Measuring pedestrian accessibility of Transit Oriented Development area in surabaya (a study case: Joyoboyo Terminal)

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Abstract. The Surabaya government has embarked development of urban public transportation to reduce the tendency of private vehicle usage. Urban transport development is also coupled with strategic planning for development around stations, known as transit-oriented development (TOD). The TOD areas are still in pre-development planning phases as the Surabaya mass rapid transit project has not started yet. One of the pre-development planning TOD in Surabaya is Joyoboyo Terminal. This research aims to evaluate Joyoboyo TOD readiness to represent the area where people are physically able to walk. The accessibility of Joyoboyo TOD measured by distance traveled to Joyoboyo terminal. Findings showed only 53.04% of Joyoboyo TOD is accessible in current condition and it is increased 6.7% if scenario 2 applied. The accessibility map represents a suitable area for public space and a decent area for high-density housing in Joyoboyo TOD. These findings represent the basis requirements for developing a TOD area in Surabaya, especially Joyoboyo TOD.

1. Introduction

The development of an urban economy in a city is characteristics by high movements within it. Surabaya is one of the business cities with various activities that take place. Tremendous heavy traffic flow in Surabaya has encouraged the government to expand new roads in the city, for example, construction of frontage road in the east and west side Ahmad Yani Street, construction of Middle East Ring Road (MERR) and other ring roads planning. In recent years, the new challenge of planning a city is limited street spaces with increasing activities. Besides that, urban development must begin to leave dependence on private vehicles and provide convenience for its inhabitants [1,2]. Thus, a city development that involves the integration of human activity and movement in Surabaya is important. One of the development concepts that apply it is Transit-Oriented Development (TOD).

TOD is a city planning concept to concentrate a mix density and good pedestrian development around transit stations to promote transit riding, thereby increasing walking and bicycle travel and reduce the use of the private vehicle [3]. The operational of TOD projects are on the individual region or street within station areas. However, planning needs to be conceptualized at multiple interrelated scales as shown in Figure 1. A city-region scale provides a point of intervention for TOD as a policy in statutory documents, such as city master plan or development plan. Corridor scales ensure that development at one station complements development at other stations, resulting in a network of transit-oriented places. Station area scales focus on areas surrounding transit stations in less than 800 meter of walking distance.
Site-level scales focus on individual developments within a station area, includes a target for internal circulation, building design, and parking [4].

![Scales of Transit Oriented Development](image)

**Figure 1.** Scales of Transit Oriented Development
(*re-draw from: [4]*)

Some countries have published the TOD’s guidelines related to its principle. The tabulations in Table 1 shows the principles of TOD that found in all guidelines are walk, easily transit, and densify. This research will focus on the potential and its opportunity of TOD in Surabaya with principles for a walk and easily transit, especially distance to transit. [5]

| TOD Principle | Short Definition                                                                 | Source |
|---------------|----------------------------------------------------------------------------------|--------|
| Walk          | Build an environment that supports pedestrians-friendly streets and makes walking enjoyable. | [6–10] |
| Bicycle       | Favor non-motorized transportation networks, such as bicycle                      | [6,7,9,10] |
| Connected Sidewalk | Create a dense and convenient pedestrian connection                              | [9,10] |
| Easily Transit | Placing the development near high-quality mass public transport networks and can be accessed by walking | [6–10] |
| Mixed-Use     | The development with mixed land use, income, and demographics.                    | [6–8,10] |
| Densify       | Optimize space density and adjust public transport capacity.                      | [6–10] |
| Compact Building | Build areas with interconnected streets and short travel distances.              | [8–10] |
| Shift Mode    | Increase the mobility of changing transportation modes.                          | [7,8,10] |
| Good Design   | Build a TOD area with a touch of stunning architectural building and street design | [6–9]   |

Some Asian cities began to develop their cities into transit-oriented and promoting public transit to commute [11]. A good public transit network connectivity between the workplace and daily activity locations might encourage people to consume around transit station areas [12]. Global experiences evidence that the integration of a good public transport system and land use can give a huge benefit for sustainability in the city [3]. From the recent research, the private vehicle users from Joyoboyo have better accessibility to Surabaya Central Business District than public transport users [13]. Surabaya Government slowly began to focus on improving public transportation to reduce the tendency of using a private vehicle. Studies on the development of rail-based mass rapid transit in Surabaya have been conducted since 1994. The proposed Surabaya Mass Rapid Transit (SMART) is consists of two corridors, north-south (served by Suro-Tram) and east-west (served by Boyo-Rail). Those two corridors meet in Joyoboyo Terminal, therefore this research was designed to explain the accessibility of Joyoboyo TOD.

**2. Study Area**
Surabaya city is located on the northern coast of East Java province. From the proximity of the city center and transit points, TOD is very potential to be applied in Surabaya [14]. One of those transit points is Gubeng Station that delimited into a 700-meter radius and divided it into 7 blocks of TOD, see
And another transit point in Surabaya is Joyoboyo. In 2014, Surabaya Government did research relate to city corridor development. From the research has selected 5 potential locations along the Surabaya Mass Rapid Transit (SMART) corridor to be development areas, and one of them is Joyoboyo [15]. From Figure 1, Joyoboyo TOD is planned to be station area scales. Within 800-meter walk radius, Joyoboyo TOD divided into 5 blocks, as shown in Figure 2. The google earth view of each TOD blocks shown in Figure 3.

Figure 2. Delineation TOD Area in Surabaya [16,17]

![Google Earth View of Joyoboyo TOD Blocks]

Figure 3. Five Block of Joyoboyo TOD in Google Earth View

In this research, pedestrian accessibility of Joyoboyo TOD will be calculated with three following calculation. Those are at current condition; with scenario one; and with scenario two.

2.1. Current Condition Scenario
In this current condition of Joyoboyo, only 4 pedestrian crossing bridges within the planned of TOD area. Those pedestrian crossings are near Surabaya Zoo (KBS); Darmo Trade Centre; Pegadaian Office; and Wonokromo Station, see in Figure 4. People from Block 3, 4 and 5 only served by those 4 pedestrian crossings. Thus in first calculation will determine the pedestrian reachable radius in current condition of Joyoboyo.

2.2. Scenario One
Current stage of Joyoboyo development is the construction of Joyoboyo bridge. This 150 meter bridge spans between block 1 and 2 in front of Joyoboyo terminal. Joyoboyo bridge will provide better connectivity between the main road and Joyoboyo terminal, see in Figure 4a. Thus in second calculation will determine pedestrian reachable buffer zone if Joyoboyo bridge has been built.
2.3. Scenario Two
Four pedestrian crossings within Joyoboyo TOD are located far from transit point, Joyoboyo terminal. Thus in third calculation will determine pedestrian accessibility if added one pedestrian crossing bridge near Joyoboyo terminal and the Joyoboyo bridge has been built. Location of pedestrian crossing bridge spans between block 1 and block 3, see Figure 4b.

3. Methodology
This section demonstrated research method which consists of observation survey in TOD area, digitize all streets within TOD area, identification of walking route from TOD area to transit point, calculate the shortest distance, re-calculate the shortest distance with scenario applied, and mapping walk accessibility of Joyoboyo TOD using ArcGIS, see Figure 5.

![](image1.png)

**Figure 5. Research Methodology**

This research needs to adopt the ideal standard walking radius for TOD area. People are tend to choose public transport if its within ¼ to ½ mile walk to passenger stop [7]. Some city that developed TOD mentioned that TOD area has within half mile walking radius, with greater intensity and mix of land uses in the one-quarter mile radius of a transit stop. New Jersey Commerce Commission, Denver Community Planning and Development (CPD) and Center for Transit-Oriented Development (CTOD) designed TOD should be planned in a half mile radius around rail stations [18–20]. In California, North Carolina and Mexico, TOD has designed in less than one-quarter mile from center to edge, as its defined as the TOD boundary [4,7,18]. In Indonesia, TOD is developed within half mile walking distance. According to Indonesia ministerial regulations, TOD divided into public area, commercial area, and housing area. The public and commercial area are planned in 400 meter walk (¼ mile) and the housing area in 800 meter walk (½ mile) [21].

Depends on some research above, the accessibility were evaluated based on a standard 400 meter or 800 meter walking distance to transit point. The walking distance obtained from analysis is classified into 17 classes, as seen in Table 2. Those classification number will be added to ArcGIS to create an accessibility map.
Table 2. Classification of Walking Distance

| Distance          | Class | Colour Indicator in Map |
|-------------------|-------|-------------------------|
| 0 – 100 meter     | 1     |                         |
| 101 – 200 meter   | 2     |                         |
| 201 – 300 meter   | 3     |                         |
| 301 – 400 meter   | 4     |                         |
| 401 – 500 meter   | 5     |                         |
| 501 – 600 meter   | 6     |                         |
| 601 – 700 meter   | 7     |                         |
| 701 – 800 meter   | 8     |                         |
| 800 – 900 meter   | 9     |                         |
| 900 – 1000 meter  | 10    |                         |
| 1000 – 1100 meter | 11    |                         |
| 1100 – 1200 meter | 12    |                         |
| 1200 – 1300 meter | 13    |                         |
| 1300 – 1400 meter | 14    |                         |
| 1400 – 1500 meter | 15    |                         |
| 1500 – 1600 meter | 16    |                         |
| 1600 – 1700 meter | 17    |                         |

4. Result and Discussion

4.1. Characteristic of Joyoboyo TOD

Principles of a transit-oriented development area consist of the walk; bicycle; connected sidewalk; easily transit; mixed-use; densify; compact building; shift mode; and comfortable design area. In walk; connected; easily transit and comfortable design area can be assessed with proper or not the streets within TOD. Five blocks of Joyoboyo TOD are located in Wonokromo Subdistrict. From an observation survey, only 21% of streets have a sidewalk, as seen in Figure 5. This number has shown that most of the pedestrians in Joyoboyo TOD still mixed with motorized traffic because does not have pedestrian separation structure or sidewalks. This might make pedestrians feel uncomfortable and insecure while walking to a destination within the TOD area.

![Figure 6. Sidewalk Availability and Street Width in Joyoboyo TOD](image)

Another data obtained from observation survey is 66% of the streets has a width less than 5 meters, while 13% of it is less than 2.5 meter. For example Bumi Arjo street in Block 1 only has 1.2 – 1.7 meter street width and the sidewalk is less than 1 meter. Whereas block 1 is the location of Joyoboyo terminal and future to be tram and monorail station. The typical of block 2 is residential area with the average street width is around 2 – 6.8 meters without sidewalk. Wide and good condition of sidewalks is found in block 3. The sidewalk in Block 3 already equipped with guiding blocks, trash bins, and street tree canopy cover along it.
4.2. Accessibility of Joyoboyo TOD

Accessibility is a measure of comfort or convenience about the interaction of land use with one another [22]. Indicators of accessibility can be simply stated by travel distance, travel cost, and travel time [23]. Basri (2012) measures the accessibility of Depok city with direct measuring to the field use stopwatch and motorcycle. He took some parameters such as distance; running time and access time then analyze with gravity mode. In Jakarta, Ilahi & Axhausesn (2017) measures accessibility in Jabodetabek by using an Activity Based Model. Daily activities of respondents in Jabodetabek are then simulated by geocoded MATsim at the destination location. Corodescu (2014) proposes a new accessibility index of rural space in Vaslui. Bilasco et al. (2018) identify the road accessibility in Alba by calculating access time using spatial analysis. In this research use walking distance to transit point as accessibility indicator. The high TOD accessibility can be characterized by the 'safe, uninterrupted, and interconnected’ access to pedestrians within the block and also has less than 800 meter distance to transit point.

The process of mapping pedestrian accessibility began with preparing the base data. Those base data are consist of TOD delimitation, street networks and the walking distances. The first step is pick all boundary coordinates of each block on Google Earth. Those boundaries then added to ArcGIS with the coordinate system 'WGS_1984_UTM_Zone_49S', as shown in Figure 6a. The next step is digitize or trace all the street networks within blocks, in this step activate 'open street map' as the base map is necessary. From the street network tracing, 1150 streets link are made in ArcGIS. Results of street network digitizing can be seen in Figure 6b.

![Figure 7. Digitizing Street in ArcGIS](image)

The length of each street link can be displayed in ArcGIS by adding 'calculate geometry' in the column bar and has less than 100 meters each link. Length data used to calculate the walking distance to transit point, Joyoboyo terminal. The distance from a point to Joyoboyo terminal can be calculated with sum up all the links length that is passed into Joyoboyo terminal. A parameter to measure TOD accessibility is the distance to transit point. For example, to calculate the distance from point A to transit point (Joyoboyo Terminal) use manual calculation, as follows:

![Figure 8. Distance Traveled From Point A to Joyoboyo Terminal](image)

\[
\text{Distance from A to TJ} = \sum \text{Length of link number 19;18;17;16;15;14;57;56;55;54;53} \\
= 22 + 16 + 19 + 17 + 10 + 18 + 39 + 21+24+24+ 37+27 \\
= 250 \text{ meter}
\]
The example above shows the distance from point A to Joyoboyo terminal is 250 meter. From the calculation for all street links, it obtained 1150 x 3 data of distance to Joyoboyo terminal. The farthest walking distance was found from a point in block 5, as far as 1.63 km in current conditions; 1.55 km in scenario 1; and 1.42 km in scenario 2. Those 3450 data of classified according to its class, see Table 2.

All classified numbers of distance traveled imported to ArcGIS to create an accessibility map. The accessibility map can be seen in Figure 9. This map shows reduced distance within Joyoboyo TOD if scenario 1 and scenario 2 applied. Percentage of each classified number shown in Figure 9, consist of walking distance in current condition; scenario 1; and scenario 2.

Table 2 shows walking distance to transit point <400 meter is classified in class 1 – 4; <800 meter in class 1 – 8; and walking distance >800 meter in class 9 - 17. In Figure 10 shows only 11.3% of the Joyoboyo TOD in current condition has walking distance to transit point in <400 meter; 53.04% in <800 meter; and 46.96% is more than 800 meter. Refer to the regulation of TOD in Indonesia, the number above means only 11.3% of Joyoboyo TOD accessible for public area and 53.04% accessible for a residential area at the current condition.

If scenario 1 applied, it shows 12.2% of the Joyoboyo TOD has walking distance to transit point in <400 meter; 55.57% in <800 meter; and 44.43% is more than 800 meter. With Scenario 1, it increased 0.9% buffer zone for public area and 2.52% buffer zone for a residential area in Joyoboyo TOD, especially in block 2.
When scenario 2 applied shows 14.7% of the Joyoboyo TOD has walking distance to transit point <400 meter; 59.9% in <800 meter; and 40.1% is more than 800 meter. Scenario 2 increased 3.4% buffer zone for public area and 6.80% buffer zone for residential area in Joyoboyo TOD, especially in block 2, block 3 and block 4. The improvement of pedestrian reachable radius for public and residential area in Joyoboyo TOD if scenario 1 and 2 applied shown in Figure 11.

![Accessibility Map of Joyoboyo TOD for Public and Residential Area](image)

Figure 11. Accessibility Map of Joyoboyo TOD for Public and Residential Area

Joyoboyo TOD area, within 400-800 meter walk, has to be a walkable place that provides daily activities, such as shopping; school; public spaces; jobs and also housing. Joyoboyo terminal is already provided with those daily activities within 800 meter walk. But from the observation survey was found that most of Joyoboyo area not sufficient yet for pedestrian. Several studies found that good urban design always favours to prioritize pedestrians [3,11,28]. In Madrid, limitation on road access for private vehicle in city increased to 9.5% in retail revenue [29]. If the Joyoboyo development create a walking distance close and comfort, it will attract more people to transit, walk and shop in Joyoboyo. From Figure 10, it shows where recommend area to improve a safe and pleasant pedestrian facilities in Joyoboyo.

5. Conclusions
The objective of the present research is evaluation walking accessibility TOD in Surabaya and selects Joyoboyo as the research object. Depending on data availability, the accessibility was evaluated based on walking distance traveled to transit point. ArcGIS adoption was used to picture the variation of pedestrian accessibility. Despite Joyoboyo TOD has delimited in an 800 meter radius, but the research finds that only 53.04% area accessible within less than 800 meter walk. It means that 46.96% of the Joyoboyo TOD area is not accessible within 800 meter walk at current condition. By applying scenario 2, when the Joyoboyo bridge had been built and added pedestrian crossing bridges near Joyoboyo terminal, it shows an improved accessible area to walk. In Figure 10 represents where a suitable area of
Joyoboyo TOD that people are physically able to walk in less than 800 meter walk. Regulation of TOD in Indonesia explains the 800 meter walk to transit point area has to be a walkable place that provides daily activities like jobs, schools, urban plazas, shopping, and high-density housing. This research strongly believes that provide comfortable walking experience within a TOD area can enhance the living environment with a pedestrian-friendly area. Therefore, improvement of walking accessibility in Joyoboyo TOD is needed to make it convenient for residents or people to travel by foot and public transportation as well as using a private vehicle. Lastly, it need a concerted effort from the government and stakeholders to make sustainable development of Joyoboyo TOD.

6. References
[1] Nope K B N, Suthanaya P A, Wedagama D M P and Astana I N Y 2020 The Jakarta TOD model application for typology of middle cities (applied research design in Kupang city) Geogr. Tech. 15 103–12
[2] Kunzig R 2019 The Cities Issue Natl. Geogr. Mag.
[3] Robert C 2006 Public Transport and Sustainable Urbanism: Global Lesson (California: California Digital Library)
[4] World Bank Group 2018 TOD Implementation Resources and Tools
[5] Sullivan A O 2003 Urban Economics (New York: McGraw Hill)
[6] Calthorpe Associates 1990 Transit Oriented Development Design Guidelines (Edmonton)
[7] California Dept. of Transportation 2002 Statewide Transit-Oriented Development Study Factors for Success in California
[8] The City of Calgary 2004 The city of Calgary (land use planning & policy) : transit oriented development - best practices handbook
[9] The City of Edmonton 2012 Transit Oriented Development Guidelines (Edmonton: Sustainable Development and Transportation Services Departments)
[10] ITDP 2017 TOD Standard vol 3 (Jakarta: ITDP)
[11] Kidokoro T 2019 Transit Oriented Development Policies and Station Area Development in Asian Cities (Tokyo)
[12] Thompson G L and Matoff T G 2003 Keeping Up with the Joneses: Radial vs. Multidestinalional Transit in Decentralizing Regions J. Am. Plan. Assoc. 69 296–312
[13] Az-Zahra A and Ahyudanari E 2020 Competition measures of TOD point to Central Business Districts in Surabaya using travel time approach (a case study: Joyoboyo Terminal) IOP Conf. Ser. Mater. Sci. Eng. 930
[14] Handayani K D M E and Ariastita P G 2016 Sustainability of transportation in Surabaya through the development of transit oriented development areas J. Tataloka 16 108–15
[15] Hansen & SUTD Lab 2014 Surabaya Urban Corridor Development Program (Surabaya)
[16] Ramadhani V S and Sardjito 2017 Gubeng station transit area development priority with transit oriented development concept (Sepuluh Nopember Institute of Technology)
[17] Nadyla A and Nurlaela S 2018 Pengukuran Tingkat Keseimbangan Node dan Place di Kawasan Transit Oriented Development (TOD) Terminal Joyoboyo, Surabaya J. Transp. 1 100–5
[18] Shinkle D 2012 Transit Oriented Development in The States (Denver)
[19] Denver Housing Authority 2011 Connecting the West Corridor Communities
[20] Michael Hancock M B 2014 Connecting the West Corridor Communities (Denver: Denver The Mile High City)
[21] Ministry of ATR/BPN 2017 Ministerial Regulation No 16 Year 2017 about Guidelines for the Development of Transit Oriented Areas
[22] Black J A 1979 Urban Acessibility and Transport Policy Transp. Commun. Bull. Asia Pacific
[23] Miller E J 2018 Accessibility: measurement and application in transportation planning Transp. Rev. 38 551–5
[24] Basri H 2016 Measurement of accessibility index in Depok city with gravity model J. Rekayasa Teknol. Nusa Putra 3 1–14
[25] Ilahi A and Axhausesn K W 2017 Measuring accessibility using an activity based model approach
in Jabodetabek *Swiss Transp. Res. Conf.*

[26] Corodescu E 2014 GIS approach in assessing the rural space accessibility - Case study: Vaslui county, Romania *Geogr. Tech.* 9 20–30

[27] Bilasco Ş, Rosca S, Pacurar I, Moldovan N, Vescan I, Fodorean I and Petrea D 2018 Roads accessibility to agricultural crops using GIS technology, methodological aproach *Geogr. Tech.* 13 12–30

[28] Taki H M and Maatouk M M H 2018 Spatial Statistical Analysis for Potential Transit Oriented Development (TOD) in Jakarta Metropolitan Region *J. Geosci. Eng. Environ. Technol.* 3 47–56

[29] Reid C 2019 Closing Central Madrid To Cars Resulted In 9.5% Boost To Retail Spending, Finds Bank Analysis *Forbes*