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CHARACTERISTICS OF TRANSIT ORIENTED DEVELOPMENT AREA (CASE STUDY: JAKARTA MRT)

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Characteristics of Transit Oriented Development Area (Case Study: Jakarta MRT)

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Abstract. *The city of Jakarta is famous because the traffic jams, so the transportation sector needs special attention. Based on data from the Jakarta Transportation Management Agency, of the 47.5 million trips in Jakarta City, only 24% used public transportation. The Jakarta City Government has provided public transportation modes, namely the MRT. This mode of transportation offers a basic concept of TOD, area around the 400 meter buffer from the station can be accessed by walking. This concept has been developed in various cities on the Continent of Europe and America. The space conditions in a TOD based area can be assessed using the TOD Index measurement. Each TOD Index criterion has its own indicators. This study uses 8 criteria and 18 indicators that can measure the value of the TOD Index at each MRT station. Processing data is using spatial processing so that each indicator can be analyzed holistically from a spatial perspective. The TOD area of Bendungan Hilir Station is a station with the highest TOD value, amounting to 0.71. TOD Station in Lebak Bulus Station takes the lowest TOD Index value of 0.31. The TOD Index's value at each station can be influenced by the weight of each indicator and criteria. Through this research, it is hoped that each policyholder can pay attention to every indicator on the station that is deemed necessary to be improved if needed for a TOD-based area that is in accordance with the concept of a smart city.*

Keywords: *TOD, space, TOD Index, smart city, 6Ds*

1. Introduction

Jakarta is the center of Indonesia's economy and government which has great potential and problems. The population of Jakarta is 10,277,628 people (BPS, 2016). In order to support the stability of the national capital, various sectors need to be improved so that people can live comfortablye. The Jakarta City Government has provided new transportation modes, namely the MRT. The MRT can carry 173,400 passengers per day with 6 train cars in each series, the capacity of each series is 1,950 people using barrier-free crossings (overpasses and underground). The presence of the MRT can also create the concept of smart cities and regions based on transit oriented development (TOD) that are popular in various major cities of the world.

The concept of Transit Oriented Development (TOD) was originally introduced by Peter Calthorpe and detailed in The Next American Metropolis (Calthorpe, 1993). Some of the main principles of TOD from Calthorpe are prioritizing the construction of commercial, residential, office, garden and use of lanes for walking from transit stops; creating a convenient pedestrian road network that directly connects destinations for road users; providing mix reductions, cost savings and encouraging sustainable development of pedestrians on every sidewalk around the transit point. The existence of the transit point certainly affects the surrounding environment. Ideally the radius of the TOD is by measuring the length of walking for about 5 to 10 minutes, which ranges from 400 meters to 800 meters from the transit center point (Tong, Wang, Chan, & Zhou, 2018; Rahmat et al., 2016). An example from the transit center point is the MRT station.

In the early days in rail-based public transportation systems in Europe, it was known as the metro. Etymologically, metro originates from the French phrase 'métro' which stands for metropolitan railroad in the late 19th century in Paris (Der Bijl et al., 2018). This term has been adopted by various languages throughout the world. However, in American, metro is identical to the subway. In addition, the term metro is very often used as the name of a general term for urban transportation systems. In Asia the expression metro is less popular, the metro is known as the MRT, which is mass transit. Definition of Mass Rapid Transit is railroad transportation with exclusive road rights that are divided into 2 types, namely high volume and light, no matter whether the rail is above ground, ground level, or underground. (Xu Weici, 1995) In conclusion, MRT can be understood as an electric rail-based railroad system (Shi & Yang, 2013).

Space is the dimension studied in various perspectives, both socially and physically. TOD is a space that is public and can be accessed by everyone. Literally, public space can be defined as an area that is limited by something (character, distance, characteristics) that is intended for the public. However, entities regarding "space" and "public" can be identified further depending on the cultural context. Space can be measured by TOD criteria. TOD criteria are indicators in determining the TOD Index in an area. The TOD measurement index departs from the theory of 3Ds (Kockelman, 1997) and 6Ds (Ogra & Ndebele, 2014). This theory considers physical and social aspects in the calculation of the TOD area.

Measuring TOD Index is the combination of various indicators that define or characterize TOD. These indicators must be measurable according to existing theories, whether they are suitable for future-oriented assessments rather than evaluations that are oriented towards the past (Evans and Pratt, 2007). An increase in the transit point is the goal of developing the TOD area. Krizek (2005) explains the importance of mobility at station transit points as follows; creating a healthy lifestyle, reducing costs from private vehicle use, saving time, saving space, creating city space suitable for economic services, creating investment certainty.

Space conditions in the TOD area can be measured by physical, economic and social criteria. 6Ds is a theory that can measure the value of TOD in a particular region (Ogra & Ndebele, 2014). 6Ds include density, diversity, design, destination, distance and demand management. This theory is a development of other TOD theories such as 3Ds. Each criterion has its own weight and indicators to measure the TOD value. Based on the development of the 6Ds theory, research methods emerge with more complex criteria such as density, landuse diversity, walkability / cyclability, economy, capacity utilization, user-friendliness, access and parking supply (Singh, Lukman, Flacke, Zuidgeest, & Van Maarseveen, 2017) The data processing of this study uses a geographic information system. Geographical information systems (GIS) are systems designed to capture, store, manipulate, analyze, manage, and present spatial or geographical data. The main tool for Spatial GIS Analysis used in this study is known as buffer, overlay, digitization, and network. GIS can explain spatial data as well as processing spatial data which is a requirement for the formation of the TOD Index. The purpose of the TOD Index is to explain the physical and social conditions in the area studied with a measure. The Dukuh Atas TOD area is expected to be the transit center for tens of thousands of users of public transportation in Jakarta. This is because Dukuh Atas Station has various types of land use, such as housing, offices and shopping centers. This diversity creates diverse human activities as well. The Dukuh Atas TOD area is also supported by a variety of public transportation modes such as BRT and KRL.

This study seeks to see the space characteristics measured by the Index TOD in the area around the station passed by the Jakarta MRT mode by considering the theories that support the TOD concept, so that the characteristics and quality of the area in each MRT station are generated, whether or not to become a TOD-based area . Another purpose of this study is to explain the spatial conditions with the research criteria so that they can be considered in the development of the area around the MRT station.

2. Methodology

2.1. Data Required

The TOD criteria and indicators were chosen from the study (Singh, et al., 2017) by considering the availability of data and field conditions summarized as follows;

Table 1. Research Criteria and Indicators

No	Criteria	Weight	Indicator	Weight
1	Density	0,15	Population Density	0,67
			Commercial Density	0,33
2	Land use Diversity	0,03	Land use Diversity	1,00
3	Access by Walking	0,06	Residential Diversity	0,10
			Road Network	0,40
			Intersection	0,20
			Pedestrian Reach Ability	0,30
4	Economy	0,22	Business Density	1,00
5	Station Capacity	0,19	Passengers (peak hour)	0,67
			Passengers (non peak hour)	0,33
6	Station Facility	0,11	Safety and Security	0,50
			Information Display	0,50
7	Accessibility from and to the station	0,15	Trips of MRT	0,40
			Branching of Train Road	0,30
			Alternative Transportation	0,20
			Accessible Building by Walking	0,10
8	Parking Availability	0,08	Car Parking	0,67
			Motorcycle Parking	0,33

Each research indicator is calculated and rated with the following conditions;

- Density includes the number of population and commercial area, for the population obtained by calculating the population in the research buffer assuming that each residential building has 4 people, so the number of people per house is multiplied by the number of houses in the research area.
- The concept of land use diversity comes from the Kamruzzaman & Baker study (2014) where land use diversity in the TOD region uses the formula: Land use Diversity = $1 - \sum(\ )^2$. Where α is the total area of certain land use categories (e.g. commercial) in the TOD buffer, and A is the total area of all land use in the buffer.
- Accessibility, indicators of accessibility include diversity of settlements, road networks, intersections and pedestrian reach. Accessibility explains the ease of people to move. This process of transfer is called accessibility, while the path that is passed by pedestrians is called access. The higher the accessibility of an area, the faster and higher the activities of human activities there.
- Economics includes the density of business locations, it must be noted that 'commercial' companies represent services and retail companies while 'business' represents non-services and non-retail or retail companies. The aim is to avoid double counting of commercial indicators.
- The capacity of the station contains the number of passengers during working hours and not working hours at each station. Morning peak hours start at 07.00-09.00 and afternoon peak hours start at 17.00-19.00. Off peak hours are the time during train services in addition to peak hours (Shanghai Urban and Rural Construction and Transportation Development Research Institute).

- Station facilities include safety and information display, safety is measured by observing whether when the passenger goes up and down the train there is a jostling. Information display is an information board that provides train departure information at the station.
- Accessibility to and from the station includes train trips, branch lines at the station, availability of alternative government transportation and the number of building travelled by walking.
- Availability of Parking Lots measured by parking indicators includes the availability of parking lots for 4-wheeled and 2-wheeled vehicles and also sees efficiency in the use of parking lots. Regions that have public parking can support the development of TOD-based concepts. Users can park their vehicles to use other public transportation modes. The type of parking lot use is very influential on the number of train passengers in the area (Li, Liu, Gao, & Liu, 2016)

Each method of data collection is explained as follows;

Table 2. Research Data Collection

No	Indicator	Indicator Unit	Source
1	Population Density	Amount	Open Street Map
2	Commercial Density	Amount	Digitized Google Map
3	Land use Diversity	Square	Open Street Map
4	Residential Diversity	Square	Open Street Map
5	Road Network	Length	Open Street Map
6	Intersection	Amount	Open Street Map
7	Pedestrian Reach Ability	Square	Ina-Geoportal
8	Business Density	Amount	Digitized Google Map
9	Passengers (peak hour)	Amount	Website MRT
10	Passengers (non peak hour)	Amount	Website MRT
11	Safety and Security	Amount	Survei (PT MRT)
12	Information Display	Amount	Survei (PT MRT)
13	Trips of MRT	Amount	Website MRT
14	Branching of Train Road	Amount	Website MRT
15	Alternative Transportation	Amount	Jtransmap
16	Accessible Building by Walking	Amount	Open Street Map
17	Car Parking	Amount	Digitized Google Map
18	Motorcycle Parking	Amount	Digitized Google Map

2.1.1. Population and Commercial Density

Density includes the large population and use of building for commercial activities in a certain area. Population density collected by calculating the building units multiplied by four. The assumption is that each unit is inhabited by four person. Residential buildings consist of individual and commercial houses. An individual houses is a single building where a family lives. Communal houses for example are apartments or flats. The number of units in the apartment is also multiplies by four, equal to the assumption of the number who stays in an individual house. The commercial desity is assesed by units, i.e. thenumber of commercial buildings in the study area. The commercial density is a retail building such as mall, plaza, hotel etc. Data for the individual houses distribution collected from open street maps, while apartment distribution data is collected by digitizing Google Maps POI. The number of units in the apartment collected from the website rukamen.com, as a website that providing information on the number of apartment units. Similar to apartment, commercial point data assembled by digitizing POI google maps.

2.1.2. Land Use Diversity

The concept of land use diversity comes from Kamaruzzaman & Baker (2014) research which was calculated using the formula:

Landuse Diversity = $1 - \Sigma\ (\alpha A)$ .....(1)

Where α is the total area of a particular land use category (for example commercial) in the TOD buffer, and A is the total area of all land use categories in the buffer. Land use area is calculated includes residential and commercial land. Both of these land uses are added up to get the value of land use diversity at each station. The higher land use diversity value indicates that the region has a high diversity. High diversity is a requirement if an area is made into an ideal TOD-based area.

2.1.3. Accessibility

Indicators of accessibility include the diversity of settlements, road networks, intersections and pedestrian ways. Accessibility is defined as the ease of people to move. The higher the accessibility of an area, the faster and higher the human activities are

2.1.4. Residential Diversity

The diversity of settlements in this study follows the formula of Zhang and Guindon (2006):

MI (i) = $\Sigma Sc \cap i \Sigma$ $(Sc + Sr)$ .....(2)

Where,
MI (i) = Residential Diversity
Sc = total area in non-residential urban land use
Sr = total area in residential land use in i

MI values can range from 0 to 1. The higher MI values indicate that the area has other types of land use other than non-housing, which supports TOD (not homogeneous) areas. This indicator is different from the diversity of land uses. It has been studied by Jacobs (1961), Evans and Pratt (2007), Zhang and Guindon (2006) and Bach et al. (2006), many trips can be done by walking or cycling in residential areas.

2.1.5. Road network

This indicator is calculated based on roads that are accessible for pedestrians / cyclists at each station. The unit of measurement is kilometers. Roads used for fast traffic such as toll roads are deleted from the road network data because walking and cycling are not permitted there. The length of this road network is obtained from OSM data in each buffer area of the research station. This idea is known as the walkable / cycling pathway, which was adapted from the research of Schlossberg and Brown (2004). The higher value of the road network indicates that the area has a high mobility value, so that road users can shorten the time to their destination. The assumption is that each type of road network is a place where people walk (except toll roads), it is hoped that in the future all road networks will be equipped with proper pedestrian facilities.

2.1.6. Intersection Density

Intersections can make walking and cycling easier because it helps them shorten the route. Higher intersection densities generally have higher walkability values (Ewing and Cervero, 2010; Evans and Pratt, 2007; Bach et al., 2006). Calculation of intersection density is measured by the number of intersections in the buffer of the study area. The intended intersection is the end point or intersection of the road network system. This intersection can be a starting point, middle point and end point. Intersections are obtained from processing network analyst data.

2.1.7. Pedestrian Reach Ability

The pedestrian catchment area, also known as 'Ped-Sheds', is the actual area for walking in ideal time from the train station. Pedestrian coverage is calculated based on a distance of 400 meters along a two-way road network. This indicator is calculated based on the ratio of pedestrian length in an area of square km and compared to the entire study area. In this study, pedestrian reach ability calculated by using network analyst on the ArcGIS application. Road network data is obtained from tanahair.indonesia.go.id. This is because the road network of OSM has a one way rule, while Tanahair.indonesia.go.id does not. Basically people walk in two directions.

2.1.8. Business Density

Economic variables include business location density. Calculation of business density is measured as calculating population and commercial density. The business variable is the number of office buildings in the study area. The office building consists of tower or skyscraper that is identical to the TOD area. The data source is taken from digitization of Google Maps POI.

2.1.9. Station Capacity - Passenger

Passenger is an indicator of the TOD index, if the passenger load at the station is large, it will increase the value of the TOD index at the station, and vice versa. Passenger is the number of MRT users going up and down at the transit station both during peak hours. Furthermore, direct observations were made at each station to see the actual condition of passengers, either during working hours and not working hours. This method was adopted from Singh, et al. (2017) research. Morning peak hours start at 07.00-09.00 and afternoon peak hours start at 17.00-19.00. Off peak hours are times during train services other than peak hours (Shanghai Urban and Rural Construction and Transportation Development Research Institute). The higher passenger value indicates that the station has a high mobility value. This will have an impact on the type of land use and activities that occur around the station. This study uses the type of commercial land use as a focus of the passenger distribution proposition, assuming that the commercial size can affect the number of MRT passengers up and down, so that passenger distribution can be known.

2.1.10. Facilities of the Station - Station safety and security

Safety and security are one of the most important things that influence the choice of transit. This is the most difficult indicator to measure. Safety and security are not only facilities from the station, but interactions between facilities and passengers that are known as passenger behavior (Der Bijl et al., 2018). This indicator is examined by observing the behavior of MRT passengers, whether there is jostling during the train queue at the station. Crowded is the situation where activity at the entry is full and the passeger is pushing people in front of he/she so that it can cause accidents. Safety observations are made during peak hours, because these hours are the densest time making it easy for researchers to make observations. The results showed by tables, whether at the station there was jostling or not. At the station where there is no pushing indicates that the passengers' behavior is good in using the MRT transportation mode.

2.1.11. Information display on the station

Static and dynamic information display systems affect the convenience of MRT users. All stations must display information with a clear display and easily seen by each passenger. The information displayed in the form of hours of departure of the next train and destination of the train (Abdallah, 2017). This indicator is measured by the number of units, of course the more number of information boards will make it easier for passengers to get information about the location of the train, departure hours and so on

Accessibility to and from stations

2.1.12. Train trips

The frequency of train trips is calculated based on the number of trains operating on working days (Monday-Friday) at each station. Higher train travel values indicate higher mobility. In this study, the number of train trips is the same, because the MRT rail system is still one track, so the value of all stations is the same. This same value is still sought out because this indicator is part of the TOD Index weighting.

2.1.13. Branching of Trains

This indicator measures the number of train routes that can be accessed at each station. A higher number of train routes can connect other destinations that have the potential to make more people choose the transit mode. This indicator is identically known as the hub on the electric rail system. The intended branching is a choice of lanes that go out of the main lane. On the MRT line, the rail system used is parallel and has no other choice of lines, unlike the hub on the KRL located at Manggarai Station.

2.1.14. Availability of alternative transportation

The high-quality transit system not only offers accessibility from the railroad system, but the flexibility of passengers to move to other public transportation modes. This indicator is measured by counting the number of public transportation integrated with the MRT in each station area. The public transportation referred to in this study is official government transportation, such as Transjakarta (BRT), Jabodebek LRT and Jabodetabek KRL. Of course, a region that has adequate availability of alternative transportation can increase the value of the TOD index. Integration between modes of transportation can increase mobility, reduce air pollution, create driving comfort and reduce congestion in the region. Other modes of transportation (other than those of the government), are still displayed in the discussion to see the characteristics of the area, but are not included in the processing of the TOD Index.

2.1.15. Locations that can be reached on foot

This indicator measures the number of buildings in the study area, so how many locations can be accessed by pedestrians from the MRT station. The building in question includes all types of building types, both housing, apartments, offices, stadiums and so forth. The assumption is that every building in the 400 meter buffer is an accessible building for MRT passengers on foot.

2.1.16. Parking Area Availability

Parking indicators include the availability of parking spaces for 4 and 2 wheeled vehicles and efficiency in the use of parking lots. The type of parking land use is very influential on the number of train passengers in the area (Li, Liu, Gao, & Liu, 2016). Parking availability is obtained from digitizing POI google maps, which are divided into types of car, motorcycle or car and motorcycle parking. The parking lot in this study is not limited to the land provided by the MRT, but the public parking area is in a 400 meter buffer, because the parking area below 400 meters is assumed to be a transit parking area for MRT users.

2.2. Data Processing

Data processing is done by geographic information system techniques to display the results of spatial and tabular research with the types of data processing as follows;

a. Overlay, in this study, the data overlaid as further data processing requirements is the MRT point, MRT line, road network and MRT buffer. The data is a collection of polygons, lines and points and mutual overlap in order to facilitate other spatial operations.
b. Buffer, in this study, the buffer is useful as a limitation of the research area at each MRT station. Later each research indicator is limited or cut with a maximum range of 400 meters or the buffer area itself.
c. Network analyst in this study includes pedestrian reach and the number of intersections. The reach of the journey is done by creating a network first, which in this process includes the road network and intersection points, then processing the service area with the station point as a reference point, so that it gets a walking distance with a radius of 400 meters. The results of the service area are new polygons.
d. Standardization of the min-max method, standardization is used in calculating unit differences for population indicators, commercial, road networks, intersections, pedestrian reach, business, visitors, safety, information display, frequency of services, branching, alternative transportation, locations that can be travelled by walking and parking which aims to standardize tabular use values in the range of 0-1 in calculating the TOD Index. Therefore, standardization of indicator units is carried out using Maximum - Minimum (Max - Min) (BPS, 2010). The formula is

$$I = \frac{X - X_{min}}{X_{max} - X_{mind}} \times 100 \quad \text{.....(3)}$$

Weighting is a method that is often used in determining categories or the influence of an indicator on the criteria above (Singh, Lukman, Flacke, Zuidgeest, & Van Maarseveen, 2017; Taki, 2017). This study uses the weighting of the TOD Index taken from Singh's research (2017), which in determining the weight values of each indicator and criterion is based on the statements of the local city planning experts (council). The weight values of each indicator and criterion can be different, because of their respective characteristics. The weighting value of the TOD index in this study can be seen in Table 2.

3. Result

The TOD Index at each Jakarta MRT station varies greatly, ranging from the range of 0.31 to 0.71. The TOD Index value interval is in the numbers 0 to 1, the higher the TOD index value indicates that the station has a high TOD characteristic. The average TOD value of the Jakarta MRT station index is 0.51. If viewed based on the average TOD Index value, there are 7 MRT stations that are above average, the remaining 6 stations are still below the average. The station in the Central Jakarta administrative area (Bundaran HI Station, Dukuh Atas BNI Station, Setiabudi Astra Station, Bendungan Hilir Station, Istora Mandiri Station and Senayan Station) has an above average TOD Index value. High TOD Index means that the area needs better quality access transit (Singh, 2015). We know that some of these stations have workplace types of office and commercial land use.

Table 3. TOD Index at each Jakarta MRT Station

Station Name	Density	Landuse Diversity	Access by Walking	Economy	Station Capacity	Station Facility	Accessibility from and to the Station	Parking Availability	TOD Index
Bundaran HI	0,45	0,45	0,41	0,27	0,58	1,00	0,50	0,78	0,52
Dukuh Atas BNI	0,08	0,67	0,74	0,45	0,23	1,00	0,94	0,61	0,52
Setia Budi Astra	0,72	1,00	0,75	0,64	0,00	1,00	0,92	0,61	0,62
Bendungan Hilir	0,21	0,75	0,92	1,00	0,52	1,00	0,85	0,53	0,71
Istora Mandiri	0,09	0,52	0,77	0,45	0,74	1,00	0,83	0,69	0,61
Senayan	0,30	0,47	0,44	0,82	0,72	1,00	0,78	0,61	0,68
ASEAN	0,01	0,20	0,25	0,00	0,86	1,00	0,78	0,61	0,46
Blok M	0,09	0,00	0,36	0,00	1,00	1,00	0,80	0,84	0,52
Blok A	0,23	0,11	0,53	0,00	0,40	1,00	0,80	0,22	0,39
Haji Nawi	0,13	0,10	0,39	0,00	0,39	1,00	0,76	0,92	0,42
Cipete Raya	0,16	0,15	0,30	0,00	0,45	1,00	0,75	0,00	0,35
Fatmawati	0,05	0,67	0,45	0,27	0,53	1,00	0,74	0,31	0,46
Lebak Bulus	0,09	0,97	0,64	0,00	0,05	1,00	0,50	0,47	0,31

Table 3 explains how the value distribution for each MRT station. The highest TOD index is in the Bendungan Hilir TOD area, while the Lebak Bulus TOD area has the lowest TOD Index value. Eight criteria for TOD Index are greatly influencing the final value of the TOD Index. Setiabudi Astra Station BNI holds the highest value on the criteria of density and diversity of land use. The highest criteria for access by walking and economy are held by Bendungan Hilir. Both of these stations have the highest dominance in the TOD Index criteria, but Setiabudi Astra Station has a TOD Index value of only 0.62. This is because the Setiabudi Astra Station on the capacity criteria is in the last rank, considering that the Setiabudi Astra Station's 400 meter buffer is currently under construction which causes the commercial area (proposition indicator) to be low. It is different from the Bendungan Hilir Station

which has higher accessibility values and is often at the top of each criteria. The walking distance remains important when analyzing TOD, as it has become the main factor in the TOD index assessment shown by some previous studies (Chatman, 2013; Nasri & Zhang, 2014; Singh et al., 2017).

For Lebak Bulus Grab Station, it has a low TOD value, because the station is ranked last in economic criteria and accessibility to and from the station. This is very important, considering that the economy holds the highest value of influence or weight rather than the weight of other criteria, which is equal to 22%. As a result, the value of the Lebak Bulus Grab Station TOD Index dropped dramatically to 0.31. Station that has low TOD Index means needs improvement (Taki, 2017). The unique phenomenon of the results of the TOD Index value occurs at stations that have similar TOD Index values, but different types of land use. This happened at Setiabudi Astra Station and Istora Mandiri Station. The TOD values of the Setiabudi Astra Index are 0.62 and 0.61 for Istora Mandiri Station. Whereas Setiabudi Astra's land use is very minimal by the use of commercial land, only 1.8 hectares. This is inversely proportional to Istora Mandiri, which is dominated by the type of commercial land use of 28 hectares. This is due to several other criteria, such as density and economic criteria. Setiabudi Astra has a high-density criteria, which is 0.72. This criteria can raise the TOD value of the Index and pursue the TOD value of the Istora Mandiri Index, which in the 400 meter buffer area of Istora Mandiri does not have individual homes and fewer apartments than Setiabudi Astra Station. This phenomenon shows that every criteria inter-related with other criterias (Singh, 2015; Singh 2017)

The other most striking phenomenon is the TOD Station Setiabudi Astra and Lebak Bulus Grab Station, where the two stations have a different TOD Index value. 0.62 for Setiabudi Astra Station and 0.31 for Lebak Bulus Grab Station. Even though both have the same type of land use in the criteria for land use diversity. Setiabudi Astra has a value of 1 and Lebak Bulus Grab with a value of 0.97. The construction process at both stations is also being worked on together. Both stations have minimal commercial land use and settlement. The commercial land will have a significant contribution towards the transit demand (Li et al., 2016). The striking difference in these 2 stations is the criteria for population density. Lebak Bulus Grab does not have an apartment, only the use of residential land is minimal, so the TOD value of the index decreases at Lebak Bulus Grab Station. While Setiabudi Astra even though residential values are minimal but have high apartments. The TOD value diverse indicates complementary among stations as mention by Huang et al (2018).

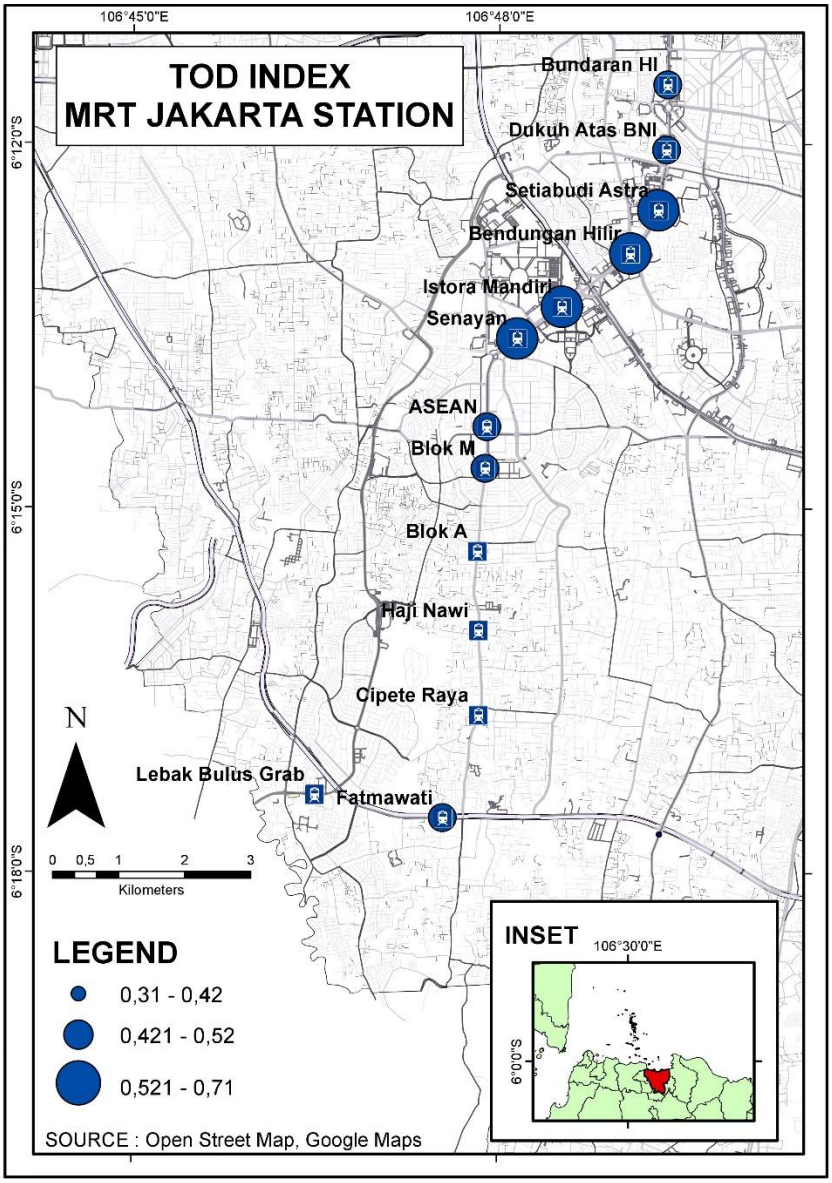

Figure 1. TOD Index MRT Jakarta Station

Figure 1 clearly shows the TOD index value for each MRT station. The division of classes into 3 categories with the natural breaks method explains that stations in the Central Jakarta administrative area have a higher class ranking. The unique thing is the Dukuh Atas Station and Bundaran HI as presented as a TOD-based area only get rank 2, losing to Setiabudi Astra Station, Bendungan Hilir Station, Istora Mandiri Station, Senayan Station. Please note that the Central Jakarta area is a CBD area which is certainly expected to have a smart city concept and including the TOD area. The unique phenomenon that occurs at the Bundaran HI dan Dukuh Atas Station needs to be studied more deeply. Figure 2 describes the trends or weighting weights on the TOD Index research criteria. Bundaran HI Station gets a small score on economic criteria, this is because some locations in the 400 meter buffer are being built for business locations that may in the future be able to raise the TOD Index. The second lowest criterion is density, which is where the construction of apartments is possible in the 400 meter of Bundaran HI Station. Dukuh Atas Station is very weak on density criteria, apartment construction is highly recommended to increase the TOD Index value. While the increase in capacity that covers the number of passengers needs to be increased. It should be noted, the number of passengers in this study

was carried out by a proposition method which is an alternative data collection because it does not get passenger data from the MRT.

The criteria for the TOD Index have their respective weights. The economy holds the highest weight, it does not mean to get a TOD The high index only needs to mine the economic sector. Keep in mind that the TOD concept itself is present to create comfort in various aspects. Comparison of the TOD Index between stations is intended as an evaluation of future-oriented development, so as to make the city more comfortable to live in. It could be that if there were additional research buffers, then the TOD value would change. This is because land use for each location will be different from other locations.

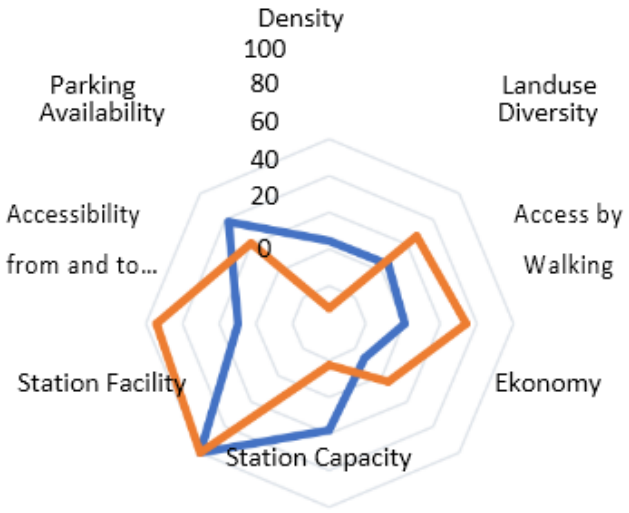

Figure 2. Criteria Chart of Bundaran HI Station and Dukuh Atas Station

Comparison with similar studies

This study shows that there are four stations with high TOD index, namely Bendungan Hilir (0.71), Senayan (0.68), Setia Budi Astra (0.62), and Istora Mandiri (0.61). Similar results also found in another study by Budiati et al. (2018), who are using 5Ds theory to measure the TOD index value. The study has found high TOD value in Istora Mandiri, Senayan, and Dukuh Atas stations. Results from both studies also shown that surrounding the stations with high TOD value is very dynamic and diverse land use, from residential to commercial area. The other study has particularly mentioned Dukuh Atas as a high TOD point because of its land-use diversity and walking distance adjacency (Budiati et al., 2018). It also discovered in this study where land-use diversity and accessibility of Dukuh Atas are among the highest value if compared with other high TOD stations.

4. Conclusion

Based on the description of the TOD Index Indicator and value, Bendungan Hilir Station is the station that has the highest TOD Index value of 0.71. Lebak Bulus Grab Station is a station that has the lowest TOD Index value, which is equal to 0.31. Stations located in the Central Jakarta administrative area have a higher TOD Index value compared to stations in the South Jakarta administrative area. The average value of the TOD Index at the central Jakarta station is 0.61 while the TOD Index value of the South Jakarta station is 0.42. The main characteristics of the Central Jakarta is as bussines area. Whereas the South Jakarta is dominated by residential area. These function differentiate by the land use domination.

The government and related agencies need to pay attention to each criterion and indicator that is considered lacking at each station, especially the Bundaran HI Station and Dukuh Atas Station if it is to be used as an oriented development-based area in the future, so that the public space is comfortable to live in.

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