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Re-Assessing TOD index in Jakarta Metropolitan Region (JMR)

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Abstract

Transit Oriented Development (TOD) is believed to be able to overcome the issues of urban transport. However, in practice, the current TOD in Jakarta Metropolitan Region (JMR) is still a deficiency in accommodating the needs of transportation movement and not in facilitating services in terms of TOD function. The objective of this paper was to re-assess the service quality of actual TOD in 54 commuter railway stations. The paper performed criteria-indicators and measured a composite TOD index by using Analytical Hierarchy Process (AHP)-multicriteria model, statistics test, and Geographical Information System (GIS) application. TOD index was found that urban areas have a high TOD index. On the other hand, the suburban areas have a low TOD-index. The statistical test showed that there was a strong correlation between different criteria. This paper concluded that most of the stations which were located in the suburban area had a low index thus need improvement. Consequently, the station areas needed to have a policy relevance.

Keywords: Re-Assessing, Transit Oriented Development (TOD), TOD index, Geographical Information System (GIS), Analytical Hierarchy Process (AHP), Jakarta Metropolitan Region (JMR).

1. Introduction

Dynamics discourse of modern cities has occurred in many countries in the world where the dispute discuss the comparison which is better between the city of car-based and public-based (Blumenauer, 2002; Miller *et al.,* 2016; United Nation, 2005). In the various paradigms, that gave rise to different periods in the pattern of the relationship between the city and transit activities (Olaru *et al.,* 2011).

The problem of a metropolitan region in many countries like Jakarta Metropolitan Region (JMR) is the occurrence of a vigorous migration between urban and suburban areas where it is known by the phenomenon of urban sprawl (Sunarto, 2009). Transportation is sometimes not able to support this condition with an optimal service. One example is the station where its function becomes less able to accommodate the needs of the population movement as well as it has not been in accordance with the policy action (Marshall, 2013). Thus, it is needed a reassessment of station function to accommodate the mobility of a population between regions through the provision of the mass public transport services in transit nodes (Fard, 2013).

This can be done by applying the concept of Transit Oriented Development (TOD). According to (Feudo, 2014), TOD emerged not in spite of historical development patterns of the metropolitan region consists of urban, suburban and connection with public transportation such as trains or buses.

TOD was introduced in America in the late 19th century in which mode of transportation serving the growth pole; (Cervero *et al.,* 2002; Evans & Pratt, 2007; Jarboui., 2012). This phase marked the existence of a separate settlement zone patterns of work zones linked by mass transportation with the facilities such as stations, rail and modes made to cater to each zone (Arrington & Cervero, 2008; Olaru *et al.,* 2011; Loo *et al.,* 2010; Nasri & Zhang, 2014; Kwon, 2015).

The zoning area between urban and suburban development process happens where land use and transportation in particular relic transit zoning has been motivating this paper to reassess TOD uses the multicriteria evaluation (Malczewski, 2006). Thus, Singh (2015) noted that assessing TOD becomes important because it is expected to improve the TOD level of success.

The main objective of this research is to provide an alternative solution to the problem of the growth of the metropolitan region that tends to develop towards auto pattern oriented by encouraging residents to use the facilities of public transport rather than private cars (Taki *et al.,* 2017). Thus, it can solve problems sprawling (Renne & Wells, 2005)

Previous TOD research for JMR has been conducted by H. S. Hasibuan *et al.,* (2014) by assessing the most potential stations for TOD using the analysis of land uses proportion around transit stations. Nevertheless, the assessment is still general. therefore, this study enhanced previous research by reassessing TOD using index accompanied by more complete criteria and indicator generated from the experts based on the study of Singh *et al.,* (2014). This paper began with an introduction, the literature reviewed relating to composite TOD index later explanation of how to reassess it based on the existing condition. The next part contained information of the study area, details about data and methods, and the results of each. This paper concluded with a discussion of the main findings of research and implications.

1.1. The case of Jakarta Metropolitan Region (JMR)

This study examined the commuter railway transportation system in the metropolitan region of Jakarta. The layout of Jakarta according to the study of (H. Hasibuan & Soemardi, 2014) is a strategic because of Jakarta is not only the capital city of Indonesia but also it is a planned region for the adopted concept of TOD.

The JMR cover urban and suburban area, they are Jakarta City, Bogor City, Depok City, Tangerang City and Bekasi City (Figure 1). It is known as *Jabodetabek*, it has a network of commuter rail serving residents to travel from the suburbs to the urban (city centre) and vice versa.

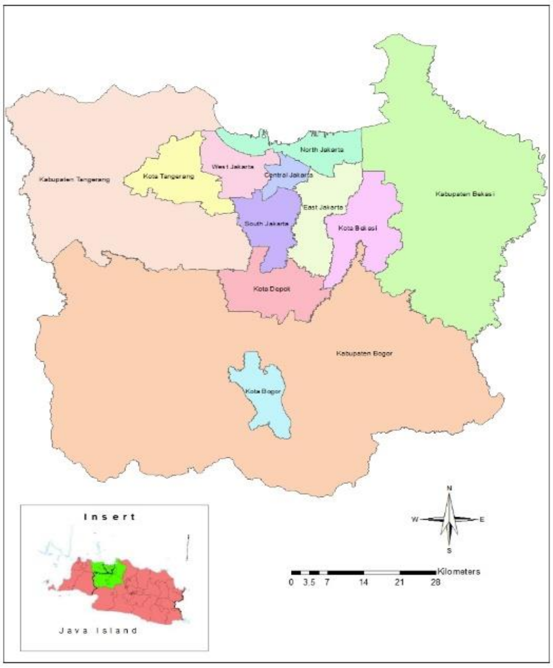


Fig. 1. Administrative boundaries of study area

The railways of transport modes being the most used daily by residents of Jakarta metropolitan region because of the economically efficient and effective in time. The commuter rail from Jakarta capital city has 4 corridors, i.e. a Bekasi Corridor (East), Bogor (South), Serpong (Southwest), and Tangerang (West) with the number of stations as much as 54 units. The main stations are Tanah Abang, Manggarai, Jatinegara, Pasar Senen, Gambir and Jakarta Kota. The condition of the station at picking and outpacing capacity by passengers. The following figure is the overall location of the stations along with the rail network which is the study area of this research.

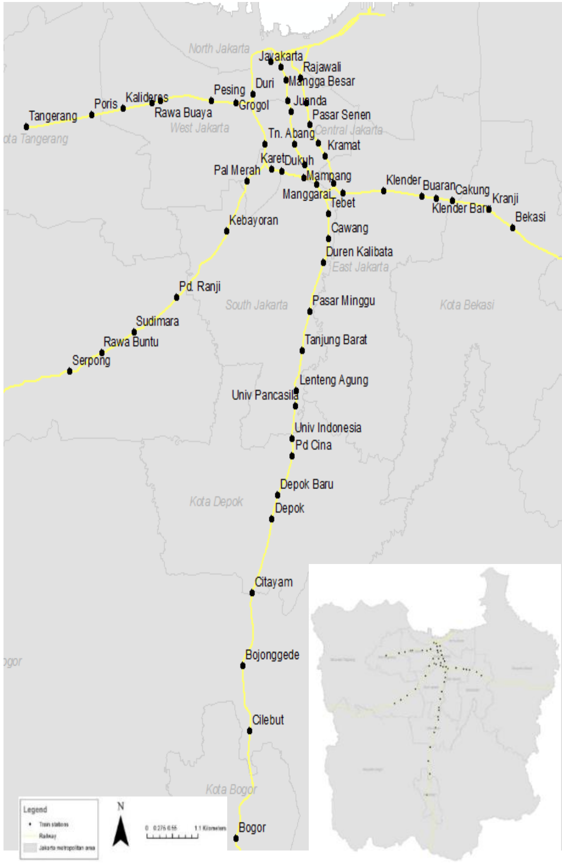


Fig. 2. The commuter rail route of JMR

2. Materials and Methods

2.1 Data collection

Required data is a variety of spatial as well as non-spatial data. The required data was collected from the ministry and agency. Administrative boundaries, railway network, station locations, land use data were all available as spatial data layers in vector format.

Table 1. Data types, year and sources.

No	Type	Year	Source
1	Shapefile of administrative boundaries of JMR (Jabodetabek)	2015	Geospatial Information Agency
2	Shapefile of land use type (residential, commercial, open space, parking area)	2014	Geospatial Information Agency
3	Railway network GIS shapefile	2015	Ministry of Transport
4	Railway station location	2015	Ministry of Transport

5	Indonesian census of population	2015	Central Bureau of Statistics Republic of Indonesia
6	Hospitals location	2014	Consultant project archive
7	Schools location	2014	Consultant project archive
8	Building Coverage Ratio (BCR)	2011	Corporation project document
9	Floor Area Ratio (FAR)	2011	Corporation project document

2.2 Chosen criteria

Chosen criteria of TOD based on the 3-D major concept of TOD consisting of Density (development), Diversity (mixing land uses) and Design (pedestrian-friendly) (Cervero & Kockelman, 1997). Economic development criteria is also an important part of the TOD concept as in the study (Fard, 2013). At that point, this study makes this concept as a measurement and the basis for selection of criteria and indicators.

Density, Higgins & Kanaroglou (2016) noted density as describing how the interactions that occur within the station area which it has two meanings, namely the ability to transact internally travel in stations such as walking, bicycles and the second is the ability to travel into a transit network system. The indicators used in this criterion are a mixed-ness for residential, open space, parking area, and a density for residential, commercial, school and hospital.

Diversity or a diversity index is a quantitative measure that informs the number of specific types (in terms of land use i.e. certain types of land use such as residential, commercial, etc.) and can also be useful to illustrate how evenly certain types of land use are distributed among the other types (Higgins & Kanaroglou, 2016). There are various kinds of diversity calculation, especially in calculating land use diversity. There are two popular indexes used: Simpson index and Shannon Index. In this study using the Simpson index to calculate the proportion of certain primary land use in each area around the station.

Economic referred to this study that is the current degree of economic performance in the station area. The measurements of these criteria are calculated in diverse sizes, such as numbers of jobs (Atkinson *et al.,* 2011), the percentage of employment (Prasertsubpakij & Nitivattananon, 2012), the number of business establishments (Fard, 2013). In the analysis of this paper, we use population density, the ratio of Building Coverage Ratio (BCR) and Floor Area Ratio (FAR).

2.3 Description of indicators

The indicators of TOD are selected from previous research by looking at the trend of a growing research (Sung & Oh, 2011; Mu & de Jong, 2012; Binglei & Chuan, 2013; Singh, 2015; Higgins & Kanaroglou, 2016) hence generated the selected criteria as in Table 2 below.

Table 2. The selected criteria and indicators from previous studies.

No	Criteria	Indicators	Sung & Oh (2011)	Mu & Jong (2012)	Binglei & Chuan (2013)	Kamruzzaman & Baker (2014)	Singh (2015)	Higgins & Kanaroglou (2016)	This study (2017)
I	Density	Commercial density	x	x		x	x	x	x
		Residential mix	x	x	x	x	x	x	x
		Parking area mix		x	x		x		x
		School density		x		x			x
		Open space mix		x	x	x			x
		Hospital density		x					x
II	Economic	Population density			x	x	x	x	x
		Floor Area Ratio (FAR)			x				x
		Building Coverage Ratio (BCR)	x			x			x
III	Diversity	Land use diversity	x	x		x	x	x	x
		Case study	Seoul, Korea	Dalian, China	Pennsylvania United States	Brisbane, Australia	Arnhem and Nijmegen, Netherlands	Toronto, Canada	Jakarta, Indonesia

Residential mix, land use diversity, commercial and population density indicators are most commonly used in TOD research. Explanation of each indicator from the above Table 2 is as described in the following description.

(1). Population density.
Data of population density (inhabitants/sqkm) from Statistics Indonesia in 2015 (http://data.jakarta.go.id/, 2016)

(2). Commercial, school and hospital density.
It is calculated using GIS by adopting formula from Nasri & Zhang (2014)

D_C = Commercial or building area / the total area (sqkm) (1)

(3). Residential, open space and parking area mix.
Measuring all of this indicators with the following formula, as adapted from Zhang & Guidon (2008):

$$MI(i) = \frac{\sum_{\cap i} S_c}{\sum_{\cap i}(S_c + S_r)} \quad \forall i \tag{2}$$

MI(*i*) means the 'Mixed-ness Index', *Sr* shows the sum of total area under residential land use within *i*, *Sc* is the sum of the total area non-residential urban land uses.

(4). Land use diversity.
The concept of diversity is derived from the Simpson index and Kamruzzaman & Baker (2014) used land use diversity in their research related to TOD with a formula:

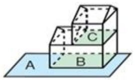
Land use diversity = $1 - \sum (a/A)^2$ (3)

Where a is the total area of a specific land use category (e.g. commercial) within the buffer of a TOD, and A is the total area of all land use categories within the buffer.

(5). Building Coverage Ratio (BCR)
Land use zones restrict the use of buildings in each categorised zone; BCR controls the volume of buildings in each zone. The ratio of the building area divided by the land (site) area. Building area means the floor space of a building when looking down at it from the sky. In this study, there are some categories of BCR such as (20 - 40) %, (41 - 60) %, (61 - 80) %, < 20%, and > 80%. For this study, the category of (61 - 80) % is taken because the building conditions in there are so dense that the building area almost covers the total area of available land. Another category, < 20% is identified as nonresidential area, > 80% is slum area.

●Building Coverage Ratio (BCR)

$$BCR(\%) = \frac{\text{building area (B)}}{\text{site area (A)}} \times 100$$

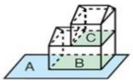


(6.) Floor Area Ration (FAR).

FAR controls the height of buildings in each zone (Binglei & Chuan, 2013). The ratio of total floor area divided by land (site) area. Total floor area means the total of all the floor space in a building. The data of FAR in this study are divided into 4 categories, those are the 1st, 2nd, 3rd and 4th floor. This research will take the area above > 1 with the explanation that shows the 1st floor is the normal house, 2nd floor is the flat house, 3rd floor is the maximum floor, and 4th is the basement.

●Floor-Area Ratio (FAR)

$$FAR(\%) = \frac{\text{total floor area (B+C)}}{\text{site area (A)}} \times 100$$



2.4 Station area analysis

The TOD area is the area of influence of the railway station in its urban and suburban context, which is different on metropolitan and city scale. To include influences from a higher scale on the city scale station areas the railway route is examined on the regional or metropolitan scale, the scale of the whole railway, as an activity corridor, an activity centre, and a transport corridor. At this scale, the influence radius of 800 meters around each station of the railway is used to understand the structure of the line as a whole. Within this radius, important networks and issues can be recognised that are influencing the direct surroundings of the station in an 800-meter radius.

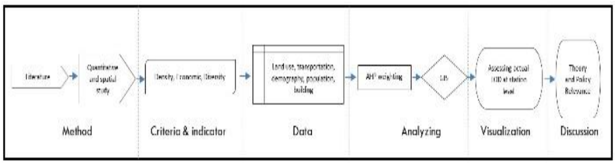
The TOD area is the walkable area around transit stations, an area of 800-meter radius from the station, called the station area. Within this radius urban transformations have a direct influence on the use of the train and the direct station areas as activity centres. Some of these station areas have better chances and more opportunities to develop, because of their well-accessible location and already existing attractions.

Fig. 3. Area analysis of railway stations within an 800-meter radius (by author)

2.5 Methodological framework in research

The method of this paper followed the study of Singh *et al.,* (2017) and was described in Figure 4 below as the analytical framework for reassessing actual TOD and analyzing the development of metropolitan region along railway network in urban and suburban areas.

Fig. 4. Illustrated cognitive map of our analytical framework in research.



2.6 Weights calculation using Analytic Hierarchy Process (AHP)

The calculation of weights with techniques of analytic hierarchy process (AHP) is done by running the paired comparisons of some expert in their field, the expert provides expertise in accordance with the assessment against criteria and indicators are proposed on a Saaty scale (Bunruamkaew & Murayam, 2011).

This technique assesses the relative significance of the proposed criteria and indicator by assigning weight to those criteria and indicators according to the priority in the form of a hierarchical order.

To maintain the credibility of the relative significance, AHP provides a way to determine the inconsistency of judgments in the form of mathematical equations according to the formula below.

$$c_r = \frac{c_i}{r_i} \quad (4)$$

Where c_r is the consistency ratio, c_i shows the consistency index, r_i is random index

The consistency index (c_i) is derived using the following formula:

$$c_i = \frac{\lambda max - n}{n - 1} \quad (5)$$

λmax means the maximum value of eigenvector and n is the criteria or indicator number.

Further information from Saaty (1990) with respect to the above formula is that the consistency level is quite acceptable if c_r is less than 10% (0.1), and vice versa, there is inconsistency in the evaluation process if c_r is greater than 10% (0.1), this means the results of AHP calculations do not produce results which mean.

3. Result

3.1 AHP weighting

The calculation of weights with the analytic hierarchy process (AHP) is performed by running the paired comparisons of 12 experts in their field, such as professional (urban planners, policy-makers, researchers, etc.) and work experience which they have worked on the project of TOD. The following table is the results of the weights calculation.

Table 3. The weight of criteria from 12 experts.

Criteria	Experts												SUM	Weighting	Ranking
	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12			
Land Use Density	0.49	0.33	0.49	0.62	0.60	0.59	0.59	0.59	0.60	0.60	0.60	0.06	6.17	**0.51**	1
Economic Performance	0.21	0.26	0.31	0.22	0.17	0.28	0.28	0.28	0.30	0.30	0.30	0.29	3.20	**0.27**	2
Land Use Diversity	0.30	0.41	0.20	0.16	0.23	0.13	0.13	0.13	0.10	0.10	0.10	0.65	2.63	**0.22**	3
inconsistency	*0.03*	*0.05*	*0.05*	*0.09*	*0.08*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.07*			
Consistency Index (c_i) =	*0.02*	*0.03*	*0.03*	*0.05*	*0.05*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.04*			
Random Index (r_i) =	*0.58*	*0.58*	*0.58*	*0.58*	*0.58*	*0.58*	*0.58*	*0.58*	*0.58*	*0.58*	*0.58*	*0.58*			
Consistency Ratio (c_r) =	*0.03*	*0.05*	*0.05*	*0.09*	*0.08*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.07*			

Table 4. Calculation of weight for the indicator

No	Criteria	Weight	Indicator	Experts												SUM	Weight	Ranking
				E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12			
I	**Land Use Density**	**0.51**	Commercial density	0.23	0.18	0.29	0.41	0.32	0.43	0.43	0.43	0.29	0.29	0.29	0.29	3.84	**0.32**	1
			Residential mix	0.39	0.46	0.14	0.30	0.19	0.22	0.22	0.22	0.32	0.32	0.32	0.14	3.24	**0.27**	2
			Parking area mix	0.10	0.09	0.22	0.11	0.18	0.09	0.09	0.09	0.07	0.07	0.07	0.32	1.51	**0.13**	3
			School density	0.09	0.10	0.12	0.05	0.11	0.14	0.14	0.14	0.14	0.14	0.14	0.10	1.41	**0.12**	4
			Open space mix	0.12	0.12	0.14	0.09	0.11	0.05	0.05	0.05	0.08	0.08	0.08	0.08	1.05	**0.09**	5
			Hospital density	0.06	0.05	0.09	0.05	0.09	0.08	0.08	0.08	0.10	0.10	0.10	0.07	0.95	**0.08**	6
			inconsistency	*0.08*	*0.07*	*0.03*	*0.08*	*0.09*	*0.01*	*0.01*	*0.01*	*0.00*	*0.00*	*0.00*	*0.00*			
II	**Economic Performance**	**0.27**	Population density	0.68	0.54	0.11	0.07	0.07	0.65	0.65	0.65	0.60	0.60	0.60	0.60	5.81	**0.48**	1
			Floor Area Ratio (FAR)	0.13	0.16	0.54	0.58	0.57	0.23	0.23	0.23	0.30	0.30	0.30	0.10	3.68	**0.31**	2
			Building Coverage Ratio (BCR)	0.19	0.30	0.35	0.35	0.36	0.12	0.12	0.12	0.10	0.10	0.10	0.30	2.51	**0.21**	3
			inconsistency	*0.08*	*0.01*	*0.05*	*0.03*	*0.05*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*			
III	**Land Use Diversity**	**0.22**	Land use diversity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	12.00	**1.00**	1

The result of weight calculation for criteria and indicator in the table above shows the consistency ratio for all the pairwise comparison already proven consistent because of the value of $c_r < 0.1$.

3.2 Standardisation of criteria-indicator using Min-Max method

There is a difference in the unit of calculation for an indicator of population density, school density, and hospital density, therefore, the standardisation of indicator unit is carried out using the Maximum - Minimum (Max - Min) method (BPS, 2010). This method means that linearly transforms real data values that the minimum and the maximum of the transformed data take certain values - frequently 0 and 1. The formula is:

$$I = \frac{X - X_{min}}{X_{max} - X_{min}} \times 100 \qquad (6)$$

Where:

X_{min} = Value of minimum target,

X_{max} = Value of maximum target.

3.3 The composite of actual TOD index calculation

The composite TOD index calculation using the following formula (Anane *et al.,* 2012).

$$R_i = \sum_k W_k r_{ik} \qquad (7)$$

Where the composite TOD index (R_i) for each station area (i), W_k is the multiplication result of the weights of all indicator or criterion and r_{ik} the standardized value of station area in the map of the indicator or criterion k.

3.4 Actual TOD index ranking

The actual TOD index for 54 stations in the JMR as in Table 5 contains the difference values of criteria and indicator. Based on this data, Indonesian University station has the lowest index 0.27 and the Duri station has the highest index 0.58.

Table 5. Actual TOD index for all 54 stations

Criteria	Density							Economic				Diversity	TOD Index
Weight	0.51							0.27				0.22	
Station	Commercial	Residential	School	Parking	Open space	Hospital	**Density index**	Population	FAR	BCR	**Economic index**	**Diversity index**	
Weight	0.32	0.27	0.13	0.12	0.09	0.08		0.48	0.31	0.21		1	
Univ Indonesia	0.01	0.35	0.00	0.05	0.36	0.13	0.15	0.05	0.30	0.51	0.22	0.62	0.27
Pd Cina	0.13	0.37	0.00	0.08	0.09	0.13	0.17	0.05	0.55	0.54	0.31	0.46	0.27
Poris	0.01	0.46	0.00	0.04	0.34	0.00	0.16	0.24	0.31	0.52	0.32	0.46	0.27
Rawa Buntu	0.05	0.79	0.00	0.05	0.15	0.00	0.25	0.10	0.38	0.60	0.29	0.38	0.29
Sudimara	0.01	0.91	0.05	0.05	0.08	0.00	0.27	0.19	0.22	0.75	0.32	0.38	0.31
Cilebut	0.01	0.76	0.00	0.04	0.23	0.00	0.23	0.17	0.77	0.30	0.38	0.38	0.31
Depok	0.01	0.87	0.05	0.05	0.12	0.32	0.29	0.17	0.06	0.78	0.26	0.46	0.32
Pd. Ranji	0.05	0.77	0.11	0.05	0.18	0.00	0.26	0.30	0.41	0.58	0.39	0.38	0.32
Bekasi	0.04	0.76	0.14	0.05	0.18	0.00	0.26	0.10	0.60	0.40	0.32	0.54	0.33
Bojonggede	0.01	0.99	0.03	0.05	0.01	0.00	0.28	0.32	0.99	0.33	0.53	0.23	0.34
Kranji	0.05	0.85	0.00	0.05	0.08	0.00	0.26	0.39	0.17	0.75	0.39	0.46	0.34
Citayam	0.01	0.86	0.00	0.04	0.14	0.00	0.25	0.19	0.84	0.29	0.42	0.46	0.34
Serpong	0.01	0.87	0.21	0.04	0.12	0.16	0.29	0.22	0.88	0.31	0.44	0.38	0.35
Univ Pancasila	0.06	0.63	0.11	0.06	0.16	0.00	0.22	0.12	0.45	0.56	0.32	0.77	0.37
Pal Merah	0.19	0.33	0.03	0.09	0.30	0.12	0.20	0.00	0.49	0.42	0.24	0.92	0.37
Kalideres	0.01	0.62	0.03	0.06	0.08	0.08	0.20	0.18	0.54	0.59	0.38	0.77	0.37
Tanjung Barat	0.11	0.71	0.12	0.06	0.13	0.11	0.27	0.16	0.46	0.56	0.34	0.69	0.38
Cakung	0.04	0.78	0.10	0.06	0.10	0.00	0.25	0.21	0.20	0.72	0.31	0.77	0.38
Pasar Minggu	0.07	0.68	0.11	0.06	0.14	0.17	0.26	0.14	0.39	0.59	0.31	0.77	0.38
Juanda	0.33	0.13	0.26	0.11	0.19	0.23	0.22	0.11	0.72	0.32	0.34	0.85	0.39
Rawa Buaya	0.04	0.58	0.11	0.06	0.18	0.16	0.22	0.19	0.51	0.55	0.37	0.85	0.40
Klender Baru	0.05	0.78	0.08	0.06	0.06	0.00	0.25	0.36	0.44	0.65	0.45	0.69	0.40
Duren Kalibata	0.10	0.56	0.00	0.07	0.11	0.00	0.20	0.20	0.51	0.56	0.37	0.92	0.40
Bojong Indah	0.03	0.64	0.10	0.06	0.06	0.11	0.22	0.25	0.74	0.59	0.47	0.77	0.41
Depok Baru	0.13	0.66	0.05	0.06	0.18	0.32	0.27	0.17	0.37	0.52	0.31	0.85	0.41
Lenteng Agung	0.14	0.69	0.00	0.07	0.10	0.26	0.27	0.37	0.26	0.65	0.39	0.77	0.41
Kramat	0.15	0.59	0.15	0.08	0.06	0.33	0.27	0.30	0.41	0.61	0.40	0.77	0.41
Buaran	0.06	0.77	0.08	0.06	0.09	0.00	0.25	0.36	0.53	0.59	0.46	0.77	0.42
Jakarta Kota	0.55	0.20	0.20	0.12	0.07	0.00	0.28	0.19	0.73	0.24	0.37	0.85	0.43
Bogor	0.25	0.69	0.55	0.07	0.05	0.00	0.35	0.25	0.72	0.39	0.42	0.62	0.43
Jatinegara	0.19	0.60	0.11	0.08	0.08	0.00	0.25	0.41	0.34	0.60	0.43	0.85	0.43
Kebayoran	0.19	0.66	0.15	0.07	0.05	0.13	0.28	0.24	0.47	0.57	0.38	0.85	0.43
Karet	0.24	0.38	0.08	0.08	0.27	0.00	0.22	0.47	0.36	0.43	0.43	0.92	0.43
Sawah Besar	0.63	0.26	0.26	0.12	0.03	0.23	0.34	0.11	0.73	0.27	0.33	0.77	0.43
Tangerang	0.03	0.83	0.45	0.05	0.09	0.50	0.35	0.06	0.66	0.44	0.33	0.77	0.43
Pesing	0.26	0.51	0.19	0.08	0.13	0.00	0.27	0.30	0.75	0.38	0.46	0.85	0.45
Dukuh	0.38	0.37	0.35	0.08	0.21	0.88	0.36	0.17	0.63	0.30	0.34	0.77	0.45
Klender	0.15	0.65	0.19	0.07	0.05	0.29	0.28	0.39	0.35	0.64	0.43	0.85	0.45
Pasar Senen	0.32	0.46	0.34	0.09	0.06	1.00	0.37	0.14	0.58	0.46	0.35	0.77	0.45
Rajawali	0.31	0.49	0.20	0.08	0.09	0.22	0.29	0.21	0.62	0.42	0.38	0.92	0.46
Gondangdia	0.32	0.40	0.23	0.10	0.06	0.50	0.30	0.27	0.75	0.38	0.44	0.85	0.46
Mampang	0.12	0.70	0.35	0.07	0.09	0.88	0.36	0.17	0.75	0.47	0.41	0.77	0.46
Jayakarta	0.51	0.36	0.07	0.11	0.06	0.31	0.31	0.40	0.60	0.36	0.45	0.85	0.47
Pondok Jati	0.14	0.69	0.34	0.08	0.01	0.00	0.29	0.53	0.37	0.67	0.51	0.85	0.47
Tn. Abang	0.31	0.45	0.26	0.09	0.13	0.57	0.32	0.29	0.46	0.45	0.38	0.92	0.47
Manggarai	0.11	0.55	0.16	0.08	0.06	0.70	0.28	0.51	0.55	0.57	0.54	0.85	0.47
Cawang	0.14	0.63	0.08	0.07	0.12	0.00	0.25	0.48	0.52	0.53	0.50	1.00	0.48
Cikini	0.19	0.52	0.10	0.08	0.08	0.88	0.30	0.41	0.75	0.45	0.52	0.85	0.48
Grogol	0.21	0.53	0.19	0.07	0.13	0.28	0.28	0.36	0.86	0.35	0.51	0.92	0.48
Tebet	0.11	0.81	0.08	0.06	0.03	0.00	0.28	0.48	0.54	0.60	0.52	0.92	0.48
Kemayoran	0.33	0.47	0.05	0.09	0.06	0.00	0.25	0.70	0.50	0.49	0.60	0.92	0.49
Mangga Besar	0.50	0.37	0.00	0.10	0.03	0.00	0.27	1.00	0.60	0.39	0.75	0.77	0.51
Gang Sentiong	0.20	0.65	0.78	0.08	0.04	0.57	0.40	0.74	0.42	0.60	0.61	0.77	0.54
Duri	0.20	0.67	1.00	0.07	0.09	0.00	0.39	0.91	0.31	0.61	0.66	0.92	0.58

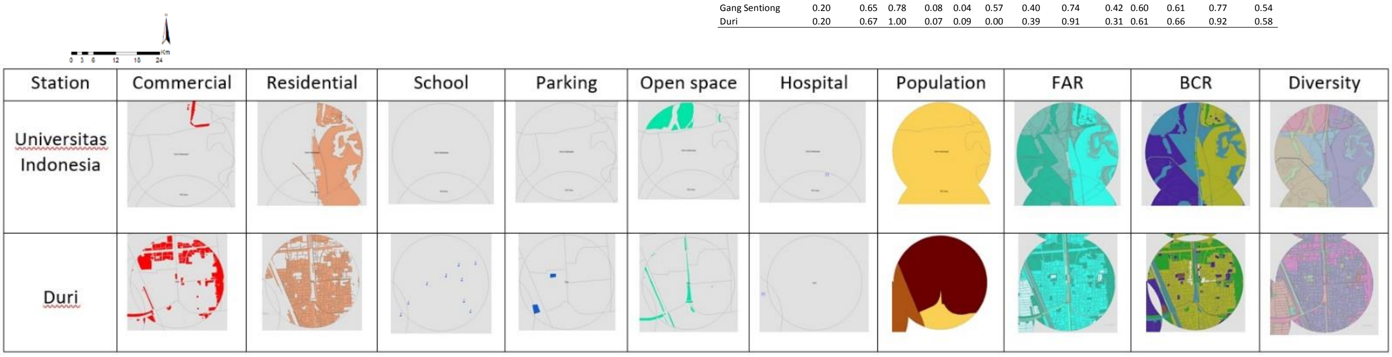


Fig. 5. Comparing the indicators with highest and least.

3.5 The composite TOD map

The result of the composite of actual TOD index is visualised into the map using GIS application. The used software is ArcGIS. This map shows the distribution of index spread per station and divided into 3 categories; (category 0.26-0.35), category (0.36-0.43) and category (0.44-0.58).

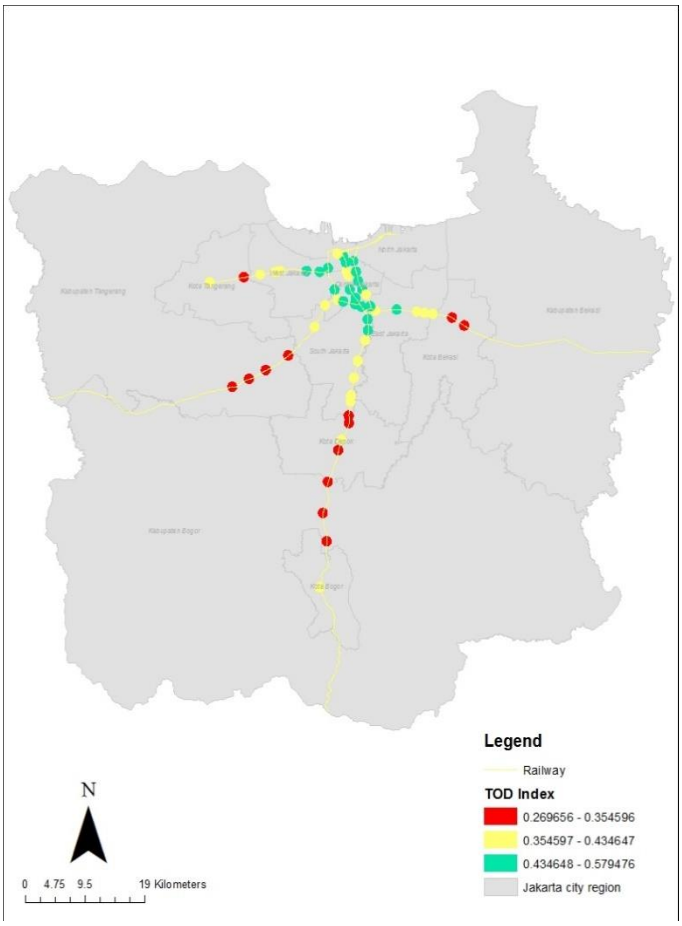


Fig. 6. The actual TOD index map

4. Discussion

4.1 Statistical analysis

Statistical analysis was performed to describe the distribution of the data and to find correlations between variables and find out whether there are significant differences between variable and corridors. The analysis is performed using descriptive statistics, and Pearson correlation method.

Table 5. Descriptive statistics of criteria

Criteria	Number of station	Minimum	Maximum	Mean	Std. Deviation
Density	54	0.15	0.40	0.27	0.05
Economic	54	0.22	0.75	0.39	0.10
Diversity	54	0.23	1.00	0.77	0.19
TOD Index	54	0.27	0.58	0.42	0.07

Based on the Table 5 above, the total number of stations is 54. The highest mean is found in the diversity 0.77 and the lowest mean of 0.27 in density indicator. The highest standard deviation is found in the criteria of diversity that is 0.19 and the lowest is found on the criteria of density 0.05.

Table 6. Pearson correlation amongst TOD criteria

TOD indicators	Density	Economic	Diversity
Density	-	.007**	.230
Economic		-	.051*
Diversity			-

** Correlation is significant at the 0.01 level (2-tailed).

Correlation amongst TOD criteria indicates there is a strong positive correlation between density and economic criterion with the value 0.07 also economic and diversity with the value 0.051. Correlation of density with diversity has a correlation that is not significant because it valued 0.230.

Table 7. Descriptive statistics of TOD index in corridors

Corridor	Number of station	Min	Max	Mean	Std. Deviation
Bekasi	13	0.33	0.54	0.2822	0.0470
Bogor	26	0.27	0.51	0.2686	0.0535
Serpong	7	0.29	0.47	0.2686	0.0387
Tangerang	8	0.27	0.58	0.2598	0.0772

Based on Table 7 above that the minimum index is found in the corridors of the Bogor and Bekasi with a value of 0.23, while the maximum index found in the Tangerang corridors is 0.58. The best standard deviation is the lowest value found in the Bekasi Corridor which is 0. 0470.

4.2 Improvement actual TOD based on corridor

4.2.1. Bekasi Corridor

There are 13 stations in the Bekasi Corridor, most of the stations have a good index. However, there is potential for improvement in Bekasi and Kranji Station.

Table 8. The ranking of TOD index in Bekasi Corridor.

Number	Station	Corridor	Density	Economic	Diversity	TOD Index
1	Bekasi	Bekasi	0.26	0.32	0.54	0.33
2	Kranji	Bekasi	0.26	0.39	0.46	0.34
3	Cakung	Bekasi	0.25	0.31	0.77	0.38
4	Klender Baru	Bekasi	0.25	0.45	0.69	0.40
5	Kramat	Bekasi	0.27	0.40	0.77	0.41
6	Buaran	Bekasi	0.25	0.46	0.77	0.42
7	Jatinegara	Bekasi	0.25	0.43	0.85	0.43
8	Klender	Bekasi	0.28	0.43	0.85	0.45
9	Pasar Senen	Bekasi	0.37	0.35	0.77	0.45
10	Rajawali	Bekasi	0.29	0.38	0.92	0.46
11	Pondok Jati	Bekasi	0.29	0.51	0.85	0.47
12	Kemayoran	Bekasi	0.25	0.60	0.92	0.49
13	Gang Sentiong	Bekasi	0.40	0.61	0.77	0.54

Fig. 7. The TOD index of Bekasi Corridor

4.2.2. Bogor Corridor

Bogor is a corridor with the most number of stations, namely 26 stations. Most of the stations are potential (red colour) for improvements, mainly located in the suburban area.

Table 9. The ranking of TOD index in Bogor Corridor.

Number	Station	Corridor	Density	Economic	Diversity	TOD Index
1	Univ Indonesia	Bogor	0.15	0.22	0.62	0.27
2	Pd Cina	Bogor	0.17	0.31	0.46	0.27
3	Cilebut	Bogor	0.23	0.38	0.38	0.31
4	Depok	Bogor	0.29	0.26	0.46	0.32
5	Bojonggede	Bogor	0.28	0.53	0.23	0.34
6	Citayam	Bogor	0.25	0.42	0.46	0.34
7	Univ Pancasila	Bogor	0.22	0.32	0.77	0.37
8	Tanjung Barat	Bogor	0.27	0.34	0.69	0.38
9	Pasar Minggu	Bogor	0.26	0.31	0.77	0.38
10	Juanda	Bogor	0.22	0.34	0.85	0.39
11	Duren Kalibata	Bogor	0.20	0.37	0.92	0.40
12	Depok Baru	Bogor	0.27	0.31	0.85	0.41
13	Lenteng Agung	Bogor	0.27	0.39	0.77	0.41
14	Jakarta Kota	Bogor	0.28	0.37	0.85	0.43
15	Bogor	Bogor	0.35	0.42	0.62	0.43
16	Karet	Bogor	0.22	0.43	0.92	0.43
17	Sawah Besar	Bogor	0.34	0.33	0.77	0.43
18	Dukuh	Bogor	0.36	0.34	0.77	0.45
19	Gondangdia	Bogor	0.30	0.44	0.85	0.46
20	Mampang	Bogor	0.36	0.41	0.77	0.46
21	Jayakarta	Bogor	0.31	0.45	0.85	0.47
22	Manggarai	Bogor	0.28	0.54	0.85	0.47
23	Cawang	Bogor	0.25	0.50	1.00	0.48
24	Cikini	Bogor	0.30	0.52	0.85	0.48
25	Tebet	Bogor	0.28	0.52	0.92	0.48
26	Mangga Besar	Bogor	0.27	0.75	0.77	0.51

Fig. 8. The TOD index of Bogor Corridor

4.2.3. Serpong Corridor

Serpong is the smallest corridor with the number of 7 stations. Same as to the other corridors, most of the stations which are potential (red colour) for improvements are mainly located in the suburb.

Table 10. The ranking of TOD index in Serpong Corridor.

Number	Station	Corridor	Density	Economic	Diversity	TOD Index
1	Rawa Buntu	Serpong	0.25	0.29	0.38	0.29
2	Sudimara	Serpong	0.27	0.32	0.38	0.31
3	Pd. Ranji	Serpong	0.26	0.39	0.38	0.32
4	Serpong	Serpong	0.29	0.44	0.38	0.35
5	Pal Merah	Serpong	0.20	0.24	0.92	0.37
6	Kebayoran	Serpong	0.28	0.38	0.85	0.43
7	Tn. Abang	Serpong	0.32	0.38	0.92	0.47

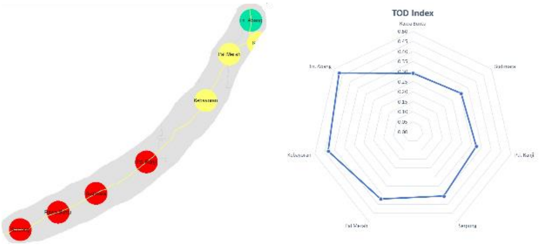


Fig. 9. The TOD index of Serpong Corridor

4.2.4. Tangerang Corridor

The Tangerang Corridor is in the western area, which consists 8 stations. Poris Station (red colour) is potential for improvement because it has the lowest index value.

Table 11. The ranking of TOD index in Tangerang Corridor.

Number	Station	Corridor	Density	Economic	Diversity	TOD Index
1	Poris	Tangerang	0.16	0.32	0.46	0.27
2	Kalideres	Tangerang	0.20	0.38	0.77	0.37
3	Rawa Buaya	Tangerang	0.22	0.37	0.85	0.40
4	Bojong Indah	Tangerang	0.22	0.47	0.77	0.41
5	Tangerang	Tangerang	0.35	0.33	0.77	0.43
6	Pesing	Tangerang	0.27	0.46	0.85	0.45
7	Grogol	Tangerang	0.28	0.51	0.92	0.48
8	Duri	Tangerang	0.39	0.66	0.92	0.58

Fig. 10. The TOD index of Tangerang Corridor

4.3 The reassessment of actual TOD index by theory and policy relevance

4.3.1. Theory relevance

The relevance of the city planning policy through reassessment actual TOD is conducted by looking at the whole and relating to various urban development theories that can be described briefly as follows.

Beginning of the 19th century about Garden City Movement is a theory that emphasises the balance between residential areas, industrial and open spaces in urban areas bounded by the existence of green belts.

Concentric theory of the Central Business District (CBD) is the center of the city located right in the middle of the city and is the center of social, economic, cultural and political life, and is the zone with the highest accessibility in a city.

The concept of sustainable development (1970) is the theory that encourages balance in the implementation of development, especially the economic, socio-cultural and environmental aspects.

The concept of integrated spatial and municipal space arrangement (early 1980s) encourages the provision of adequate open spaces and balance of space for occupancy and work activities, including the preservation of old towns and rebuilding of old warehousing areas.

The Transit-Oriented-Development (TOD) (1990s) theory of mixed residential and commercial zones with ease of pedestrian accesses to freight (developed at locations along the railway or bus route), each TOD on the city has its own character in accordance with the environment.

The 2000s emerges the concept of smart city with one of its policies is the provision of guidelines for green public transport planning. This concept offers an enhancement the quality of life.

Based on the theory above and associated with the development of the JMR, it can be seen the development that occurred in this area is as follows.

The rapid development of urban areas, especially in capital city of Jakarta led to the expansion of development areas to the suburban areas along with improved infrastructure. The city area reignited with the emergence of various centers of integrated economic zones after the revitalization of urban renewal in addition to the economic center and business as a place of work is the main reason for commuters to commence travel activities.

Along with the time, it is occurred the formation of growth and maturation process of suburbs. Some new towns become independent cities that seek to meet the socio-economic needs of their inhabitants. For example, the cities i.e. Depok, Bekasi, Serpong, and Tangerang grow into satellite cities of Jakarta that seek to meet the socio-economic activities of its citizens.

The railway transport connection of all these satellite cities becomes vital. It means the connection is not only as a solution to the problem of urban and regional transportation but also has a mean of connecting between urban and suburban areas. Rapid developments are occurred on public transport routes linked to the existence of new cities on the outskirts of the city and along the existing corridors.

The phenomenon that occurs above encourages the emergence of the needs of residential areas that have the characteristics of TOD, namely: friendly to pedestrian (walkable), mixed-use between residential, business and commercial, and located near the railway station network.

Therefore, the reassessment of the actual railway station in JMR is a very important thing in determining the TOD characteristics through index. This method distinguishes between stations to facilitate the treatment increasing the area to the ideal TOD.

4.3.2. Policy relevance

Based on the overall TOD reassessment, it is found that high TOD with index 0.44-0.58 is in urban area (Jakarta City) and low TOD with index of 0.26-.0.35 located in suburban area (Tangerang, Serpong, Bekasi, Bogor) for that need an increase to TOD with low index by various policies as follows.

Improvement of low TOD areas need to pay attention to the main indicators of density, economy and diversity, but not limited to those indicators that can be expanded by considering the area that combines green, growth and job.

Density indicator is the main indicator based on expert judgment, the emphasis on special policy on demography and the strategy of developing new settlement centers.

The quality of life of the population within the TOD area is enhanced by special arrangements in the utilization of locations for public interest such as residential, commercial, business, education, health.

Making community-based on participatory planning considering the role of the private sector and the community are the main actors of urban development. The engagement process starts from planning, utilization and control. In the context of cooperation, effective coordination mechanisms are developed.

5. Conclusion

The range of TOD index values of 54 stations in JMR is ranging from 0.26 to 0.58 with the details as follows, 6 stations (range 0.26-0.35) spread over suburban region, 11 stations (range 0.36-0.43) scattered in the transition area of suburban and urban, last 37 stations (range 0.37-0.58) dispersed in urban areas or city centre. It can be concluded that a high index value of stations tends to be in the urban areas, and, vice-versa, the station with low index value located in the suburb. This is because of the difference of acquisition in criteria and indicator of each the station. Therefore, the recommended stations eligible for improvement should apply the concept of TOD well. The level of improvement in each of these stations is adjusted to the value of the achievement of criteria and indicator.

The provision of a good public transport, especially the management of transit area, like TOD is critical to the city management due to the nature of the public mass and providing physically as well as non-physical fulfilment for the satisfaction of its inhabitants. Planning for good TOD that meets the needs of the community regarding effective transportation and efficient travel service-based paradigm consequently reduce and even overcome the problems of everyday life of the city such as road congestion, air pollution and traffic safety.

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