. Hotel: Mercure, Swiss Bell Pondok Indah, Swiss Bellin Simatupang

d. Schools: PTIQ, MAN 4 Jkt, SMK Grafika Yayasan Lektur, SMA Bakti Mulia 400

e. Hospital: Bhayangkara Hospital

f. Business & industry: Carrefour Lebak bulus

g. Offices: Balai Teknik Bendungan Kemen PUPR, Plaza Simatupang, BCA Finance Pondok Indah

<u>Dukuh Atas Condition:</u>

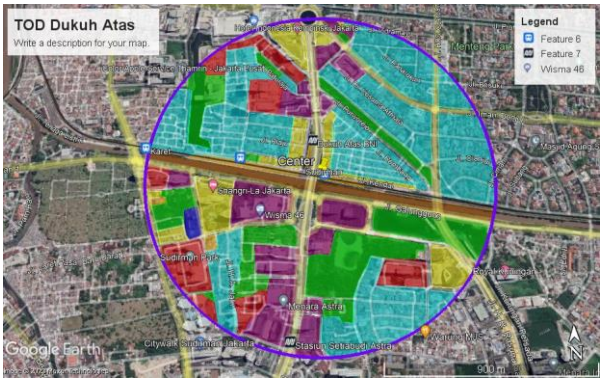

Fig. 5. Index measurement in Dukuh Atas

The categories of land use are as follow:

a. Transit node: MRT-KRL-Rattangga station, BRT (Transjakarta) station
b. Residential: land use (Karet Tengsin, Dukuh Atas Menteng) & apartment (Thamrin Residence, Casa Domain, Pavilion, Sudirman Park, Andamaya Residence)
c. Hotel: Shangrila, Kempinski, Mandarin Oriental Jkt
d. Schools: SMKN 38 Jkt
e. Business & industry: Grand Indonesia, Plaza Indonesia
f. Offices: Grha BNI, Wisma 46, Landmark Building, Wisma Indocement, Menara Taspen, UOB, Grha Mandiri, Wisma KEIAI

Kelapa Gading Condition:

Fig. 6. Index measurement in Kelapa Gading

The categories of land use are as follow:

a. Transit node: LRT Jakarta (Kelapa Gading-Velodrome) Station
b. Residential: land use (Kompleks Kelapa Gading, Gading Harmony)
c. Business & industry: The Kensington Commercial, some integrated shop and house in Kelapa Gading Boulevard
d. Offices: Perum Bulog Kanwil DKI Jakarta dan Banten
e. Public facilities: GOR Badminton Bulog Jakarta

Each area will be given an assessment for each sub-factor and then given a total score. After that, it is classified based on the TOD index range above. For the capacity factor assessment criteria (external accessibility criteria), the sum of each type of transportation means along with the suggested headway at the transit node. After measuring min – max method and do the normalization process, the data are as follows:

Table 2. Measurement Results for Three Locations

Criteria	Factor	Sub Factor	Unit	Indicator Score		
				Lebak Bulus	Dukuh Atas	Kelapa Gading
External Accessibility	Publik transport capacity (Sit & stand)	Multimodes	passenger / hour	0.762	1.000	0
Internal Accessibility	Distance to transit	Average route distance from station to residential quarters	meter	0	0.000	0.6
		Average route distance from station to work places	meter	0.000	0.543	1.000
		Average route distance from station to hotels	meter	0.778	0.000	0.000
		Average route distance from station to health facilities	meter	0.000	0.000	0.000
		Average route distance from station to educational facilitie	meter	0.000	0.000	0.000
		Average route distance from station to shopping center	meter	0.733	0.867	0.900
	Pedestrian infrastructure	Proportion of pedestrian area to catchment area	%	0.015	0.033	0.022
		Physical obstacles in pedestrian lane	unit / 100 meter	0.35	0.25	0.25
		Wayfinding in pedestrian lane	unit / 200 meter	0.1	0.15	0.1
	First & last mile connectivity	bikesharing	unit	0.000	0.087	0.000
		shuttle service (sag)	unit	0.000	0.500	0.000
	Bicycle and micromobility infrastructure	Proportion of bicycle lane to catchment area	%	0.000	0.002	0.000
		Bicycle lane safety	/km^2	0	0.3	0
		Bicycle lane convenience	/km^2	0	0.5	0
		Proportion of bicycle parking area to catchment area	%	0.000	0.000	0.000
	On demand microtransit	motorbike as public transport *(ojek)*	Unit/hour	0.25	1	0.25
		public transport *(angkot)*	Unit/hour	1	0.3	0
Land use	Density	Population density	People/km^2	0.000	1.000	0.434
		Job density	Employee/km^2	0.000	0.115	0.000
	Keberagaman tata guna lahan	Proportion of residential area	Ratio to catchment area	0.346	0.299	0.650
		Proportion of public offices area	Ratio to catchment area	0.000	0.284	0.100
		Proportion of industrial area	Ratio to catchment area	0.079	0.123	0.200
		Proportion of educational facilities	Ratio to catchment area	0	0	0
		Proportion of health facilities	Ratio to catchment area	0	0	0
		Proportion of public facilities area	Ratio to catchment area	0.0874	0.0348	0.05
		Proportion of mixed used area	Ratio to catchment area	0.446	0.0288	0
		Proportion of green open space area	Ratio to catchment area	0.042	0.0917	0
	Floor Area Ratio	Floor to land area ratio	-	0.556	1.000	0.333
			Total Score	**5.544**	**8.507**	**4.889**
			Rank	2	1	3

4 Results

The index can measure multidimensional aspects based on the characteristics or typical potential of an area. By calculating the index based on the design criteria above and using the minimum maximum method, it will be possible to determine the level of suitability of an area to the ideal TOD criteria with the main indicators of external accessibility, internal accessibility (first & last mile travel) and land use.

The index in Dukuh Atas TOD is 8.507 which mean the TOD level in Dukuh Atas about 0.85 to TOD ideal categories. After this the second rank is Lebak Bulus with score 5.544 which means so far the accessibility of many public transport in Lebak Bulus taken this area have level 0.55 into TOD ideal categories. And last Kelapa Gading which has LRT station, has the lowest score 4.889 which means has 0.48 into TOD ideal.

5 Conclusion

The ranking applies where the area with a higher index means it has the highest level of conformity to the TOD criteria. In this case Dukuh Atas has the most score which means most criteria has been fulfil by Dukuh Atas, it has been proven that good accessibility in the transit node area (both internal and external) will increase the area suitable with TOD ideal.

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