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Travel demand and the 3Ds (Density, Diversity, and Design) for Support Bus Trans Semarang

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Abstract. The growing number of private transportation ownership yearly creates congestion problems, especially in urban areas. Public transportation conditions such as Rapid Transit Bus (BRT) are an alternative use of transportation. BRT Trans Semarang Corridor 1 is the busiest Trans Semarang Bus route compared to other routes, this corridor departs from Mangkang Terminal to Penggaron Terminal. The results of previous research samples show that 50% of the passengers of BRT Trans Semarang Corridor 1 chose to walk to and from the bus stops. However, the current condition of the pedestrian paths is less optimal in creating pedestrian comfort, such as the lack of shady vegetation to designs that do not meet the standard needs of the user and the integration system is still minimal with various modes. The purpose of this study is to identify a travel need model such as design and ease of access in accordance with the pedestrian travel demand of BRT Trans Semarang Corridor 1 passenger using the new 3D urbanism approach (Density, Diversity, Design). Density analysis uses descriptive statistical analysis methods and simulates the interpolation of population data and building density using the ArcGIS 10.3 application to generate pedestrian needs such as pedestrian design or elements of pedestrian paths and access to pedestrian paths to environmental density. Analysis of the diversity was performed using the land-use distribution simulation method with ArcGIS 10.3 and FAR (Floor Area Ratio) analysis was performed using the 2016 Sketchup simulation. Compile a pedestrian path model recommendation under pedestrian demand.

Keywords: Density, Diversity, Design, BRT Trans Semarang, Pedestrian.

INTRODUCTION

Bus Rapid Transit (BRT) is a form of public transportation that can improve land accessibility [1]. Another definition states that Bus Rapid Transit (BRT) is mass transportation capable of increasing the movement of people in urban areas [2]. This mode of transportation is known as a bus-based mass transportation system that has high capacity and speed and has a good level of service and relatively low cost [3]. Several studies on the effect of BRT on land prices have been carried out in several parts of the world. Research by Cervero and Kang [4] states that BRT can influence land price increases by 5-10% if the land distance is 300 meters from bus stops. The condition of BRT, which is the object of research in several countries, already has complete components, such as having a special route. The existence of this special lane affects bus speed performance so that it can avoid traffic congestion. This is different from Trans Semarang, which is one of the models for developing Bus Rapid Transit (BRT) in Indonesia. Trans Semarang does not yet have complete components such as special routes. As a result, the given speed performance is still not optimal. This can be seen during rush hour, where Trans Semarang will be stuck in traffic with other private vehicles. As a result, public interest in using Trans Semarang is still low.

The low public interest can be seen from the value of the passenger load factor for all corridors which is still below standard, namely at least 70%. However, in the several years since Trans Semarang inaugurated, the number of passengers has increased. Previous research data showed the number of Trans Semarang passengers in 2010 was 369,326 passengers then significantly increase in 2017 to 9,125,472 passengers. The number of Trans Semarang passengers increased along with the addition of corridors [5]. Based on research conducted by Moudia and Haryadi [6], passenger access to the Trans Semarang BRT bus stop is dominated by pedestrians with a percentage of 60%, and the average travel distance from their residence to the bus stop is less than 250 meters. Where pedestrians are one of the mobility choices that are considered the most natural. However, it is also the most complicated component to understand. Because the mobility on foot has a variety of infrastructure such as pedestrian paths, crossings, connectivity between buildings, etc. [7]. Pedestrian movement is difficult to predict because it does not have a definite route and is usually influenced by environmental factors [8]. Various studies on the effect of pedestrian demand on the design of pedestrian paths and city shapes show that the components of an attractive, safe, and comfortable urban design and shape will increase the tendency of residents to walk towards their destination [9]. Meanwhile, according to Appleyard (2003), Southworth in [7], states that changes in the built environment such as land use planning (mixed-use neighborhoods), changes in area design, and security can increase current activities. Based on previous research [10], the result is a gap between current pavement performance and the wants or needs of pedestrians along Corridor 1 BRT Trans Semarang. In response to this, this study seeks to see the trend of pedestrian demand for Trans Semarang BRT trips to urban design components such as Density, Diversity, and Design.

Urban planning researchers have developed a normative framework to measure the relationship between the built environment and travel behavior in support of the new urbanism concept direction [11]. The approach used to describe the built environment into elements that are easier to measure is using a 3D model approach: Density, Diversity, and Design [12]. Where based on research conducted by Talat Munshi in [13], states that density can be measured by observing population density per household or building density per unit area of land in the area. Meanwhile, what is meant by diversity is represented as a mixed index and balance of land use or diversity of land use which can be viewed from the ratio of developed and undeveloped land according to its use. Meanwhile, the design element in question is a component that forms a pedestrian path that is comfortable for its users. In general, Cervero and Kockelman in [12], have formulated several indicators related to the assessment of travel demand models based on 3D models (Density, Diversity, Design) as follows:

TABLE I. 3D Concept Built Environment Assessment Indicator

Element	Source		
	Robert Cervero and Kara Kockelman, (1997).	Talat Munshi, (2016).	Indicator Synthesis
Density	• Population density: total population per area (Hectares). • Employment density: number of jobs per area (Hectares). • Access to jobs: using gravity models.	• Population density per unit area (Hectares). • Job density per unit area (Hectares).	• Net population density. • Net job density.
Diversity	• Difference index: the proportion of different land uses among hectares of grid cells per unit area. • Entropy: average for the land use category among hectare grid cells within a half mile radius of each hectare grid cell in a tract. • Vertical mix: mixed intensity of land use per hectare with land uses for residential, commercial, office, industrial, institutional, garden and recreational uses. • Mixed activity centers. • Intensity of commercial land use. • Estimated commercial retail use.	• Employment to household ratio. • Entropy index, a measure of the gap between the economy and industrial concentration. • Land use inequality index. • Balance between retail and household as a proportion of employment per retail opportunity.	• Land-use mix. • Land-use balance.
Design	• The road network includes patterns, intersections and areas. • Pedestrian and cycling requirements: proportion of curb blocks and the components therein. • Site design: off-street parking area.	• Bicycle or pedestrian paths. • Road congestion leading to blocks. • Road congestion. • The width of the sidewalk. • Proportion of front and side parking.	• Road junction. • kernel density. • Pedestrian ways design and component.

Based on the needs of the analysis, environmental conditions in the study area, and considerations of relevant theoretical studies, in this study several components of 3D analysis are formulated which include population density and land use and building height analysis to assess density, comparison of land use changes to measure diversity, and components pedestrian ways designs such as width and furniture for design analysis. Density is related to the distance between buildings in relation to walking distance. In research on accessibility and public transportation planning, the walking distance is basically the average distance a person walks from or to a transit point to a point in a certain area. According to Chapleau and Morency in [14], get 500 meters as the distance that can be accepted by pedestrians in reaching the destination and the distance of the rule of thumb which is usually used by planners is 400 meters and 800 meters [15]. The addition of the FAR (Floor Area Ratio) component to the diversity analysis refers to Yang and Yao's research in [16], which states that to see the optimization of built-in land use on transportation development, it can be seen from the intensity of vertical residential development. In other words, the number of building floors on the left and right of the road will show the density of the area and the degree of integration between the built-up land. Density and diversity conditions are also directly related to urban sprawl, which often occurs, especially in developing countries such as Indonesia.

METHODOLOGY

The method used in this research is a quantitative research method that focuses on the analysis of the 3D built environment (Density, Diversity, Design). The data were collected using naturalistic observation techniques to observe the condition of the object of research in a more real way directly to the field. In analyzing the density aspect, descriptive statistical analysis methods were used. Calculating population density (people per hectare) and building density (units per hectare) and spatial simulation methods used the ArcGIS 10.3 application which as a whole will produce a trip demand indicator based on density elements. Meanwhile, to meet the objectives of diversity analysis using the percentage comparison method of built-up land area and visualization of changes and distribution of built land using the ArcGIS 10.3 application. In addition, in helping to see the optimization of land use along corridor 1, the FAR (Floor Area Ratio) analysis method is used by taking samples of existing buildings in each segment of the area. All results of the diversity component analysis will produce indicators of pedestrian demand when viewed from land use. The design analysis method will emphasize the identification of the existing conditions of the pedestrian pathway and its components which will be visualized in the form of cross-sections which will be adjusted to the criteria for safe and comfortable pedestrian pathways for its users. The focus of the object of this study is the effect of land use changes that occur along Trans Semarang Bus Corridor 1, and an increase in the area of built-up land used as analytical infrastructure. The discussion in this study will be divided into 3 observation segments, namely segment 1 of the Mangkang suburb area, segment 2 of the Simpang Lima city center area, and segment 3 of the Penggaron suburb area. By taking a radius of 500 meters on the right and left of the road along Trans Semarang Corridor 1 in accordance with the maximum average distance for a person to walk (Figure 1).

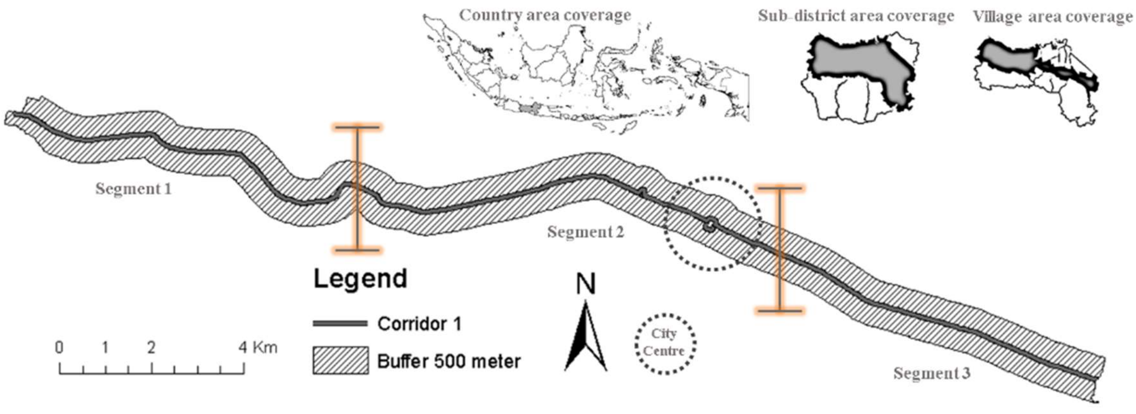


FIGURE 1. Study area (buffer 500 meters)

RESULT AND DISCUSSION

Demand Model based on Density

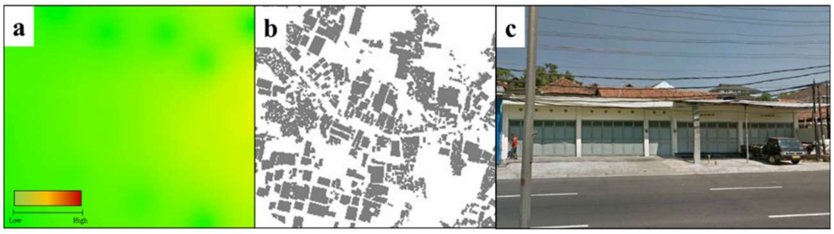
Corridor 1 of Trans Semarang BRT is one of the most crowded corridors for travel needs among other corridors in the city of Semarang. The number of BRT passengers in this corridor has increased significantly from year to year, from 369,326 passengers in 2010 to 3,408,650 passengers in 2017 (an increase of> 100%). Based on the results of research conducted by Moudia and Haryadi in [6], the characteristics of pedestrians who use BRT Trans Semarang Corridor 1. In general, pedestrians are mostly residents in the age range of 14-17 years with an Occupation as a student or university student (see Table II). Dominated by people with middle to lower-income who have income <500,000 rupiahs or have no income at all. The majority of BRT Trans Semarang Corridor 1 users are residents with family members of more than 4 people (>4 people) with most of the families owning 2 motorized vehicles. The use of BRT as a preferred type of transportation is generally used to return from work or school activities with access to bus stops when departing and returning is dominated by walking users. The distance between the bus stops to origin or destination is relatively close, that is, on average only a small distance of 250 meters (<250 meters).

TABLE II. Passenger Characteristics of BRT Trans Semarang Corridor 1

Characteristics	Item Domination	Persent (%)
Gender	Female	78,9
Age	17-24 years	45
Occupation	Student/student	55,5
Income (IDR)	None / <500,000	71,1
Origin of travel	Boarding house	47,22
The purpose of the trip	Return	46,11
Frequency	Every day	32,78
Place of origin or destination access to bus stops	On foot	60,56
The distance to the stop down to the destination	<250 meter	35,56

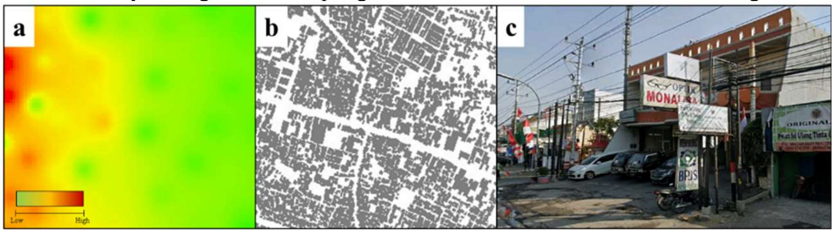
Based on the results of data, the current population density in each segment has a significant variant. The characteristics of population density in segment 1, namely the suburb of Mangkang, have a low level of population density and building density compared to other segments in the Trans Semarang BRT Corridor 1 area (see Figure 2). If viewed based on the level of urban sprawl, this segment has the highest sprawl rate, which is 61% (high) based on the calculation of changes in building density in 2000 and 2020. This condition occurs because the western part of Semarang City is the center of continuous industrial development and warehousing. It has increased significantly every year. In contrast to segment 1, the area of segment 2, which is the center of the city, has a characteristic of a larger area density which is indicated by the dominance of red color scale in the results of the 2020 population density interpolation (see Figure 2). The high population density is accompanied by a development pattern that tends to be more compact with a grid pattern. Where Yunus in [17] states that the morphological condition of a compact city is more effective in accommodating all urban functions for its residents. In the development of modern cities in developed countries, the grid construction pattern is considered effective in creating good accessibility between buildings, making it easier for pedestrians to reach their destination due to the relatively close distance among buildings.

Based on the calculation of the urban sprawl rate, this area has the smallest sprawl rate compared to other segments, which is 32% (low) due to the regional development dominated by high rise buildings and residential development patterns. This regional development tends to optimize land due to high land prices in the city center. Segment 3 is an area with a medium population density with more diverse development than other segments (see Figure 2). The level of spread of buildings or urban sprawl in this area is included in the medium category with the calculation of the sprawl rate showing a figure of 48% (moderate). Because some areas still have a strong influence on the development of the city center, marked by the red and yellow colors in the western part of this segment. Also, the development in the suburb towards Demak looks more organized than the development pattern in the suburb towards Kendal (segment 1). The results of research conducted by Yang and Yao in [16], in the analysis of integrated transportation network development in Japan, state that a more compact development by maximizing vertical development with mixed-use can save energy and tend to be environmentally friendly. Integration between transportation modes can be easier, especially for pedestrians because access to their destination would be closer to one another.



Density of Segment 1 Mangkang - Corridor 1 BRT Trans Semarang

Density of Segment 2 Simpang Lima - Corridor 1 BRT Trans Semarang



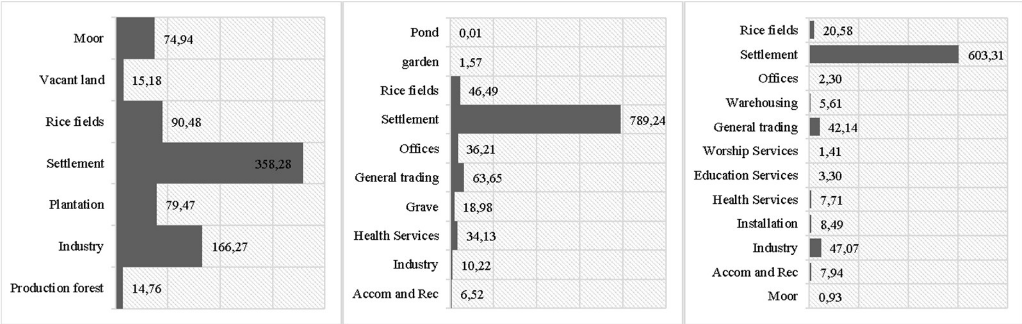
Density of Segment 3 Penggaron - Corridor 1 BRT Trans Semarang

FIGURE 2. Density Model a) Population, b) Buildings, and c) Existing Buildings

Demand Model based on Diversity

Land use is one of the assessments in looking at the demand model based on the new urbanism development concept. Based on the results of data processing, the land use along Corridor 1 BRT Trans Semarang is as a settlement (19.13%) and green open land (24.76%) when compared to the total area of 4000 Ha in the Corridor 1 area (radius 500 meters). When viewed based on the characteristics of land use in each segment, segment 2 area dominates in the use of developed land. Its location in the City Region 1 (BWK 1) of Semarang City makes the area along Corridor 1 the center of trade and services for the City of Semarang. The position of segment 1 as the city center causes the dominance of land use in this area to tend to commercial and government activities. With a more diverse and quite massive use of land as offices, public trade, settlements, public services, and others. The areas of segment 1 and 3 as periphery areas have less built-up land characteristics compared to the downtown area (segment 2). Segment 1 as a suburb of Mangkang is more dominated by industrial land use and open land. Meanwhile, segment 3 as the outskirts of Penggaron has the dominance of land use for settlement and trade and services.

Based on the results of data processing in Figure 3, the existing land uses along Corridor 1 of the Trans Semarang BRT are very diverse (mix use). Where if viewed from the area of commercial land use, the total areas of land are 3,422 Ha (85%) consisting of land use for settlements, trade and services, offices, institutions, parks, and recreation. Land use in segment 1 Mangkang is dominated by for settlements land use (358.28 Ha) and industry (166.27 Ha). Judging from its diversity, land use in this section varies less than other segments. Where in segment one Mangkang, only consists of seven types of land use with non-built land that's still relatively large. Meanwhile, segment 2, which is the city center area, has more diverse land uses with ten types of land use. The dominant land use in this segment is as a center for commercial activities such as settlements, trade, and services, as well as offices. The dense area in this segment can be seen from the area of settlements (789.24 Ha) whose is quite large compared to other segments. Based on the results of observations made, the development of Semarang City that tends to the west of the Demak Districts is trigger by the movement of labor that causes land use in Segment 3 Penggaron to become more diverse. There are as many as 12 types of land-use are dominated by commercial land use in Segment 3 Penggaron. The flow of population and labor which increase every year has made many new residential areas appear so that the areas of land for settlements (603.31 Ha) are large than other types of land use. In general, based on the theory put forward by Cervero and Kockelman in [12] and Munshi in [13], it is stated that the measurement of the level of diversity can be seen from variations in land use and the balance of use between commercial and non-commercial land uses. This relates to the provision of land or circulation for comfortable walking. Wherein commercial activities will tend to cause many disturbances and side barriers to transportation activities such as walking.



(a) (b) (c)

FIGURE 3. Intensity chart of corridor 1 land use : (a) Segment 1 Mangkang ,

(b) Segment 2 Simpang Lima, (c) Segment 3 Penggaron.

The height of the building and the configuration between land uses using the FAR (Floor Area Ratio) method, which shows a high level of land use optimization [16]. This supports the compact city theory that optimizes vertical land growth accompanied by an optimal increase in mass transportation services. Based on research by Yang and Yao [16], in transportation hubs in Japan, the growth of buildings in a vertical direction with mixed functions aims to create a compact and optimal urban development pattern, thereby minimizing irregular city traffic. Figure 4 shows that there are differences in the configuration of the building floor height between the 3 segments in Corridor 1 BRT Trans Semarang. Where segment 1 Mangkang shows a relatively similar building height pattern, ranging from 5-10 meters which are widely used as housing, warehousing, and industry. Meanwhile, segment 2 Simpang Lima shows the optimization of vertical buildings with the height of up to 40 meters. In segment 2, the building is widely used for commercial purposes and has a mixed function as a residence, offices, shopping centers, and also a vehicle parking lot. Segment 3 has a building height ranging from 5-10 meters with the use of buildings for residential and commercial use.

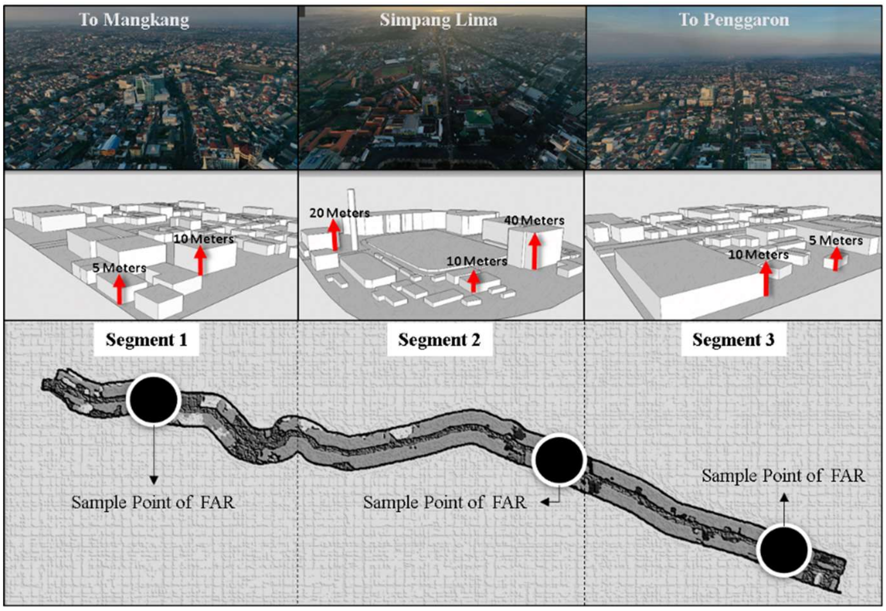
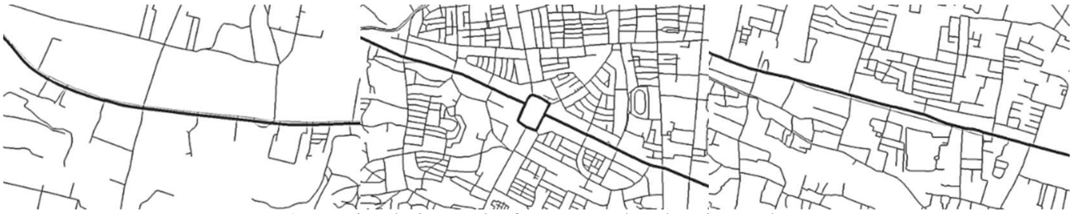


Figure 4. Appearance floor area ratio (FAR) per segment

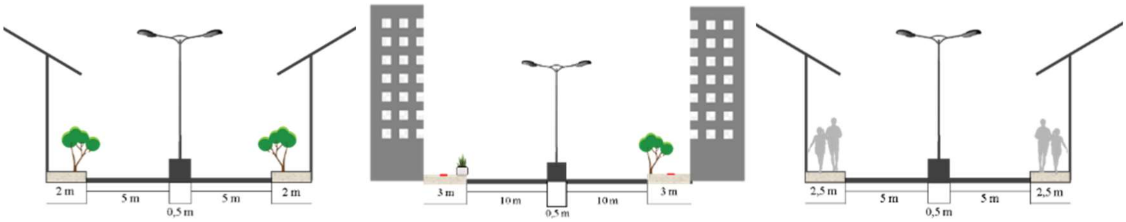
Demand Model based on Design

The next component in assessing the demand model through the new urbanism concept is the design component. Walking activities that tend to be integrated with various modes, especially in this case the Trans Semarang BRT, make it necessary to have a container that suits the needs and requests of passenger trips. The assessment of the built environment design according to Cervero and Kockelman [12] and Munshi [13] consists of an assessment of road junction conditions, traffic density around pedestrian paths, shapes and elements of pedestrian paths in the area. Figure 5 shows that the condition of the road network around the pedestrian lane is not too dense and the road arrangement is not too complex. Based on the land use, in segment 3, there is still a lot of green open land that can be used as a parking area for vehicles. However, it is relatively far from pedestrian settlements.

The pedestrian path design component in this segment is incomplete because it only consists of 2.5 meters wide pavement that is directly connected to the main road and some have no dividers. The condition of the pedestrian paths in this segment is also very minimal in terms of shady vegetation, especially near the BRT bus stops, so it is indicated that BRT passengers who wait a long time will feel uncomfortable during the day. The integration of pedestrian paths with environmental road networks that connect other activity functions is still minimal. If viewed back from the characteristics of its users, the majority are workers and students who go and return using the Trans Semarang BRT transportation. The number of BRT stops in this segment is 55 units. If it is reviewed based on the research results of Purwanto and Manullang [10], it states that the condition of the sidewalks in segment 1 still needs to be repaired where there is a gap between current conditions and user expectations. The elements that need to be improved are lighting, seats, weather protection and the slope of the sidewalk ramp.



a) Circulating paths form around pedestrian paths



b) Existing pedestrian path designs: Segment 1, Segment 2, and Segment 3.

FIGURE 5. The shape of the pedestrian path in the Trans Semarang BRT Corridor 1 area.

The pedestrian lane in segment 2 has more complete components than the other segments. The condition of the road network and the arrangement of the road which is more compact has resulted in good integration between other networks and transportation systems. The activities of BRT users in this area are more diverse, ranging from work, school, to recreation, where land use is dominated by commercial land use. The 3-5-meter-wide pedestrian path is equipped with chairs, trash cans, bollards, shady vegetation, streetlights, distribution lanes, and special pathways for the disabled. The pedestrian paths on most of the main roads are directly connected to commercial buildings such as offices, malls, recreation centers, and others. However, in this area the distance to the location of the bus stops is still not being paid attention to because there are still bus stops that are too close to the point, causing frequent traffic jams caused by accumulating BRT at one point and making passenger waiting times longer. Also, some of the pedestrian lanes in Corridor 1 are not yet equipped with special bicycle lanes and special parking so that vehicle accumulation often occurs on the side of the pedestrian path. The number of BRT stops in segment 2 is 154 units. If it is reviewed based on Purwanto and Manullang in [10], it states that the condition of the sidewalks in segment 2 still needs to be repaired where there is a gap between the current condition and user expectations. The elements that need to be improved are safety fences and lighting.

The condition of the pedestrian path in segment 3 has characteristics that are almost similar to the conditions of the existing pedestrian paths in segment 1. Where the available components are only pavements and some shade vegetation. When viewed based on the characteristics of the surrounding road network pattern, it is predicted that the maximum ability of a person to walk is 400-800 meters according to [15]. Residential conditions and relatively dense land use have resulted in the lack of parking space for vehicles around the area. If it is reviewed based on the research results of Purwanto and Manullang in [10], it states that the condition of the sidewalks in segment 3 still needs to be repaired where there is a gap between the current condition and user expectations. The elements that need to be increased are the height of the pavement floor with roads, safety fences, flat surfaces, and lighting.

TABLE III. The summary of the pedestrian demand model for BRT Trans Semarang Corridor 1

Component	Density	Diversity	Design	Recommendation
Segment 1	Low population and building density.	• Non-commercial land uses dominate. • Allocation of land for commercial activities includes industry and settlements. • The height of the building is 5-10 meters.	• The distance between the pedestrian path and the dwelling is relatively far. • Low road network integration. • Lack of optimal functionality affects user comfort.	High sprawl rates, far from facilities, and expensive travel costs. Recommended for: • Provide bike lanes or park near sidewalks. • Procurement of pedestrian bridges, vegetation and shade buildings, additional street lights, road dividers, and repair of ramps.
Segment 2	High population and building density.	• Domination of commercial land use. • Allocations of land for trade and services and for settlements	Less optimal function of some pavement components.	Low sprawl, ideal city, high integration, and pedestrian friendly. It is recommended to upgrade the BRT and intermodal systems, adding barriers, vegetation and lighting to walking paths.
Segment 3	Medium population and building density.	• Domination of commercial land use. • Allocations of land for trade and services and for settlements.	Less optimal function of some pavement components.	High sprawl rates, far from facilities, and expensive travel costs. Recommended for: • Provide special lanes for bicycles or parking around sidewalks. • Addition of lighting, safety fences, leveling of sidewalk surfaces, sidewalk floor heights, and road distribution.

CONCLUSION

The results of the analysis of the pedestrian ways design model using the BRT Trans Semarang Corridor 1 transportation mode based on the analysis method of the new urbanism 3D built environment components (Density, Diversity, Design) show that in general there are unique characteristics in each segment of the area. Where the results of the density analysis show that segment 1 Mangkang belongs to an area that has a characteristic low density with an irregular building distribution pattern and is included in the high urban sprawl category. If viewed based on the results of the diversity analysis, this segment is dominated by non-commercial land uses, namely green open land with commercial built-up land dominated by industrial areas. The two analyzes then affect the pedestrian design needs of pedestrians, especially Trans Semarang BRT users. Where the pattern of the irregular distribution of buildings (sprawl) will require long-distance and longer travel time from the residence to the bus stop if on foot. Also, the comfort aspect of the pedestrian path is still not optimal because based on Purwanto and Manullang in [10], there is a gap between performance and pedestrian needs. Based on these results, pedestrian indicators are formulated based on needs when viewed from the results of field observations and results analysis with the addition of special bicycle lanes or dedicated parking lots to accommodate vehicles such as motorcycle taxis or private vehicles. Also, it is necessary to improve the performance of sidewalk components such as streetlights, vegetation and shade buildings, pedestrian bridges, road guardrails, and ramp improvements to create user comfort.

The results of segment 2 Simpang Lima analysis show that this area tends to have the characteristics of a compact arrangement (compact city), where the diversity value tends to be high with a relatively lower sprawl rate compared to other segments. The very diverse land uses are dominated by commercial land uses such as trade and services as well as settlements. Optimization of land in this area is quite good when viewed based on the value of FAR (Floor Area Ratio), where the building construction is carried out in a vertical direction with the optimization of mixed-use. The existing sidewalk design components are quite good, where the average width of the sidewalks in this area is 3-5 meters which are equipped with guardrails, vegetation, chairs, lights, special lanes for disabilities, trash cans, and ramps. However, based on the results of Purwanto and Manullang's research in [10], there are still gaps where there needs to be an increase in the performance of the barrier components, vegetation, and lighting on pedestrian paths.

Meanwhile, the analysis of segment 3 Penggaron shows that this area has a moderate level of density and urban sprawl. Where the dominating land use in this area is in the form of land use for settlements and trade and services. The building pattern which is dominated by residential areas makes the FAR value in this area tend to have the same height, which is around 5-10 meters. When viewed from the sidewalk design component, segment 3 has the same condition as segment 1. Where there is still a gap between sidewalk performance and pedestrian demand, so it is necessary to increase the performance of sidewalk components which include lighting, safety fences, leveling of sidewalk surfaces, and pavement floor height, and road distribution [10].

In general, the influence of pedestrian demand on pedestrian path design and city shape shows that the design components and an attractive, safe, and comfortable city design will increase the tendency of residents to walk towards their destination [9]. Where in measuring the pedestrian demand model in an area it is highly dependent on environmental conditions, especially about the shape of the city and land development. Where the important findings in this study indicate that the urban sprawl process is an effect of the density and diversity components which in turn affect the pedestrian path design that is suitable for its users. So in this case, the government as the executor of development needs to include land regulations and adjustments to the shape of the city in creating a pedestrian path design that is comfortable and has good integration with mass transportation systems such as the Trans Semarang BRT.

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