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THE IMPACT OF TRANSIT ORIENTED DEVELOPMENT ON WALKABILITY: A CASE STUDY OF DUKUH ATAS STATION, JAKARTA

DAMPAK PEMBANGUNAN BERORIENTASI TRANSIT TERHADAP WALKABILITY: STUDI KASUS STASIUN DUKUH ATAS, JAKARTA

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ABSTRACT

Jakarta has one of the world's lowest averages daily step counts due to a variety of factors, including a changing urban environment and a lack of pedestrian infrastructure. In response, the Jakarta government shifted its development strategy to prioritize mass transportation and pedestrians over private vehicles. However, tackling relatively complicated urban issues cannot be accomplished solely by strengthening the transport system; it must be followed by urban development oriented towards transit locations. Therefore, "transit oriented development" (TOD) has been introduced to increase the neighbourhood's walkability. Walkability is described as a key indicator of active travel or as a parameter of how useful the built environment is for people who walk to various locations and for multiple purposes. The Dukuh Atas TOD, one of Jakarta's earliest TODs, is used as a case study – focusing on a 400-meter-radius core area – to analyze how TOD intervention impacts the walkability of an area. The study used descriptive qualitative methods, including the production of maps at two different time periods to compare conditions before and after the construction of the MRT station and the Dukuh Atas TOD, conducting field observations to directly observe and understand, capture phenomena that arise, record them, and consider the relationships between aspects of these events, and gathering pedestrian and commuter perceptions through questionnaires and interviews to analyze the variables of intermodal conflict on the pathway, maintenance and cleanliness, connectivity, amenities, and disability infrastructure. According to the variables used in this study to determine whether TOD intervention has affected walkability in Dukuh Atas area, despite some of sidewalks are still inaccessible to everyone, the results indicate that several government interventions implemented of Dukuh Atas TOD development have significantly improved walkability in several zones. This research is expected to contribute to the improvement of Dukuh Atas TOD in creating a walkable environment.

Keywords: *Transit Oriented Development (TOD), Walkability, Urban development, Active travel, Walkable environment*

ABSTRAK

Jakarta memiliki salah satu rata-rata jumlah langkah harian terendah di dunia akibat berbagai faktor, termasuk perubahan lingkungan perkotaan dan kurangnya infrastruktur pejalan kaki. Sebagai respon terhadap permasalahan ini, pemerintah Jakarta mengubah strategi pembangunannya dengan memprioritaskan transportasi massal dan pejalan kaki dibandingkan kendaraan pribadi. Namun, penyelesaian masalah perkotaan yang kompleks tidak dapat dicapai hanya dengan memperkuat sistem transportasi; upaya ini harus diikuti dengan pengembangan kota yang berorientasi pada lokasi transit. Oleh karena itu, konsep "Transit-Oriented Development" (TOD) diperkenalkan untuk meningkatkan walkability dalam suatu kawasan. Walkability didefinisikan sebagai indikator utama perjalanan aktif atau sebagai parameter yang mengukur seberapa efektif lingkungan binaan dalam mendukung mobilitas pejalan kaki untuk berbagai tujuan. Dukuh Atas TOD, sebagai salah satu TOD pertama di Jakarta, dijadikan studi kasus dengan fokus pada area inti dalam radius 400 meter untuk menganalisis dampak intervensi TOD terhadap walkability suatu kawasan. Penelitian ini menggunakan metode deskriptif kualitatif, termasuk pembuatan peta dalam dua periode waktu berbeda untuk membandingkan kondisi sebelum dan sesudah pembangunan stasiun MRT dan TOD Dukuh Atas, observasi lapangan untuk memahami fenomena yang muncul dan menganalisis keterkaitan antar aspek, serta pengumpulan persepsi pejalan kaki dan pengguna transportasi melalui kuesioner dan wawancara. Analisis dilakukan terhadap berbagai variabel, seperti konflik antar moda di jalur pejalan kaki, pemeliharaan dan kebersihan, konektivitas, fasilitas pendukung, serta

infrastruktur bagi penyandang disabilitas. Berdasarkan variabel yang digunakan dalam penelitian ini untuk menilai dampak intervensi TOD terhadap walkability di kawasan Dukuh Atas, meskipun masih terdapat beberapa trotoar yang belum dapat diakses oleh semua orang, hasil penelitian menunjukkan bahwa berbagai intervensi pemerintah dalam pengembangan TOD Dukuh Atas telah secara signifikan meningkatkan walkability di beberapa zona. Penelitian ini diharapkan dapat berkontribusi terhadap perbaikan TOD Dukuh Atas dalam menciptakan lingkungan yang ramah bagi pejalan kaki.

Kata kunci: *Transit-Oriented Development (TOD), Walkability, Pengembangan Perkotaan, Perjalanan Aktif, Lingkungan Ramah Pejalan Kaki*

1. INTRODUCTION

Urban planning plays a vital role in shaping the quality of life, as seen in the growing preference for urban over suburban living. Currently, more than half of the global population resides in cities, a figure projected to reach 70% by 2050. As urban areas expand, addressing urban sprawl becomes increasingly crucial due to its links to greater car dependency, environmental degradation, and a diminished quality of life. To counter these challenges, cities such as Tokyo (Wellman, 2024) and Singapore (Khurmi, 2024) have adopted Transit Oriented Development (TOD) strategies, integrating transportation and urban development to foster sustainable mobility and reduce reliance on private vehicles.

Tokyo's approach to urban planning, exemplified by its extensive rail network and pedestrian friendly spaces, has been a model for sustainable urban growth. The city's commitment to Transit Oriented Development (TOD) over the past century has not only enhanced its own urban identity but also set a global benchmark for urban planning (Wellman, 2024). In Singapore, Transit Oriented Development (TOD) strategy provides valuable insights for cities worldwide in addressing the complexities of urbanization, traffic congestion, and environmental challenges. Khurmi (2024) asserts that strengthening transportation infrastructure, integrating diverse land uses, and promoting sustainable urban design enable cities to create resilient, high quality urban environments that can effectively adapt to rapid growth.

While cities like Tokyo and Singapore have successfully implemented TOD strategies, Jakarta continues to grapple with urban mobility challenges, highlighting the need for more effective transportation solutions. As the nation's capital, Jakarta has been known for decades as a busy city with government activities, business, fast lifestyle developments, and a reasonably high commuter flow with the low quality of existing transportation (Hasibuan et al., 2014). It is estimated that about 1.4 million commuters from the capital city commute daily (MRT Jakarta, 2019). According to the Jakarta Central Bureau of Statistics (2022), about 21 million private automobiles are in Jakarta, and only 24% of people use public transportation (Media Indonesia, 2016). Congestion has thus emerged as one of Jakarta's major issues, causing the nation to suffer annual economic losses of $4.6 billion (Singgih & Sipahutar, 2019). The Jakarta government shifted its strategy to development by focusing more on mass transit and pedestrians than private vehicles (MRT Jakarta, 2019). In the last decade, a rail based transit system known as Mass Rapid Transit (MRT) has been constructed, with the early stages of development focusing on the main arterials of downtown Jakarta (MRT Jakarta, 2019).

As stated by Muhammad (2019), Indonesia had one of the lowest average daily step counts worldwide in 2017, with 3,513 steps. This low figure in contrasts with the 4,961 average daily steps taken by the entire world's population. There are several reasons why people are less interested in walking, including changes to the urban environment (Rafiemanzelat et al., 2017) and a variety of physical issues such as disconnect paths, the lack of sidewalks or their narrowness in some places, the presence of street vendors on the pavement, and the improper use of sidewalks as motorcycle lanes (Muhammad, 2019).

To alleviate Jakarta's congestion problems, MRT Jakarta (2019) contends that providing public transportation is insufficient; instead, a mixed-use area around the transit area is needed to allow people to carry out diverse activities without having to travel to another location. In response, the government

developed the concept of a Transit Oriented Development (TOD) neighbourhood at several stations in phase 1 of the south-north MRT corridor, with the Dukuh Atas area being the first TOD project (MRT Jakarta, 2019). Hamdi (2021) asserts that if the pedestrian path's condition is improved, people's habits will alter, and their interest in walking will rise. With a focus on public transit, TOD strives to create a walkable environment and increase active mobility (AM).

TOD is defined by Calthorpe (1993) as "a mixed -use community within an average 2,000 foot walking distance of a transit stop and core commercial area. TODS mix residential, retail, office, open space, and public use in a walkable environment making it convenient for residents and employees to travel by transit, bicycle, foot, or car." It is a pedestrian friendly, high density mixed use neighbourhood built around a transit hub to increase the use of public transportation while minimizing the usage of private vehicles (Choi & Guhathakurta, 2020) with an emphasis on integration between networks of mass public transport and between networks of mass public transport and non-motorized forms of transportation.

Walking is the most basic form of physical activity (PA) that has been regarded as the essential mode of transportation before the introduction of any other kind of transportation in the twentieth century (El Messeidy, 2019), which enables mobility for many individuals, particularly low income people who have no other alternative (Leather et al., 2011). Walking activity is primarily restricted to the individual's ability to walk. The relationship between a person's walking restrictions and the physical form might affect how walkability is considered in the built environment (Shrestha, 2020). The term "walkability" characterizes various current events in several domains, including geography, health sciences, urban planning, and urban design. Walkability, considered a component in enhancing the urban economy, is a topic that has received a significant amount of attention from academics.

According to Merriam-Webster (1736), the definition of walkable is "capable of or suitable for being walked". Initially, the walkable neighbourhood was an effort to enhance people's interest in walking in private vehicle based cities; nevertheless, it has become one of the most crucial variables for promoting good health and the economy (Talen & Koschinsky, 2013). Walkability is described as a key indicator of active travel or as a parameter of how useful the built environment is for people who walk to various locations and for multiple purposes (Frank et al., 2006; Frank et al, 2004; Blei et al., 2015, cited in Annunziata & Garau, 2020). According to the findings of a study carried out by Iamtrakul et al (2021), the variables in walkability that may be defined on a macro scale include things like the length of the blocks, problems with urban planning, and problems with the built environment. On the micro scale, walkability variables include vendors, food, facilities, and art components.

According to Guzman et al (2022), walkability has become a topic and matter of attention to scholars, particularly regarding the sustainability of standards; nevertheless, the perception element of pedestrians themselves is rarely considered. The development of Dukuh Atas TOD has attracted the interest of a significant number of researchers and academics, who are analyzing the degree of walkability in this area by calculating the walkability index, a tool for rating cities based on safety, security, and comfort of the pedestrian environments (Krambeck, 2006), based on various characteristics that differ from one study to another. One of the purposes is to improve research about the development of TOD and its advantages that may be employed as information for the government. Through this study, we attempt to supplement previous studies by Agah Muhammad Mulyadi (2020) and Rafi Dewangga & Damayanti Asikin (2022) by examining walkability based on physical changes in the walking environment in the Dukuh Atas station area following the TOD intervention and also based on the opinions and experiences of the community and pedestrians in the region, considering that in its actualization, the availability of information regarding travellers' or users' perceptions of degrees of comfort plays a crucial role (Ferreira, 2022).

2. DATA AND METHODS

2.1. Case study metod

This research analyses the impact of TOD on walkability through a case study. A case study was chosen because it permits an in-depth examination of the particular context and circumstances of a specific site or area. TOD Dukuh Atas, Jakarta, has been selected as the case study location for this study. This location was chosen because Dukuh Atas is the first TOD to be established in Jakarta and is part of a larger urban renewal project that aims to increase walkability by improving the infrastructure, access to public transport, and creating attractive and inviting spaces for pedestrians. Furthermore, according to MRT Jakarta, referenced in Tambun (2018), Dukuh Atas was selected as a pilot for future TOD developments. As a pilot project for other TODs being constructed or developed in Jakarta, it is essential to evaluate the intervention and collect data to see how it affects the walkability of the area before implementing it in other TOD projects. Hence, it is expected that the outcomes of this study can serve as data or information to support the future development of further TODs.

The study was designed to have three major phases: in the initial stages, secondary data were collected through a literature study. In addition, this research will collect primary data through various methods, such as field observations, the creation of maps for two distinct periods, and interviews. Numerous phases are involved in each process (see Figure 1.)

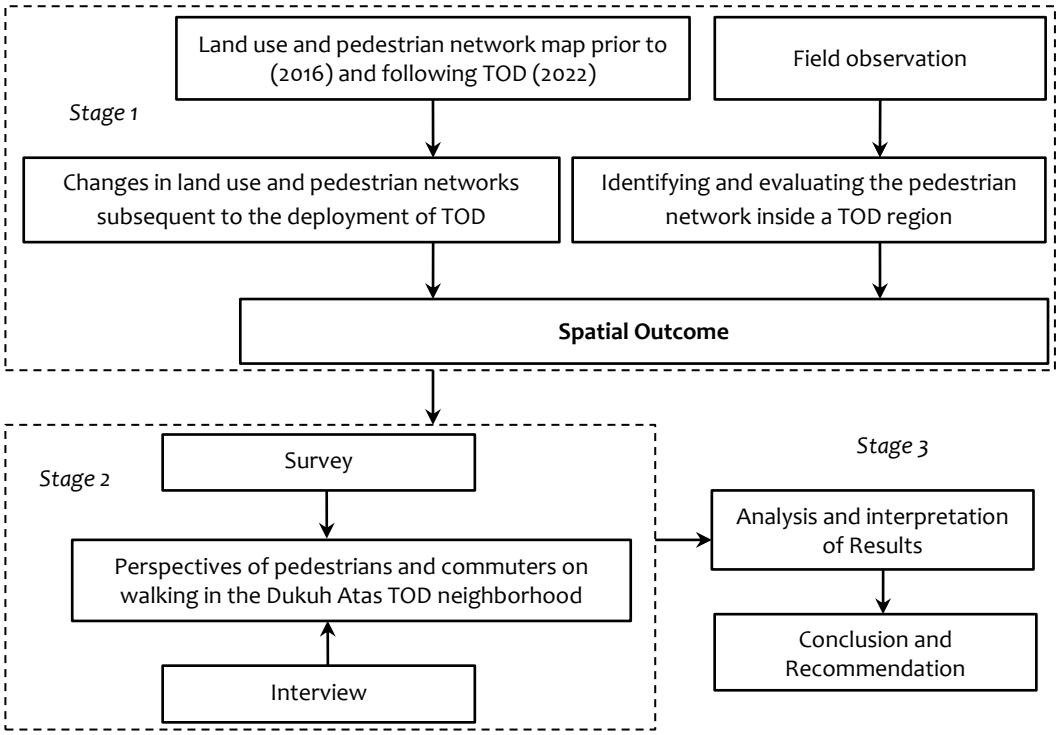

Figure 1. Research Design

2.2. Walkability assessment variable in this study

This study determines the variables that will be utilized as references in evaluating walkability as an impact of TOD development in Dukuh Atas. The Global Walkability Index parameters and survey parameters from Asia, as well as built environment variables concerning travel behaviour, were used as the basis for these variables. The variables are modified under the development program in the short term planning, which is the initial five year program of Jakarta TOD's implementation.

For the World Bank, Krambeck (2006) created Global Walkability Index (GWI), a qualitative analysis to evaluate walkability or the walking environment by examining the elements of safety, security, the convenience of a pedestrian environment, as well as policy support. The walkability score produced using GWI demonstrates the quality of the environment that people use to move around. Table 1 depicts these components' indicators. The walkability index can be used to create pedestrian-friendly neighbourhoods, determine how walkable a specific location is, and identify potential improvement areas.

Table 1. Global Walkability Index

Component	Variable
Safety and Security	1. Proportion of road accidents that resulted in pedestrian fatalities (most recent year avail.)
	2. Walking path modal conflict
	3. Crossing safety
	4. Perception of security from crime
	5. Quality of motorist behavior
Convenience and Attractiveness	6. Maintenance and cleanliness of walking paths
	7. Existence and quality of facilities for blind and disabled persons
	8. Amenities (e.g., coverage, benches, public toilets)
	9. Permanent and temporary obstacles on walking paths
	10. Availability of crossings along major roads
Policy Support	11. Funding and resources devoted to pedestrian planning
	12. Presence of relevant urban design guidelines
	13. Existence and enforcement of relevant pedestrian safety laws and regulations Policy Support
	14. Degree of public outreach for pedestrian and driving safety and etiquette

Source: Krambeck, 2006

Asia's cities are no longer enjoyable to walk through these days. There is little interest in walking due to the high percentage of motorized vehicle users, the restricted development of transit, and the attention paid to pedestrians. According to Gota et al. (2010), the notion of walkability can be connected to factors including the built environment's quality, urban shape, connection, safety, need for continuity, and access to infrastructure. In his study, fifteen significant cities from various nations were chosen for examination, including Jakarta (Indonesia), Bangalore (India), Karachi (Pakistan), and Hong Kong SAR (China). This study uses GWI adopted parameters that have been modified for Asian city conditions (see Table 2).

Table 2. Walkability Survey Parameter in Asia

Parameter	Description
Walking Path Modal Conflict	The extent of conflict between pedestrians and other modes, such as bicycles, motorcycles, and cars on the road.
Availability of Walking Paths	This parameter is added to the original Global Walkability Index (combined with the original parameter "Maintenance and Cleanliness"). It reflects the need for, availability, and condition of walking paths.
Availability of Crossings	The availability and distances between crossings to describe whether pedestrians tend to jaywalk when there are no crossings or when the distances between crossings are too long.
Grade Crossing Safety	This refers to the exposure of pedestrians to other modes while crossing, the time spent waiting and crossing the street, and the sufficiency of time given to pedestrians to cross signalized intersections
Motorist Behavior	The behavior of motorists toward pedestrians, which may well indicate the kind of pedestrian environment there is in that area.

Parameter	Description
Amenities	The availability of pedestrian amenities such as benches, street lights, public toilets, and trees. These amenities greatly enhance the attractiveness and convenience of the pedestrian environment, and in turn, the city itself.
Disability Infrastructure	The availability, positioning, and maintenance of infrastructure for the disabled.
Obstructions	The presence of permanent and temporary obstructions on the pedestrian pathways. These ultimately affect the effective width of the pedestrian pathway and may cause inconvenience to the pedestrians.
Security from Crime	The general feeling of security from crime in the street.

Source: Gota et al., 2010

In this study, we employ variables based on the GWI and Walkability survey parameters in Asia, which are then adapted to the newly formed TOD program in Indonesia, which is still in its first five years of short term development. Table 3 shows the walkability parameter used in this study.

Table 3. Walkability Parameter

Component	Variable	Measurements
Built Environment	Density	employment densities
	Diversity	Mix uses
	Design	Block length
		The proportion of four way intersections
		Pathway width
	Destination Accessibility	Distance to the central business district
		number of jobs or other attractions reachable within a given travel time
	Distance to Transit	Distance between transit stops
Safety	Intermodal conflict on the pathway	Concerned walkers about conflicting modes on the pedestrian walkway (between walkers and automobile users or non-automobile users)
	Crossing security	Availability of crossing
		Pedestrian bridge
		Length of time waiting and crossing
	Security	Well-lit streets for strolling (Availability of street lights)
Convenience	Maintenance and Cleanliness of walking paths	Maintenance of pathway
		Presence of open sewers along walking paths
		Obstruction
	Disability infrastructure	Infrastructure for the visually impaired and the disabled: availability and quality
	Connectivity	Connectivity between activity centre
		Pathway connectivity
	Pedestrian amenities	Amenities (i.e. trees, street lights, public benches, public toilets)

A variety of methods were employed to analyze the variables. The initial method entailed the creation of a map illustrating the land use and pedestrian network during two distinct periods: before and after the TOD development. This map will be utilized to examine several variables pertinent to the built environment, including mixed land use, block length, and intersection density. According to Saelens & Handy (2008), higher mixed uses, number of intersections, and block or pathway length affect the walking activity formed in an area.

Observations were conducted in the field to observe and document the phenomena and realities that demonstrate the existence and quality of the walking space in this area. Observation will be used to evaluate variables including intermodal conflict on the pathway, amenities, crossing safety, maintenance and cleanliness, street width, and disability infrastructure.

According to Guzman et al (2022), walkability has emerged as a subject of discussion and a focus of attention among academics, particularly regarding the viability of standards; however, the perceptual aspect of pedestrians themselves is almost never taken into account. In light of this, it is intended that the collection of public opinions will supplement previously conducted research. This study used questionnaires and interviews to assess walkability, focusing on public perceptions to obtain insight into how people perceived their surroundings and the condition of their local pedestrian infrastructure.

The number of pedestrians and commuters in Dukuh Atas is unknown since users of this mode of transportation are not frequent visitors to the area. Given this, the Lemeshow method was applied to determine the number of samples to be surveyed in this study (Invander, 2018) as follows:

$$n = \frac{Z\alpha^2 \; x \; P \; x \; Q}{L^2}$$

With a significance level/margin of error of 8% with the following calculation results:

$$n = \frac{Z\alpha^2 \; x \; P \; x \; Q}{L^2} \; = \frac{(1.96)2 \; x \; 0.5 \; x \; 0.5}{(0.05)^2} = \; 96{,}04 \; \approx 100$$

Where n is the minimum sample size, Zα is the standard value of the distribution according to the value of α = 5% = 1.96, P is the prevalence (Because no data was obtained for outcome prevalence, 50% was used), Q is the result of 1 - P, and L is the accuracy level.

Therefore, a minimum of 100 responders is required for this survey. In practice, we surveyed 162 pedestrians and public transit users in the TOD neighbourhood of Dukuh Atas. Given that one of the variables to be analyzed here is a convenience for all, with a measurement of accessibility for disabled people, I also surveyed disabled people I met in the area during the two week survey.

3. RESULT AND DISCUSSION

3.1. Land use and pedestrian Network Changes

To identify changes in land use and pedestrian network, maps were created using two different periods. The first period is before the TOD intervention, in this case using the 2016 map. The second map uses data in 2022 when TOD is implemented. Both maps were created using information taken from Google Earth.

The main purpose of these two maps is to look at various walkability variables in the built environment (see Table 3). The first variable is diversity (related to mixed land use), the second is design (related to block length and intersection proportion), the third is accessibility to destinations, and the fourth is distance to transit. The map also shows how the land area changes for each land use and how the pedestrian network is formed due to the spatial changes caused by the TOD intervention.

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Figure 2. Land Use and Pedestrian Network in 2016

Dukuh Atas is an epicenter located in the golden triangle area of Jakarta, as delineated by the regional and detailed spatial plans for the Province of DKI Jakarta (Provincial Government of DKI Jakarta, 2019). This area has undergone significant development over several decades, evolving from a primarily business and residential district into a renowned entertainment center (Kompas Cyber Media, 2022). From the 2016 map (see Figure 2), it can be seen that the residential, office, service, and trade (business) and land cover (vegetation) components dominate the spatial pattern in the Dukuh Atas area. The train station is situated on the road in the southern part of this area during this period.

Figure 3. Land Use and Pedestrian Network in 2022

The map in Figure 3 reveals that the majority of the land that has been converted is happening to the east of the Dukuh Atas MRT station. The conversion of vacant lots and abandoned structures into commercial areas has enhanced the area's appeal, facilitating pedestrian navigation. Cervero (1994); Frank

& Pivo (1994) cited in Ewing & Cervero (2010), argue that walkers are greater in areas with higher employment densities and a greater mix of land uses. Figure 3 shows that the office area, which includes a mix of housing, service and trade, is primarily located north and east of the MRT station, creating the potential for greater walkability.

3.2. Neighbourhood Condition in a TOD Region

Field observations were performed to measure various built environment, safety, and convenience aspects. A rating has been assigned to each road segment in the Dukuh Atas TOD area in accordance with the rating reference established for this study, using the design guidelines outlined by Krambeck (2006).

Figure 4. Classification of Pathway

Figure 4 captures the classification of Dukuh Atas TOD's pathways resulting from field observations. The field observation data was processed using a rating system on several walkability variables used in this study.

A. Modal conflict on pedestrian pathway

According to Krambeck (2006, p. 89), the presence of substantial confrontations between walkers and other means of transportation implies a low degree of pedestrian safety and security in the area. Pathways with such circumstances can be found in the Dukuh Atas region with a grade of 1. The higher the rating, the greater the level of safety and security connected with modal conflict on pedestrian routes.

B. Amenities

The observations indicate that the Central Business District, specifically the rating 3 lanes, exhibits a higher density of trees and streetlights when compared to the rating 1 and 2 residential areas, situated to the east and west of the MRT stations. In residential areas, the arrangement of trees is more haphazard. The ideal scenario would involve the strategic placement of trees and streetlights, serving as key amenities that would enhance the level of safety and attractiveness of the walking environment (Krambeck, 2006).

C. Crossing Safety

Krambeck (2006) asserts that the presence of crossing facilities is crucial for preventing jaywalking and enhancing pedestrian safety. In addition, crossing facilities should be installed every 300 meters, according to his research. Field findings indicate that zebra crossings can be found on road segments less than 300 meters between crossings. In addition, crossing safety is also affected by the time required to cross (Krambeck, 2006).

D. Maintenance and Cleanliness of pedestrian paths

These observations focused on the availability of open sewers along the pedestrian path, obstructions, the availability and distribution of public amenities to support walking comfort, and the availability and quality of infrastructure for the blind and disabled. All of these factors can impact the safety and convenience of pedestrians.

E. Street width

The Ministry of Public Works and Housing (2018) asserts that the effective width of the pedestrian lane, considering the needs of a single individual, is 60 centimeters, with an additional 15 centimeters allocated for movement without the carriage of goods. Consequently, the total lane requirement for two pedestrians holding hands or two pedestrians passing without intersecting is a minimum of 150 centimeters. Observation reveals that the pedestrian thoroughfare in area rated 1 fails to comply with the technical planning criteria for pedestrian facilities in Indonesia.

F. Disability infrastructure

The accessibility of facilities for disabled people in the Dukuh Atas TOD area, such as ramps and braille boxes, was documented. Ramps help not only disabled people but also people carrying luggage or baby strollers (Krambeck, 2006). As such, ramps not only increase convenience for disabled people but also make the area more accessible and inviting. Areas with adequate disability infrastructure and good maintenance can only be found on road sections with a rating of 3. Since not all road sections have good facilities for people with disabilities, many connections are cut off, making it hard for people with disabilities to travel safely and comfortably. It also indicates why disabled people are uncommon in the Dukuh Atas neighbourhood.

G. The presence of Lighting

During nighttime observations, the lighting situation in the pedestrian area of the Dukuh Atas neighborhood was analyzed.The findings reveal that certain areas in the vicinity of the station experience very low illumination levels, leading to significant visibility issues. According to Azarine & Satiawan's (2019) research, people's perceptions of an area's security level are correlated with its lighting. People believe that a location with sufficient lighting is safer. The lack of nighttime lighting in the station neighbourhood, which is the core of TOD, can undermine the security perceptions of walkers and commuters.

Table 4. Observation Results

Rating 1 Poor pathway condition with an effective width of equal to 1 meter, low maintenance and cleanliness, numerous broken paving materials, and a poor disability infrastructure condition. Under these circumstances, routes with a rating of 1 have poor walkability and are nearly impossible for disabled people to traverse. These paths can be found in residential neighbourhoods.	
Rating 2 The designated pedestrian thoroughfare meets the minimum requirements for accessibility, though it is less conducive to efficient navigation, with an effective width of at least 1 meter. While there are provisions for visually impaired pedestrians, the path at rank 2 still features obstacles that impede pedestrian circulation, particularly for individuals with disabilities.	
Rating 3 Pedestrian pathways are in optimal condition and suitable for transit. Walkways classified under this category boast a width exceeding 1 meter, exhibiting commendable material quality, meticulous maintenance, and the absence of obstructions. Disability accessible infrastructure, such as ramps and braille pavements, is also maintained to ensure safety and accessibility for all users. These conditions are prevalent in proximity to MRT stations, the Dukuh Atas Tunnel, and primary thoroughfares within office parks and business centers.	

3.3. Perspectives of pedestrians and commuters on walking environments

Drawing upon the perspectives and experiences of pedestrians and commuters, a structured ten day survey and a series of in depth interviews were conducted to systematically examine the factors contributing to intermodal conflicts within pedestrian pathways. This study specifically analyzed key variables, including the nature and frequency of conflicts arising from interactions between different transportation modes, the state of infrastructure in terms of maintenance and cleanliness, the degree of connectivity between pedestrian pathways and transit nodes, the availability and quality of amenities that enhance pedestrian accessibility and comfort, and the adequacy of infrastructure designed to accommodate individuals with disabilities.

A survey was conducted on 162 pedestrians and public transit users in the TOD (Transit Oriented Development) neighborhood of Dukuh Atas. Given that one of the variables to be analyzed is convenience for all, respondents of varying ages and genders were selected to determine the impact of age and gender on their responses regarding walking comfort following TOD. To ensure a diverse sample, several disabled individuals identified in the Dukuh Atas region were included as well.

The majority of the population is not from Dukuh Atas, as indicated by the responses to the survey's residence question. However, the sample can still be considered representative because the population analyzed in this study consists of pedestrians and commuters. With a focus on understanding the effect of TOD on walkability, a sample of pedestrians and public transit users may be appropriate, as these groups are likely to be most impacted by changes to the built environment and transportation infrastructure.

In light of the finding that only a small percentage of the subjects had been utilizing the Dukuh Atas region prior to the implementation of TOD construction, I opted to conduct in-depth interviews with pedestrians and commuters who had been acquainted with the area before the advent of TOD.

The findings of the interviews were subsequently analyzed by categorizing the respondents' statements into several major groups for each of the variables identified in this study. The following are the conclusions that can be drawn from the interview.

Table 5. Interview Results on Built Environment and Safety Variables

Informant	Built Environment		Safety	
	Mix uses	crossing	pathway mode of conflict	Lighting
I1	1	1	-1	-1
I2	1	0	-1	0
I3	1	1	0	1
I4	1	1	0	1
I5	1	-1	-1	0
I6	1	1	1	1

Informant	Amenities				Services and facilities for disabilities		
	Bench	Open space	Trees	public toilet	signage	braille blocks	ramp
I1	-1	1	1	-1	1	0	0
I2	0	1	1	0	1	1	1
I3	1	1	0	-1	0	1	1
I4	1	1	0	-1	0	1	0
I5	0	0	-1	-1	1	1	1
I6	1	1	1	-1	0	0	0

Notes:
I1: woman (32 years)
I2: men (43 years)
I3: street vendor
I4: youth
I5: visual impaired
I6: elderly >60 years old
1: positive changes
0: no response
-1: no changes/negative

Informants have provided a variety of replies in response to the numerous variables to identify changes following the TOD interventions. All of the informants provided positive feedback regarding the mix uses in the area. According to informants, the vicinity of the Dukuh Atas MRT station neighbourhood has undergone considerable modifications, which have had a major influence on the activity and led to the quality of walking. The changes, such as the addition of public space, better crossing, and other public amenities, have made it safer for people to walk and made the public spaces more appealing.

Kendal tunnel, a car lane before and did not have convenient access for pedestrians, has been converted into a walking space. This shift has been advantageous to pedestrians. The conflict between pedestrians and other modes of transportation has been eliminated in the area, and people can now

traverse safely and conveniently. However, according to several sources, conflicts between pedestrians and automobiles are still prevalent in residential areas. Ideally, people can walk comfortably throughout the TOD area if interventions are distributed evenly. Based on what was stated in the interview, the development of the pedestrian area has only focused on the area around the MRT station and has not paid attention to the residential area.

The participants appreciated the availability of pedestrian crossings. Except for the visually impaired informant, they believed that crossing the road near the station is now easier and safer due to the installation of clear crossings. To create socially sustainable urban transportation, everyone must experience the benefits of mobility (Cervero, 2014). However, the disparity in responses regarding the safety of crossings between groups with disabilities and other respondents who do not require walking aids indicates that there are still inequities in accessing development benefits.

All participants were generally pleased with the physical improvements made to the Dukuh Atas walking space. They believed that prior to the construction of the TOD, the Dukuh Atas area was unsafe for strolling, particularly through the Kendal tunnel. Although the building and improvement of pedestrian paths have not yet been completed in all regions of the Dukuh Atas district, numerous major road sections now have adequate pedestrian paths with braille blocks. This, in turn, has greatly improved safety conditions for pedestrians and increased mobility in a particular region, which has also benefited people with disabilities, making it easier for them to access services in the station area.

3.4. Discussion

Built Environment

Iamtrakul et al (2021) identify walkability factors at both macro and micro scales, with macro level elements encompassing block length, urban planning, and the built environment, while micro level factors include commercial activity, amenities, food vendors, and artistic features. Spatial analysis (see Figure 3) indicates that the implementation of TOD has enhanced built environment planning, contributing to greater land use diversity, as corroborated by field observations and commuter feedback. In accordance with Governor Regulation 2019/67 on Transit Oriented Areas, the first phase of development prioritized key infrastructure projects, including the construction of the Jakarta MRT station, the revitalization of Sudirman Street and Pasar Blora, and the pedestrianization of Kendal Street. Observational and survey data confirm the successful execution of these initiatives in the core area of TOD Dukuh Atas, establishing a pedestrian oriented, vehicle free zone with enhanced public amenities, clear signage, designated food vending areas, and integrated artistic elements.

During the second stage of development, key priorities include enhancing the quality of the waterfront area and green open spaces, improving connectivity with adjacent developments, and constructing a pedestrian bridge. However, several pedestrian areas fail to meet proper design standards, as obstructions hinder movement and significantly impact pedestrian circulation. These barriers not only compromise walkability but also disrupt the integration of the MRT station with surrounding areas within a 400-meter radius, highlighting the need for comprehensive infrastructure improvements to ensure seamless urban mobility.

Safety

The findings from observations and interviews are comparable in analyzing conflicts between pedestrians and other modes of transportation, street lights, and crossing safety. The results indicate that there are still numerous conflicts on the pathway that interrupt pedestrian circulation, and some sidewalks are completely inaccessible to pedestrians due to parked automobiles and motorcycles. On the classification of the pathway map (see Figure 4.), the road segment with ratings of 1, 2, and 3 are indicated. Given that the development of the built environment, including street connectivity, and the frequency of walking are directly proportional (Saelens & Handy), areas with low street connectivity are characterized by low walking frequency.

Field observations are inversely proportional to survey results regarding street light variables. The survey results indicate that both variables' presence and condition are quite good. Still, based on nighttime observations, many lights are off or in dim conditions, leaving some areas deserted after sunset. This gap could be because pedestrians seldom access the Dukuh Atas neighbourhood at night. In order to reduce the existing gap, it is necessary to implement a survey that employs a more specific method. For this purpose, it would be beneficial to survey respondents who frequently engage in nighttime activities in Dukuh Atas.Additionally, a participatory approach involving local communities and road users could be adopted to obtain more accurate data.

Convenience

Survey findings generally indicate positive perceptions of convenience; however, interviews suggest that significant improvements are limited to specific areas, such as the Kendal Tunnel pedestrian zone. Field observations further highlight issues related to poor road maintenance and obstructions, including street vendors and trees. While infrastructure accessibility is rated highly in the Kendal Tunnel, Dukuh Atas MRT station, and the CBD office district, it remains low in residential areas. Accessibility depends not only on infrastructure development but also on connectivity between activity centers, which remains inadequate in some parts of Dukuh Atas, particularly between residential areas and the station.

For urban transportation to be socially sustainable, mobility benefits must be equally distributed (Cervero, 2014), requiring the elimination of inequalities in infrastructure access based on social and physical conditions, such as age and disability. Limited accessibility, as noted by Soltani et al (2012), increases travel challenges for people with disabilities. The disparity in infrastructure ratings between different neighborhoods (see Figure 3) signals that accessibility barriers persist, preventing all residents, particularly disabled individuals, from fully benefiting from Jakarta’s infrastructure development.

4. CONCLUSION

The study indicates that TOD interventions in Dukuh Atas have led to significant walkability improvements in several zones, particularly during the initial two phases of development, yet residential areas still suffer from low walkability due to minimal changes in pedestrian pathways. Despite the neighborhood's close proximity to the station (100 meters) and CBD offices, poor pedestrian infrastructure reduces accessibility, preventing residents from fully benefiting from their location. A major improvement is the conversion of Kendal Tunnel from a car road with poor walkways into a pedestrian-friendly space, enhancing connectivity between transit, housing, trade, and offices. This transformation has not only improved access to multiple destinations but also encouraged public life, as people use the space for leisure and social activities. By creating a safe and pedestrian-friendly environment, the intervention has significantly enhanced accessibility and quality of life in the area.

Following Cervero's theory of the built environment, physical changes in Dukuh Atas have made the area more walkable, especially within a 400-meter radius where mixed land use has been developed. The study shows that factors like street width and public space density play a key role in improving pedestrian mobility and accessibility. Many previously abandoned buildings have been repurposed for offices, businesses, and services, increasing land value and turning the area into a thriving business hub. Once a slum known for its nightlife, Dukuh Atas has transformed into a socially and economically vibrant district. A new open plaza near the station offers public gathering spaces connected to various transport modes, improving urban livability. A major improvement is the conversion of Kendal Tunnel from a vehicle dominated road into a pedestrian friendly space, creating a safer and more inclusive walking environment. These government efforts demonstrate a strong commitment to improving pedestrian safety, comfort, and convenience, significantly enhancing the area's walkability.

Key pathways in zones such as the MRT station, station plazas, Kendal Tunnel, and CBD offices are well developed, providing safe and comfortable walking spaces. However, residential areas near the station

still lack sidewalks that meet accessibility standards. Poorly paved walkways, obstacles, conflicts with other transport modes, and inadequate disability infrastructure reduce overall connectivity and accessibility. When high quality infrastructure is limited to certain zones and disconnected from others, accessibility declines, particularly for vulnerable groups. This highlights the need for government action to ensure inclusive access for all, including people with disabilities.

The community perceives walking in the Dukuh Atas area as more convenient and secure compared to the period before TOD development, as reflected in the analysis. Despite ongoing criticism regarding inadequate pedestrian infrastructure in residential areas near the station, there is a general acknowledgment of the government's efforts to prioritize pedestrian-friendly development. The statement of an elderly interviewee, who noted an improvement in his walking experience due to recent TOD interventions, further reinforces the notion that a safer and more comfortable walking environment has been established. This perception highlights the positive impact of TOD development on the area's overall walkability.

5. RECOMMENDATION

Pedestrian pathways in the Dukuh Atas transit-oriented development (TOD) area need further improvements to meet national standards. Currently, several zones, including residential areas, do not fully comply with the Pedestrian Facilities Technical Planning Guidelines (2018) set by the Ministry of Public Works and Housing. To ensure accessibility and safety, future pedestrian upgrades in Dukuh Atas and other TOD projects in Jakarta should follow these guidelines to meet government standards.

Improving walkability requires both macro and micro level interventions. At the macro level, urban design and zoning regulations play a crucial role in reshaping communities and supporting sustainable city development, though these processes can be complex. Effective planning and policy implementation require collaboration among multiple stakeholders, including urban planners, public works, and health sectors, to ensure that regional development enhances both the urban environment and public health. At the micro level, infrastructure development, amenities, and area master plans can improve accessibility and attractiveness. Successful implementation depends on coordination among city government departments to ensure comprehensive and well-executed infrastructure development.

A limitation of this study is the lack of data on pedestrian numbers in Dukuh Atas before and after TOD development, which is crucial for understanding changes in walking behavior and transportation patterns. Collecting this data would provide a clearer picture of how TOD interventions have influenced pedestrian activity and mobility. Further analysis could also explore factors affecting visitor numbers, helping to identify key elements that impact walkability and accessibility. Additionally, this information would be useful in assessing whether TOD development has increased or reduced traffic flow, offering insights into its overall effect on urban mobility.

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