Determining the potential for Transit Oriented Development along the MRT Jakarta corridor

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Determining the potential for Transit Oriented Development along the MRT Jakarta corridor

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Abstract. Rapid population growth has increased the mobility of people, which leads to traffic congestion. Transit-oriented development (TOD) is a planning approach that is being adopted in many cities as it favours to reduce private vehicle usage by developing mass transit stations around high-density mixed land use and walkable (and cycle-able) environments. However, TOD development needs good strategies learned from historical and current conditions. In this research, we measured the current conditions of proposed TOD areas in thirteen MRT stations in Jakarta to determine the potential TOD development. These thirteen stations were divided into three types based on environmental characteristics of the station location such as CBD, urban, and neighbourhood characteristics. The 5D of built environment variables were used as indicators to examine the potential of TOD areas. Then, stakeholders were involved to fit and weigh the indicators. The weights of the indicators were applied to the Geographic Information System (GIS) platform for quantifying all spatial indicators. TOD indexes for each station were examined to identify potential improvement strategies. The 13 stations are classified as having a high, medium or low TOD index. The results showed that three out of thirteen stations have high levels of TOD; six are classified as having a low TOD level. The low index proposed TOD stations should improve their built-up area, for example by intensifying the floor area ratio (FAR), adding green space, and enhancing the transit and pedestrian-oriented design. By understanding the specific strategies for different TOD indexes, this paper is intended to support those development areas to improve local urban development towards higher levels of TOD.

1. Introduction

Jakarta as the capital city of Indonesia and the centre of governmental, economic, and political activities in Indonesia experiences mobility problems, among which congestion is prominent. Congestion in Jakarta is predicted to get worse as 1,000 to 2,000 new motorcycles and 500 new cars appear on the roads every day [1]. If there is no improvement in transportation planning and/or infrastructure development, vehicular gridlock will truly happen in Jakarta. Consequently, Jakarta aims to reduce the road capacity problem by promoting mass public transport such as BRT, MRT and LRT, and encouraging transit-oriented development (TOD) around public transport stations. TOD can be an opportunity to reduce the number of motorized trips, increase the share for non-motorized trips and reduce travel distance [2]. The construction of a new MRT in Jakarta is an opportunity to plan for TOD and to gain maximum benefit of urban development from TOD planning. The planning of TOD should be examined carefully since it will not automatically follow when mass public transportation is built.

The indicators to examine whether TOD has been developed to support the function of mass transit and to accommodate the liveability of an area are determined by the variables of the built environment. The built environment is defined as "the humanitarian-made space in which people live, work, and
recreate on a day-to-day basis”. The "built environment encompasses places and spaces created or modified by people, including buildings, parks, and transportation systems” [3]. The dimensions of the built environment that promote successful TOD are density, diversity, design, destination accessibility, and distance to transit [2][3]. For example, the D for design refers to the presence of amenities such as lighting, benches, and trees on the street which creates areas that are suited for non-motorized trips [2]. Likewise, building commercial areas or shopping centres typically increases land use diversity which may lead to a higher proportion of shorter trips for which non-motorized modes are suitable. These trips may substitute trips outside the local area [5]. Similarly, creating a concentration of business activity in the compact commercial core in the centre will lead to a high density and short trip distances which encourages people to walk [6].

In this research, we investigate the potential for TOD planning along the Jakarta MRT corridor. We want to measure the current condition of the proposed TOD areas along the corridor and, based on the results, develop strategies for TOD development to encourage people to use non-motorised modes of transportation. In order to determine the future potential of TOD development, we first establish a baseline of current TOD conditions. This will reveal weaknesses and strengths of those development areas, which will provide us with inputs into concept strategies to improve local urban development towards higher levels of TOD.

2. Case study description

A tremendous number of people commute every day from surrounding cities Bogor, Depok, Tangerang, and Bekasi (also referred to as BODETABEK) to the city centre of DKI Jakarta (Figure 1). The number of commuters to Jakarta has increased tenfold between 1985 and 2002 [7], and 1.5-fold from 743 thousand trips in 2000 to 1.105 million trips in 2010 [8] and has further grown to 1.382 million trips in 2014 [9]. Most of the trips are made by personal modes of transportation such as car and motorcycle; a relatively low number of trips are made by public transport. Despite congestion, the popularity of personal vehicles keeps increasing; the JUTPI Commuter Survey shows that car and motorcycle ownership has increased from 2002 to 2010, at the expense of public transport. This condition calls for the improvement of transportation planning and the strengthening of public and non-motorised modes of transportation.

The development of MRT and LRT in Jakarta is meant to facilitate a shift from private to public transport but also allows local area based planning around the rail-based station areas to promote TOD. The operator of MRT Jakarta wants to promote TOD development in every station but the Spatial Planning Policy 2030 of Jakarta mentions that stations in which TOD will be promoted shall be designated (1) in the intersection of mass transportation corridors (two or more): (2) in the areas with predicted high economic value; and in the areas that are planned or defined as activities centres [10]. TOD is planned in every station of MRT which is legitimated in the Urban Guide Line of MRT Jakarta (Figure 2a). This study focuses on MRT Corridor 1 (Figure 2b).
In this study, a typology of stations is proposed based on three sections of the MRT Corridor because the station locations have different prominent characteristics. They are clustered in three sections, i.e., Fatmawati street to Panglima Polim Street, Sisingamangaraja Street and Jenderal Sudirman Road to M.H. Thamrin Road. Typical stations for each of these sections are Cipete Raya station, Sisingamangaraja station and Bundaran HI station which are shown in figure 2. Lebak Bulus and Fatmawati station, which are located at Kartini Road, are categorized similar to the stations located at Jenderal Sudirman and M.H. Thamrin Road because they have similar environmental characteristics. Table 1 shows the station’s type and their location.
Figure 3. MRT Jakarta corridor and stations [12]

Table 1. Station types

<table>
<thead>
<tr>
<th>Stations</th>
<th>Station type</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lebak Bulus</td>
<td>3</td>
<td>Kartini Road</td>
</tr>
<tr>
<td>Fatmawati</td>
<td>3</td>
<td>Fatmawati and Street</td>
</tr>
<tr>
<td>Cipete Raya</td>
<td>1</td>
<td>Panglima Polim</td>
</tr>
<tr>
<td>Haji Nawi</td>
<td>1</td>
<td>Street</td>
</tr>
<tr>
<td>Blok A</td>
<td>1</td>
<td>Sisingamangaraja</td>
</tr>
<tr>
<td>Blok M</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Sisingamangaraja</td>
<td>2</td>
<td>Street</td>
</tr>
<tr>
<td>Senayan</td>
<td>3</td>
<td>J. Sudirman and M.H. Thamrin Road</td>
</tr>
<tr>
<td>Istorra</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Bendungan Hilir</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Setiabudi</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Dukuh Atas</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Bundaran HI</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

Type 1 Stations
Type 1 Stations are represented by Cipete Raya station. In this area, many interior decoration shops; a traditional market; clinic and hospital; house equipment and tool shops; sanitary shops; and a small mall can be found. The area in the vicinity of the street has one to two land uses per building with building characteristics as low-rise residential buildings and shopping buildings. The housing types are mid-rise, low-rise, town houses and small-lot single family houses. There are two types of open space: park and small park. This street is served by public transportation such as metromini, kopaja and small minibus.

Type 2 Stations
Type 2 stations are represented by Sisingamangaraja station. It is a conservation area and development is heavily restricted. This area has one to two land uses per building. There are offices, parks, schools, and a big mosque which attract people. The building characteristics of this area are mid-rise buildings and low-rise buildings. The housing types are mid-rise and low-rise townhouses. The open spaces are medium to large size parks. Various public transport services are provided in this street such as TransJakarta, city bus, metromini, and kopaja.
Type 3 Stations

Type 3 stations are represented by Bundaran HI. These stations located at Jenderal Sudirman and M.H. Thamrin road within the Jakarta CBD. The buildings in the vicinity of this road have more than two land uses per building with functions such as offices, big malls, hotels, embassies, university, sports fields, sports halls, stadium, concert space, exhibition hall, and car-free day location. High-rise and mid-rise apartments and condos and low-rise buildings can be found in this area. This area is served by public transport systems like TransJakarta, city bus, metromini, and kopaja. Open spaces in this area function as small plazas, sports fields or parking space. In this road, Dukuh Atas station is located. This is a local transport hub where many public transportation systems connect. It is expected to become the largest TOD location in the city because it will combine the MRT, LRT, a commuter line, TransJakarta, and the speed train to Soekarno-Hatta Airport. Lebak Bulus is a residential area, but it tends to develop into offices and commercials area although the development is limited due to the area’s function as a water catchment area in the Detailed Spatial Plan of Jakarta.

3. Research methodology

This study measures the potential level of TOD implementation in the MRT Jakarta corridor based on built environment characteristics – the five dimensions mentioned by Ewing and Cervero (2010). We determined the measurement by reviewing indicators from researches, such as measuring TOD by SMCA approach in city region Arnhem and Nijmegen, in The Netherlands and some variables of the built environment [4]. By combining these views and other previous research, the potential of future TOD for the MRT Jakarta corridor can be determined.

3.1 Measuring TOD

The indicators selected for the present study were derived from the 5Ds of the built environment indicators: density, diversity, design, destination accessibility, and distance to transit [4]. These TOD indicators were spatially quantified within a spatial scale of a 700-meter buffer around each transit station. The size of the buffer corresponds to a 10 minutes’ walk to/from the stations. Spatial Multi-Criteria Analysis (SMCA) was used to compute a TOD index for each station. All calculations were done using the software ArcGIS.

First, density was expressed by residential density, commercial density, and employment density. These indicators reflect the intensity of residential and employment development, which are measured for the potential of commuting in a TOD area. The original data for these density indicators are the number of jobs and land use data in Jakarta, measured using a data apportion for non-conterminous polygon method. This operation is used for disaggregating data from regional data into the area of interest for residential and commercial density, while the employment data was converted from small zone data into the area of interest. A higher density value contributes to a higher TOD level.

Second, the diversity of land use influences travels demand, because people can reach the facilities and the services within short distances. For instance, locating residential development near markets or health facilities and locating offices near shops, retail services, restaurants, banks, etc. makes the land use of an area diverse. There are different methods to calculate this indicator such as the notion of entropy, the popular Simpson index of land use diversity and the proportion of land use in one area [13][14]. To calculate the diversity of land use, this study uses the entropy method that was applied in the Dutch spatial context by Ritsema Van Eck & Koomen [15], which was also adapted by [13]. A high score indicates that the area has a higher mixed-ness of land use.

\[
LU_d(i) = -\sum Q_{li}(\ln Q_{li}) \ln (Q_{li}) (q_i)^{-1}
\]

(1)

\[
Q_{li} = S_{li} (S_i)^{-1}
\]

(2)

LU_i = Land use class within the buffer area i
Q_{li} = \text{The share of specific land use within the buffer area } i \\
S_{li} = \text{Total area of the specific land use within the buffer area } i

Third, the design dimension for the built environment is generally related to the street network. Street network design includes the shape of streets and sights of sidewalks on highly interconnected streets toward transit [4]. The convenient and pleasant design of streets positively influences pedestrians to walk. In this paper, street design indicators refer to the sidewalk condition and the presence of trees, benches, and lamps for pedestrians on sidewalk information. The data was collected during fieldwork and supported by google street view, while the presence of green open space data was acquired from Jakarta Capital City Government. Street indicators were sampled within half the radius of the TOD area, i.e. 350-meter buffer from each station because according to UDGL MRT Jakarta, this is the core area of transit movement that pedestrians are willing to walk to reach an MRT station.

Fourth, destination accessibility measures potential access to destinations. It can be categorized as regional and local destination accessibility [5]. Regional destination accessibility refers to the access from residential locations to business centres or the city centre, while local destination accessibility refers to access from residential areas to the nearest shops. The interaction potential is measured using gravity measurements considering population, employment, and travel time. This is measured with a formula adapted from Higgins & Kanaroglou [14]. For station areas oriented to population, the total interaction potential is quantified as:

$$DA_{ij} = \ln \left( \frac{\text{Pop}_i \times \text{Emp}_j \times (T_{ij})^{-1}}{g} \right)$$

\(\text{Pop}_i = \text{The total population in the labour force in station } i\)
\(\text{Emp}_j = \text{The total employment in station } j\)
\(TT_{ij} = \text{The travel time on transit between station } i \text{ and } j\)

The population data used for this indicator is the population in the labour force within the age range of 20 – 54 years old. We adopted another indicator for destination accessibility that seeks to measure the interchange possibilities to other bus-based systems at each MRT station. In Jakarta, these systems are the TransJakarta corridors, LRT corridors, the speed train of Indonesia-China (KCI C) to Soekarno-Hatta Airport, commuter lines (regular train) and intercity or regular bus stations. Like Singh [16], interchange to other transit system indicator was calculated by measuring the number of different mode stations and the average of walking distance to the other mode stations. If there is more than one station in the same mode or corridor within the station area, the nearest station will be adopted. A higher number of different mode station implies a higher destination accessibility. which is illustrated by a normalized value of 0 and 1, i.e., lowest to highest. In contrast, the higher the average walking distance of different mode station the lower the destination accessibility. Therefore, the normalized value from 0 to 1 represents the highest to the lowest contribution of this indicator. The total score of the interchange to other transit modes is the sum of the normalized values of both abovementioned indicators.

Fifth, distance to transit relates to the distance from origin to transit. This indicator shows how a station is reachable within 10 minutes walking in a circular buffer area [14]. It was calculated using the “closest facility” function of Network Analyst in ArcGIS. The closest facility was calculated from the centre point of each building to the nearest MRT station, through the road network. The average value of the distances was calculated for every TOD area.

The TOD index was computed using the abovementioned indicators, within a spatial scale of a 700-meter buffer. SMCA was used to calculate the index at each station from the indicators computed using ArcGIS. In addition, we hypothesize that not every indicator contributes the same weight to the TOD
index. Therefore, we have conducted a survey with 14 local stakeholders (Jakarta Capital City Government, Non-governmental Organizations (NGO), urban planners, academia/university, MRT Jakarta operators, and the private sector). The questionnaire asked respondents to rank the indicators for the three types of MRT stations. The result is a weighed TOD score for each of the 13 MRT stations.

Table 1. TOD indicators, data, format and source

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Indicator</th>
<th>Data requirement</th>
<th>Year</th>
<th>Format</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>Residential density</td>
<td>Land use map</td>
<td>2010</td>
<td>Shp</td>
<td>Government of Jakarta</td>
</tr>
<tr>
<td></td>
<td>Commercial density</td>
<td>Administrative boundaries</td>
<td>2010</td>
<td>Shp</td>
<td>Government of Jakarta</td>
</tr>
<tr>
<td></td>
<td>Employment density</td>
<td>Number of employment</td>
<td>2011</td>
<td>Shp</td>
<td>ITC (Previous research)</td>
</tr>
<tr>
<td>Diversity</td>
<td>Land use diversity</td>
<td>Land use map</td>
<td>2010</td>
<td>Shp</td>
<td>Government of Jakarta</td>
</tr>
<tr>
<td>Design</td>
<td>Sidewalk condition</td>
<td>Sidewalk figures</td>
<td>2015</td>
<td>image</td>
<td>Google Street view</td>
</tr>
<tr>
<td></td>
<td>Green open space</td>
<td>Green open space area</td>
<td>2016</td>
<td>Shp</td>
<td>Government of Jakarta</td>
</tr>
<tr>
<td></td>
<td>Trees, benches, lamps</td>
<td>Sidewalk figures</td>
<td>2010</td>
<td>image</td>
<td>Google Street view</td>
</tr>
<tr>
<td></td>
<td>Number of employment</td>
<td></td>
<td>2011</td>
<td>Shp</td>
<td>ITC (Previous research)</td>
</tr>
<tr>
<td></td>
<td>MRT lane and stations</td>
<td></td>
<td>2014</td>
<td>Shp</td>
<td>Government of Jakarta</td>
</tr>
<tr>
<td>Destination accessibility</td>
<td>Road network map</td>
<td></td>
<td>2010</td>
<td>Shp</td>
<td>Government of Jakarta</td>
</tr>
<tr>
<td></td>
<td>LRT plan Map</td>
<td></td>
<td>2015</td>
<td>Pdf</td>
<td>Government of Jakarta</td>
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<tr>
<td></td>
<td>BRT lane and station</td>
<td></td>
<td>2015</td>
<td>Shp</td>
<td>Open Street Map</td>
</tr>
<tr>
<td></td>
<td>Speed train to airport lane</td>
<td></td>
<td>2015</td>
<td>Pdf</td>
<td>Government of Jakarta</td>
</tr>
<tr>
<td></td>
<td>MRT lane and stations</td>
<td></td>
<td>2014</td>
<td>Shp</td>
<td>Government of Jakarta</td>
</tr>
<tr>
<td></td>
<td>Big station of buses</td>
<td></td>
<td>2015</td>
<td>Shp</td>
<td>Open Street Map</td>
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<td></td>
<td>Commuter line</td>
<td></td>
<td>2015</td>
<td>Shp</td>
<td>Open Street Map</td>
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<tr>
<td>Distance to transit</td>
<td>Road Network Map</td>
<td></td>
<td>2010</td>
<td>Shp</td>
<td>Government of Jakarta</td>
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<tr>
<td></td>
<td>MRT lane and stations</td>
<td></td>
<td>2014</td>
<td>Shp</td>
<td>Government of Jakarta</td>
</tr>
<tr>
<td></td>
<td>Building footprint</td>
<td></td>
<td>2017</td>
<td>Shp</td>
<td>Open Street Map</td>
</tr>
</tbody>
</table>

3.2 Determining the potential for TOD
After calculating the TOD index for each station, the next step is to define strategies for TOD improvement. Stations with higher levels of TOD were used to learn how these stations can reach a high level of TOD in terms of its characteristics. An evaluation of these strategies is required to understand whether the strategies are applicable in the field or not. The strategies are focused on the spatial planning of land use, infrastructure, and urban design. Table 3 shows the documents that were used to support the definition of the detailed strategies for TOD improvement at each station level.

4. Results
4.1 Measuring TOD
The result of the TOD index measurement is a single index for every station. For visualization purposes, the index was classified into three levels, representing low, medium and high levels of TOD. In addition to the map of Figure 3, spider diagrams (Figure 4 to 7) show the performance of each TOD indicator. Based on the calculation, Haji Nawi station has the lowest TOD index and Istora station has the highest TOD index (0.33 and 0.74, respectively).
Table 2. Documents revised for the determination of strategies

<table>
<thead>
<tr>
<th>Documents</th>
<th>Type</th>
<th>No/ Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial Planning of Jakarta 2030</td>
<td>Regional Regulation</td>
<td>1/2012</td>
</tr>
<tr>
<td>Detailed Spatial Planning of Jakarta</td>
<td>Regional Regulation</td>
<td>1/2014</td>
</tr>
<tr>
<td>Urban Guide Line Design MRT Jakarta Phase I</td>
<td>Governor Regulation</td>
<td>182/2012</td>
</tr>
<tr>
<td>Guide Line of TOD Development area</td>
<td>Draft Guideline</td>
<td>2017</td>
</tr>
<tr>
<td>SITRAMP for JABODETABEK Phase I</td>
<td>Report of Masterplan study</td>
<td>2001</td>
</tr>
<tr>
<td>Regional Spatial Arrangement of Kebayoran Baru</td>
<td>Governor Regulation</td>
<td>146/2016</td>
</tr>
<tr>
<td>Preservation and utilization of environmental and cultural heritage buildings</td>
<td>Regional Regulation</td>
<td>9/1999</td>
</tr>
<tr>
<td>Granting Compensation exceeds of the building floor coefficient</td>
<td>Governor Regulation</td>
<td>210/2016</td>
</tr>
</tbody>
</table>

Figure 4. TOD Index [12]

The Top Three Stations

Figure 4 presents spider diagrams of the top three stations (stations with highest TOD indexes). All stations have high values for the diversity indicator, expressing the high mix of land use around each station area. For destination accessibility, Dukuh Atas station has the highest score because it contains many other transit points with adjacent walking distance from the MRT station and it has high interaction with other stations. Istora scores the highest for the design indicator, followed by Senayan. These two areas score high in this dimension because the station areas are adjacent to a sports arena, with huge green open spaces. However, the influence of the density characteristic on Istora is lower than for the two other stations because few people work or live in the sports arena and exhibition area.
The stations classified as medium-level TOD are Blok M, Sisingamangaraja, Setiabudi and Bendungan Hilir station. The scores of each TOD indicator are shown in figure 5. In all cases, indicator scores for density, diversity, and design are medium (around 0.5), except for one station, Blok M, which has a high destination accessibility due to its good interaction with other transit services. However, distance to transit is low for all stations, meaning that the stations cannot be reached easily by pedestrians.

The Bottom Six Stations

The stations classified as low-level TOD are Bundaran HI, Cipete, Lebak Bulus, Fatmawati, Blok A and Haji Nawi. The indicator scores of the stations are shown on the spider diagrams in figure 6. In general, all of these stations score low for almost all of the indicators.

Surprisingly, Bundaran HI station being in the CBD, with a huge number of activities, has an overall low-level TOD. The distance to transit indicator scores lowest, meaning pedestrians cannot easily reach the station. This could be because this area has long blocks and pedestrians must walk farther to access the station. Cipete, Blok A, and Haji Nawi station have an almost similar pattern of TOD measurement but the distance to transit of Cipete station is prominently higher than the others. Fatmawati and Lebak Bulus have a similar spider diagram pattern. Overall, all stations need much development toward TOD implementation.

Figure 5. Spider diagram for the stations with high-level TOD

Figure 6. Spider diagram for the stations with medium-level TOD
4.2 Determining potential for TOD

To determine the improvement strategies, we made comparisons between the low and the high-level TOD of each station type. The idea is to make an internal benchmark, i.e., comparing the TOD index within a typology because we assume that stations of the same type may have same environmental characteristics and therefore will get the same treatment from people and government. Strategies will potentially be easier to implement when we learn from the strength of other stations with a higher index. After that, the strategies were evaluated using the applicable regulations and policies of the city. The typologies were discussed previously in section 2.

Strategies for Stations Type 1

All three stations of this type were classified as having low TOD level. Based on these results and after revising the regulations, Cipete, Haji Nawi, and Blok A should be developed as high density mixed areas with a dominant socio-cultural residential function. This can be achieved by building additional floors in one-story residential or landed houses, which are intended for multi-cultural and multi-social strata residents. This strategy is in line with stakeholder opinions, who suggest the balancing of socio-economic diversity for high-quality TOD. However, these areas still need other functions or attractions to improve the diversity characteristic. Some areas that have purely residential land use should consider mixing the land use. The timeline for land use improvement needs further studies, although some of the interviewees said that the land use changes are possible within a five-year period.
Some areas around Blok A station include conservation areas and cannot expand development, implying that the density characteristic can only be improved by maximizing the potential building floor area from special provisions on zoning regulation and utilizing the incentive of additional floors for buildings, or utilizing the active corridor of this area for commercial functions to increase density. Diversity can be increased by the development of green space areas on land acquired, especially because the vision of this conservation area is “a green and dynamic restoration area” [17].

One problem for diversity development is the land acquisition in these three stations. According to the stakeholders, the stage of land acquisition is one of the problems for construction, for example, the development of pedestrian paths toward the stations and the rearrangement of the road network within the TOD area, which will influence the distance to transit characteristic. Consequently, if the land is available, it will easier to develop all TOD characteristics. Another implication for the design dimension, according to interviewee 5 (urban planner), is that the microclimate should also be considered because it influences people to walk. Jakarta has a tropical climate; the highest temperature in October is 30.21°C and the lowest in February is 27.76°C with humidity ranging from 54 to 98 percent [18]. It is not pleasant to walk, especially in the afternoon. The strategies include mass building arrangements such as arranging the height of buildings to accommodate wind flow, planting big trees, and considering building facades, wall paint colours, glass, and pavement types.

The other aspects that influence the design dimension are the fence, frontage, and side back of the building. First, the building system in Indonesia recommends fences for safety. According to a stakeholder, these fences increase the distance between the building and the sidewalk, which gives a perceived uncomfortable feeling because pedestrians feel alone when they walk. Second, the frontage building design of, for example, shops or commercial buildings with glass design in the shop window, makes pedestrians feel more comfortable and not alone. In addition, because almost all buildings in Jakarta have air conditioners; when the shop door is open this makes people feel refreshed from the heat. Figure 8 shows people sitting in front of buildings to take a rest and feel the air conditioner from the entrance of the buildings. Also, these stations are elevated, which suggests to close off the stations and complement them with canopy for the vertical circulation and platform structure to protect passengers from rain and high temperatures [11].

Figure 8. Spider diagram for the stations with high-level TOD

Regarding the destination accessibility indicator, according to SITRAMP and network planning from the government, there is no plan for mass public transportation besides the MRT along Fatmawati Street (where the Haji Nawi, Cipete, and Blok A stations are located). However, improvements can still be achieved by improving the services and existing infrastructure in the proposed TOD area, for example, the planned LRT, TransJakarta or local bus/express bus. This suggestion for mass transit development is also mentioned in the Jakarta spatial planning 2030 document and the draft guideline of TOD.
Strategies for Stations Type 2

All three stations of this type were classified as having low TOD level. Based on these results and after revising the regulations, Cipete, Haji Nawi, and Blok A should be developed as high density mixed areas with a dominant socio-cultural residential function. This can be achieved by building additional floors in one-story residential or landed houses, which are intended for multi-cultural and multi-social strata residents. This strategy is in line with stakeholder opinions, who suggest the balancing of socio-economic diversity for high-quality TOD. However, these areas still need other functions or attractions to improve the diversity characteristic. Some areas that have purely residential land use should consider mixing the land use. The timeline for land use improvement needs further studies, although some of the interviewees said that the land use changes are possible within a five-year period.

In addition, contributing to the design indicator, pedestrian paths should be improved through the base floor of commercial buildings, yards, or parks and new outdoor pedestrian paths to make easier for pedestrians to reach the stations. This will also benefit the distance to transit characteristic. The design dimension will also improve with increasing the quality of pedestrian paths and equipping them with trees, benches, lamps, canopy, and green spaces alongside the paths.

For density, the strategy could be to utilize the incentive of additional building floors and utilizing activities allowed in the zoning regulation within a radius of no more than 300 meters from the station. As for diversity, some areas can still be developed into a residential function. For Blok M, the existing residential land use is only 37 percent. Additionally, improving green open spaces can improve both diversity and design of this area.

Strategies for Stations Type 3

Six stations have typology 3, but to help the visualization and discussion, stations with lower-level TOD are illustrated in Figure 10 whereas high-level TOD stations are seen together in Figure 11.
The same strategies as mentioned before are applicable for improving the design dimension, such as constructing new green open spaces, and good pedestrian paths toward stations. Additionally, the fences of buildings and the building frontage should be more pedestrian-friendly.

“...to beautify the sidewalk, it is not only wide but has attractive frontage such as no fences and no car parks which cause people to not be interested to walk... for the outdoor, having scenery can make people distracted about distance or creating a sidewalk with a roof like a canopy can stimulate people to walk more.” Interviewee - Planner

For the diversity indicator, an adjustment of land use in these proposed TOD areas is necessary to meet the requirements of the Draft TOD Guideline from the Ministry of Agrarian and Spatial Planning of Indonesia, which plans a composition of space utilization of 30 percent for residential and 70 percent for other uses. Meanwhile, the proposed TOD areas should have less existing residential land use. Some of residential land use should be changed to office and services uses, as well as social and public facilities function to place infrastructure that supports transportation. According to an interviewee, the adjustment of land uses can be done in five years from this detail spatial plan set up, together with the interventions of the density characteristic. In addition, utilizing the building floor incentive is applied along the Fatmawati road.

“The Detailed Spatial Plan of Jakarta should be revised. It will be revised in 2019.” Interviewee – Government official

For the destination characteristic, Fatmawati TOD area, which is only served by MRT as mass public transportation, is located at the edge of Jakarta, where people from suburbs come into Jakarta. Consequently, it will increase the destination accessibility characteristic. For distance to transit, the strategies are to avoid constructing large blocks on the side of the MRT corridor, to corporate with building owners and to incorporate the incentive of building floors. As for the design characteristic, the objective is to provide pedestrian paths through the base floor of buildings towards the station, so that pedestrians can easily reach the station.

“Private sectors are very enthusiastic to support TOD development. Compensation exceeding KLB due to MRT construction should be used for MRT development”. Interviewee – NGO
5. Conclusions and recommendations

This study was conducted to determine the potential for TOD development along the new corridor of MRT Jakarta. To measure the potential for TOD at each station, the concept of the 5D characteristics of the built environment was adopted [2][4]. This concept provides a comprehensive way to incorporate important aspects of TOD to measure the existing TOD level. This was done by developing a TOD index, which was calculated using Spatial Multi-Criteria Analysis with stakeholders’ involvement to determine the importance of the criteria, which was used to calculate weighted scores for the index.

The literature review provided insight into the important characteristics and indicators related to the study area that would need to be considered to measure the TOD index. Stakeholders were involved in two parts: first, evaluating the weight of the ten indicators that were selected to measure TOD index and second, providing additional information for the feasibility of TOD development in the study area. From the prioritized calculations based on stakeholders’ questionnaires, the three dimensions of density, diversity, and design are the key aspects of the pedestrian-friendly characteristic for ideal TOD development. These “3D” indicators are well established in the literature as the most prominent TOD criteria [2]. The stakeholders expressed that design and distance accessibility characteristics related to the transit system are the most important for TOD development in the study area.

The spatial analysis calculation shows that only three out of thirteen stations have high levels of TOD, while six are classified as having low TOD levels. Consequently, the proposed TOD areas need improvement. The areas that score a low TOD level need improvement in all 5D characteristics. With the use of spider diagrams, we have visualized which improvements would need to be made in the low scoring areas for these to achieve higher TOD values.

The type 1 stations should emphasize the new construction and development of the land acquisition because new development is crucial for sustainable TOD. The type 2 stations should focus on the development within a 300m buffer from the station, with for example a recreation area and the development of green space. The stations of type 3 should emphasize good connections to the stations including rearranging the fences to create pedestrian-friendly environments. For example, Fatmawati station needs a lot of improvement because it has a low level of TOD but it is located as a gateway to the city centre for people from suburban areas. The improvement should include regulations that can support the implementation of the TOD developments that have been suggested in this paper, such as the policy about FAR, minimum green space percentage in TOD area, incentives for buildings with good design and accommodating pedestrian flows. Also, the regulations should cover the cooperation and business model between the government, operators, and the private sector in the TOD area to assure the operational implementation because the cooperation and the business models of these three institutions are very important for implementing the strategies that promote TOD development successfulness in the study area.

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