

Enabling the Physical Elements of a Pedestrian Friendly District around a Rail Station for Supporting Transit Oriented Development

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Abstract—Rail-station area development that is based on the concept of TOD (Transit Oriented Development) is principally oriented to pedestrian accessibility for daily mobility. The aim of this research is elaborating how far the existing physical elements of a rail-station district could facilitate pedestrian mobility and establish a pedestrian friendly district toward implementation of a TOD concept. This research was conducted through some steps: (i) mapping the rail-station area pedestrian sidewalk and pedestrian network as well as activity nodes and transit nodes, (ii) assessing the level of pedestrian sidewalk connectivity joining trip origin and destination. The research area coverage in this case is limited to walking distance of the rail station (around 500 meters or 10-15 minutes walking). The findings of this research on the current condition of the street and pedestrian sidewalk network and connectivity, show good preference for the foot modal share (more than 50%) is achieved. Nevertheless, it depends on the distance from the trip origin to destination.

Keywords—Accessibility of daily mobility, pedestrian friendly district, rail-station district, Transit Oriented Development.

I. INTRODUCTION

IN the cases of the Indonesia rail station district, quality improvements of rail service and development commonly have not been integrated to rail district land use development. The low rate of rail station district livability and accessibility contributed to less passengers of commuter rail compared to road transport passengers in daily mobility.

Development of rail station areas with the concept of TOD encourages the creation of pedestrian-friendly neighborhoods. It will push the city's public transport performance and reduce the use of private vehicles in daily mobility. Pedestrian friendly rail station districts will encourage people to choose walking or bicycling or riding non-motorized transport in the near distance mobility (an average walking distance) inside the rail station district (≤ 500 meters).

For future development, Tugu and Lempuyangan rail station areas are appropriately developed according to its potential as the city's public transportation transit mode. Toward the area of rail-based TOD, a good pedestrian network should be developed as the basic component for a pedestrian-friendly area that supports TOD.

Questions that are the focus of this research are: "To what extent does the condition of the rail station area pedestrian

paths network represent a pedestrian-friendly district?" This research uses the case of Tugu rail station and Lempuyangan rail station neighborhoods in Yogyakarta, where currently land arrangements around stations to improve quality of rail transport services are being carried out.

Some studies related to pedestrian-friendly zones on TOD neighborhoods have been done with a variety of cases and scales of research areas as well as a variety of research methods. Research on a low density suburban neighborhood [1] proposed a model of TOD with several typologies: TOD in the pedestrian area, TOD in the area that slows the speed of motorized vehicles, as well as a transit-transfer station that is coordinated with an intermodal network. On the other hand, in the case of high density urban areas [2], research was conducted that examined how far TOD and its factors of planning have increased transit ridership.

The studies mentioned above are generally carried out in developed countries and in sub-tropical climates, while this research used the case of developing countries with tropical climates. The method used is also different, in these studies used mostly quantitative methods, whereas this study involves a mix of quantitative and qualitative methods.

II. THEORETICAL REVIEW

TOD is a form of transit area development that is located within a radius of 10 minutes' walk or approximately 0.5 mile (800 meters) from the transit station (light rail, heavy rail, commuter rail). This includes the development of a transit corridor area (buses, BRT, waterborne). Mixed land use of residential, retail, office, characterizes the TOD area. Principally, TOD is also characterized by a high density for enhancing proximity to transit access. High density is also required for encouraging the achievement of a pedestrian-friendly district [3], [4].

The physical condition of the transit district contributed to creating comfort through the good quality of the streetscape. It will encourage people to walk, reduce the use of motor vehicles and increase the use of the transit system. One of the things that led to the creation of a pedestrian-friendly district is the design of the street and pedestrian path network [5]. The character of the street network that contributes to the design features include a variety of spatial patterns, size of the block of lots, the proportion of street intersections and the number of intersections in certain unit of area. In this case, the various components of street space could determine the degree of friendliness to pedestrians, i.e. the sidewalk coverage, building

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setback, the width of the street space, the number of pedestrian crossings, the trees along the street space as well as physical components that distinguished a pedestrian-oriented environment with an auto-oriented environment.

In establishing a pedestrian-friendly district, the quality of neighborhood walkability (design for walkability) is essentially needed. Walkability is defined as the comfort and safety in walking on a pedestrian path network formed by the built environment [6]. Walking activities comprise two important components, i.e. the point of origin and the point of destination (origin and destination) as well as pedestrian pathway [7], [8].

The focus of the pedestrian-friendly design on the TOD area is the completion of a streetscape that provides comfort and safety for pedestrians from the origin point to the destination point. The components that play a role in encouraging the formation of a pedestrian-friendly area are sidewalk connectivity and quality of pedestrian paths. This research focused on pedestrian sidewalk connectivity components that emphasize the aspects of street network connectivity and pedestrian paths in an area that will provide accessibility for pedestrians in the rail station district.

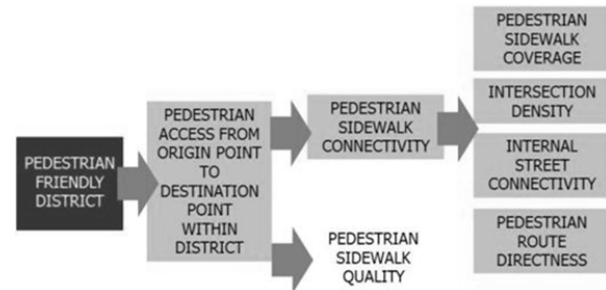


Fig. 1 The scope of research

III. RESEARCH METHOD

To answer the research question, a mix of quantitative and qualitative methods is used. The area of research is limited to a radius of 500 meters from the rail station which is the limit of a comfortable distance to walk.

In the first stage, the circulation path or linkage of street space is mapped on the delineation of the area within 500 meters from the rail station. The next step is to map pedestrian paths.

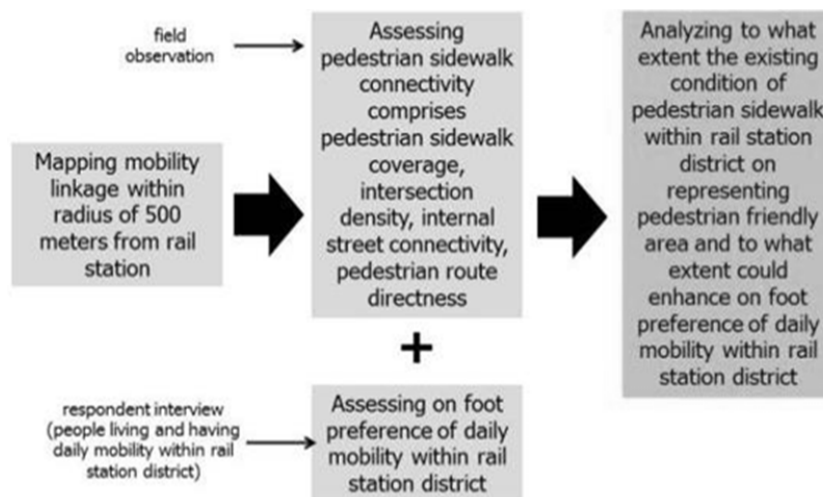


Fig. 2 Research method

In the second stage, field observations and assessment of pedestrian connectivity are conducted focusing on pedestrian sidewalk coverage, intersection density, internal street connectivity, as well as pedestrian route directness. In addition, interviews were conducted with respondents (100 families) living and having daily mobility in the rail station neighborhood in order to assess preferences on foot for short distance mobility.

In the third stage, a simple correlation analysis was used to find the extent to which the condition of the network of pedestrian paths in the rail station district represents a pedestrian-friendly environment and encourage on foot daily mobility preferences.

IV. ANALYSIS AND DISCUSSION

A. Pedestrian Sidewalk Connectivity

The main streets in Tugu rail station district have facilitated pedestrian paths, however not constantly on the path of secondary streets where pedestrian paths are interrupted in many pieces. Availability of pedestrian sidewalk on the existing primary and secondary streets is covering 70% of the total length of streets. Meanwhile, narrow neighborhood streets are generally only reserved for pedestrians, bicycles, and motorcycles.

The main streets in Lempuyangan rail station district have facilitated pedestrian paths but are still cut off in some parts. On the other hand, pedestrian paths are not available in the secondary streets, especially in the southern part of the district. The availability of pedestrian sidewalks in the primary and

secondary streets today accounts for only 52% of the total length of the streets. Similar to Tugu rail station district, narrow neighborhood streets are generally only reserved for pedestrians, bicycles, and motorcycles.



Fig. 3 Pedestrian sidewalk connectivity in Tugu rail station district

A. Intersection Density

Intersection density or density of the street intersection is the number of street intersections in the unit area of the district [9]. Intersection density represents the size of blocks in the rail station district; the smaller the size of the block, the higher the intersection density. A rail station district with either small blocks or large blocks, but which can be penetrated by pedestrian paths (high permeability) will encourage the formation of a friendly-pedestrian district.

In the area of Tugu rail station, large blocks are located at the center of the district (rail station block). The large block is impenetrable for pedestrian paths, with entry only on the two sides of a large block. A large block is also located on the eastern part of the district with commercial (retail, office) functions. Meanwhile, small blocks are located at the northern and southern parts of district with a residential function. Tugu rail station district within a radius of 500 meters from the rail station has 174 street intersections or 2.22 street intersections per hectare.

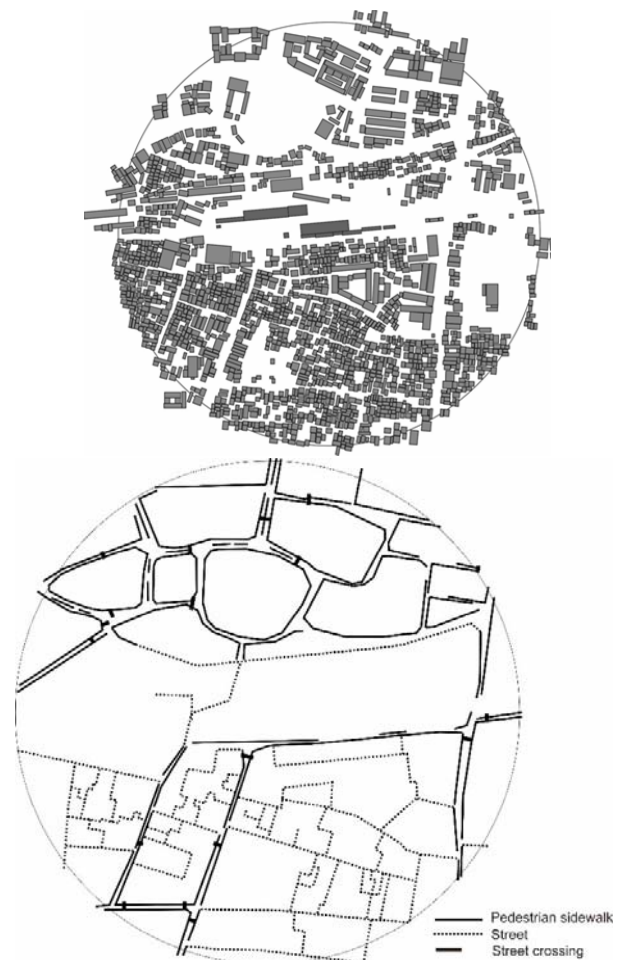


Fig. 4 Pedestrian sidewalk connectivity in Lempuyangan rail station district

Similar to Tugu rail station district, there is a large block in the Lempuyangan rail station district located at the center of the area that is impenetrable by pedestrian paths and entry is possible only on one side of the block. Medium block size is located at the northern part of the district with a mix of residential functions, commercial, offices and public facilities. Small blocks are located in the southern part of the district which is dominated by settlement blocks. Lempuyangan station area within a radius of 500 meters from the station has 130 street intersection or 1.66 street intersections per hectare. Intersection density at the northern part is lower (0.71 intersection / ha) than the intersection density at the southern part of the district (2.60 intersection / ha).

B. Internal Street Connectivity

Internal street connectivity is the number of street intersections compared to total number of intersection and dead ends (cul-de-sac). The greater the proportion of intersections compared to the total number of intersections and dead ends, the higher the street connectivity [10]. An area with high connectivity of streets will reach the index of 0.7 - 0.9.

Tugu and Lempuyangan rail station districts have a high index of ISC (0.97). The existence of cul-de-sacs is not

commonly found in these rail station districts.

C. Pedestrian Route Directness

Pedestrian Route Directness [11] is the ratio between the distance on the path of the pedestrians and the actual distance between locations (route distance, geodetic distance); the smaller the difference between actual pedestrian routes from origin to destinations with geodetic distance, the better connectivity of street space.

With a random distribution of the origin point in the district and the rail station as a destination point, the PRD gained 1.64 for Tugu rail station district, with the distance of pedestrian paths on average 523 meters for a geodetic distance of 320 meters. Walkability threshold is more than 500 meters, so it can be said the Pedestrian Route Directness from Tugu Station is not good enough, though still slightly above the standard PRD of 1.5.

Similar to Tugu rail station district, with a random distribution of origin points in the district and the rail station as the destination point, the PRD obtained 1.60 for Lempuyangan station district with the distance of pedestrian paths on average 589 meters to 369 meters geodetic distance. The walkability threshold is more than 500 meters, so it can be said the Pedestrian Route Directness of Lempuyangan rail station district is not good enough, although still slightly above the standard PRD 1.5.

D. On Foot Modal Split

Pedestrian accessibility in daily mobility is a fundamental aspect in creating a pedestrian-friendly district. In this research, connectivity of pedestrian paths and walking distance is the focus of the study.

To determine the level of walking preference in daily mobility within a rail station district, the data of respondents of 100 households, with the average of four people per household, were observed. The results show only 40% of respondents with daily mobility within the Tugu rail station district, and 56% of respondents with daily mobility within Lempuyangan rail station district. Selected respondents were people who perform daily mobility for the purpose of work, school or daily shopping within walking radius from their residence (home-based and home-based work trip of trip).

The results from respondents interviewed related to modal choice for daily mobility within the rail station district can be seen as:

TABLE I
 DAILY MOBILITY MODAL CHOICE WITHIN RAIL STATION DISTRICT

| Area | Travel Purpose | On Foot | Non-motorized Vehicles | Private Motorized Vehicles |
|-------------|-------------------|---------|------------------------|----------------------------|
| Tugu | Home-based Work | 64% | 5% | 31% |
| | Home-based Other | 54% | 7% | 39% |
| | Total Modal Split | 59% | 6% | 35% |
| Lempuyangan | Home-based Work | 44% | 18% | 38% |
| | Home-based Other | 53% | 14% | 33% |
| | Total Modal Split | 49% | 16% | 36% |

Walking preference for daily mobility in the rail station

districts is still high when compared with the preference for private motor vehicles (Tugu rail station district 5:3, Lempuyangan rail station district 4:3). On the other hand, the distance from the origin point to the destination point is also influential in determining preferences of walking, this can be seen in the average distance that people choose to walk and people choose to ride in private motorized vehicles.

TABLE II
 MODAL SPLIT BASED ON TRAVEL DISTANCE

| Area | Modal Split | Average Travel Distance |
|-------------|----------------------------|-------------------------|
| Tugu | On Foot | 346 m |
| | Private Motorized Vehicles | 649 m |
| Lempuyangan | On Foot | 283 m |
| | Private Motorized Vehicles | 543 m |

From Table II, it can be seen that walking preference is normally chosen at a distance range below 400 meters, while for more than 400 meters people prefer to ride in motorized vehicles. In general, the character of street and pedestrian path connectivity in the case of Tugu and Lempuyangan rail station districts can be described as:

TABLE III
 STREET AND PEDESTRIAN PATH CONNECTIVITY

| | Tugu Rail Station District | Lempuyangan Rail Station District |
|------------------------------|----------------------------|-----------------------------------|
| Pedestrian Sidewalk Coverage | 72% | 52% |
| Intersection Density | 2.22 | 1.66 |
| Internal Street Connectivity | 0.97 | 0.97 |
| Pedestrian Route Directness | 1.64 | 1.60 |
| On Foot Modal Split | 59% | 49% |

With the condition of the street and pedestrian path network that exists in Tugu and Lempuyangan rail station districts at this time, the level of on-foot mode choices in the area are already quite high compared to private motorized transport mode choices. Nevertheless, on-foot mode choices are also influenced by the distance from the origin to the destination points. In the present conditions, on-foot preference that is supported by good street and pedestrian path connectivity will be effective at a distance of ≤ 400 meters. At a distance of over 400 meters, the preference of private motorized vehicles is higher.

In finding the most influential factor in the preference modes of walking, simple correlation analysis has been taken for further analysis. This analysis is done by looking at the preference of walking and its interrelationship with the components of pedestrian sidewalk coverage (availability paths exclusively for pedestrians), intersection density, pedestrian route directness (blocks of permeability for walking activity), and the average distance from the origin point to the destination point. The results obtained are as follows:

Table IV shows the most robust connectivity to walk preferences shaped by the intersection density; the higher the number of intersections per unit area, the higher the preference for walking. The results of this analysis reconfirmed also the results of a previous study [5] that expressed the preference for walking is influenced by the density of crossing paths with

an elasticity of 0:39 with intervention of urban design. In this case, if the density of the intersection increased 10%, the preference modes for walking will increase by 3.9%. If the density of the intersection is increased two-fold (100%), the preference mode for walking will increase by 39%.

TABLE IV
 CORRELATION BETWEEN PREFERENCE OF WALKING AND PHYSICAL ELEMENTS OF PEDESTRIAN PATH CONNECTIVITY

| | Preference of Walking | |
|-------------------------------|-----------------------|----------|
| Pedestrian Sidewalk Coverage | 0.086 | Sig. 436 |
| Intersection Density | 0.734* | Sig. 048 |
| Pedestrian Route Directness | 0.574 | Sig. 117 |
| Distance Origin - Destination | 0.430 | Sig. 197 |

V. CONCLUSION

In addition to the distance from the origin to the destination as well as the quality of streetscape along the way, aspects of street and pedestrian path connectivity in facilitating the mobility of pedestrians is a component of the physical elements of the built form that shapes a pedestrian-friendly environment in the rail station district. The principle of a pedestrian-friendly area must be met toward the development of the rail station district that is based on the concept of TOD.

Although the current condition of the street and pedestrian connectivity in both areas has shown not to be good, it is able to stimulate a preference of walking for short distance mobility. The level of walkability at Tugu rail station district is a little better than Lempuyangan rail station district, mainly from the intersection density component. The number of street and pedestrian path intersections is more influential in the preference for walking mode than the distance from the origin to the destination. The higher density of intersections will increase the preference modes of walking, with an elasticity of 0:39.

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- "Transforming Principle of Diversity of World Rail-transit Oriented Development Best Practices into Indonesia Rail Station Districts," International Conference on Architecture and Built Environment, Kulliyah of Architecture and Environmental Design, International Islamic University, Kuala Lumpur, 5-6 October 2016, with Danang Parikesit, Ikaputra, Bambang Hari Wibisono;
- "Encouraging Walkability around Railway Station, Case: Indonesia Rail-Station Area," Great Asian Streets Symposium, National University of Singapore, 11-12 December 2014, with Bambang Hari Wibisono, Danang Parikesit, Ikaputra