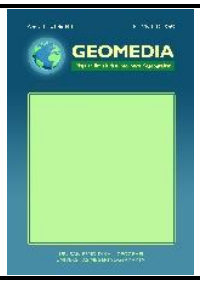

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Reciprocal-relationship between the development of "Trans Jogja" public transportation and urban spatial structure in Yogyakarta agglomeration

Arif Ashari[a, 1*], Raisya A. Olivia[a, 2], Az-Zahra A. Reswari[a, 3], Rayung W. Brotowiranti[a, 4], Bambang S. Hadi[a, 5], Muhamad Ervin[b 6]

[a] Department of Geography Education, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia
[b] Geography Education Master Program, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia
[1]arif.ashari@uny.ac.id*; [2]raisyaazety.2022@student.uny.ac.id; [3]azzahraardhana.2022@student.uny.ac.id, [4]rayungwulan.2022@student.uny.ac.id, [5]bambang_saefulhadi@uny.ac.id, [6]muhamadervin.2022@student.uny.ac.id
*korespondensi penulis

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A B S T R A K

Aktivitas transportasi tidak dapat dipisahkan dari struktur spasial suatu wilayah. Struktur spasial lokal berlaku pada wilayah yang dicirikan oleh sistem urban-hinterland dengan cakupan tidak terlalu luas seperti di Yogyakarta. Dalam makalah ini, kami mengevaluasi hubungan timbal balik antara pengembangan transportasi umum "Trans Jogja" dengan struktur spasial kota di Kota Yogyakarta dan wilayah satelitnya. Data yang dikumpulkan berupa data sekunder yang diperoleh dari dokumentasi dan data primer hasil observasi, meliputi: rute dan halte Trans Jogja, lokasi pusat aktivitas penduduk, penggunaan lahan, dan data kependudukan. Analisis data dilakukan dengan analisis SIG menggunakan average nearst neighbour, buffering, dan overlay; analisis statistik menggunakan regresi linear sederhana; serta analisis deskriptif. Terdapat dua temuan utama dalam studi ini. Pertama, pelayanan transportasi berkembang mengikuti karakteristik aktivitas penduduk, dibuktikan dengan pola sebaran rute dan halte yang mengikuti lokasi pusat aktivitas dan kepadatan penduduk. Kedua, pengembangan transportasi juga memicu pembentukan bentanglahan kota yang cenderung pada tipe eksurbanisasi. Secara ringkas, studi ini menawarkan informasi alternatif yang memberikan wawasan baru mengenai hubungan timbal balik pengembangan transportasi dengan struktur spasial kota di Indonesia.

Keywords:
Transportation geography
Urban transportation
Urban spatial structure
Yogyakarta

A B S T R A C T

Transportation activities cannot be separated from the spatial structure of a region. Local spatial structure applies to areas characterized by urban-hinterland systems with modest coverage, such as Yogyakarta. In this paper, we evaluate the reciprocal relationship between the development of public transportation "Trans Jogja" and the urban spatial structure in Yogyakarta City and its satellite areas. The data collected are secondary data obtained from documentation and primary data from observation, including Trans Jogja routes and bus stops, location of population activity centres, land use, and population data. Data analysis was conducted using GIS analysis using average nearest neighbour, buffering, and overlay; statistical analysis using simple linear regression; and descriptive analysis.

There are two main findings in this study. First, transportation services develop following the characteristics of population activities, as evidenced by the distribution pattern of routes and bus stops that follow the location of activity centres and population density. Second, transportation development also triggers the formation of urban landscapes that tend to exurbanize. In summary, this study offers alternative information that provides new insights into the reciprocal relationship between transportation development and the spatial structure of cities in Indonesia.

Introduction

Transportation, as one of the essential elements in modern society is life, is always attractive to discuss from various perspectives. In the study of transportation geography, the discussion of transportation includes its relationship with the spatial structure of an area. In this context, transportation is a very relevant topic to be approached by geography because transportation activities are related to spatial organization. Rodrigue (2020) explains that spatial organization depends on two dimensions. First, it relates to spatial differentiation, where attributes such as location, size, and density show a picture of the unequal distribution of a feature. Second, it relates to spatial interaction where attributes such as origin, destination, and flow also illustrate disparities. Transportation is an activity related to location, distance, accessibility, origin, destination, and flow, highly relevant to geography's concepts, themes, and approaches. Discussing the relationship between transportation and spatial structure is very important because there is a mutual influence between transportation and spatial structure.

The discussion of transportation and its relationship with spatial structure has attracted the interest of many previous authors. Many publications have contributed insights on this topic, especially studies conducted in urban areas. Garcia-Lopez (2012), in a study in Barcelona, showed that the improvement of transportation infrastructure affects suburbanization, where there has been a change in population location patterns in Barcelona, Spain, from 1991 to 2006. Tung et al. (2024), in a study in China on the spatiotemporal dynamics of urban spatial structure from 2006 to 2019, showed that transportation impacts the formation of urban spatial structure in prefecture-level cities. The study conducted by Sasaki & Kaiyama (1990) shows how improvements in the transportation system will affect the urban spatial structure, especially how the rental profile in a city will be affected and how the size of industrial and residential areas will change when the transportation system is improved. All three studies conducted by Garcia-López (2012), Tung (2024), and Sasaki and Kaiyama (1990) show that transportation affects the spatial structure of cities. In a study conducted in Paris, Salov & Semerikova (2023) found that about 1.5 million new jobs were created in Paris in half a century with uneven spatial distribution. Significant changes in rail transportation accompanied the dramatic shift in employment geography. Meanwhile, a study by Zhang et al. (2024) in China found that urban spatial structure affects per capita carbon emissions from daily travel. Salov & Semerikova's (2023) and Zhang's (2024) studies show that urban spatial structure affects transportation.

In Indonesia, a study on the influence of urban spatial structure on transportation has been conducted by Saputra & Widyasmara (2014). This study compares the bus services of "Trans Jogja" in Yogyakarta and "Batik Solo Trans" in Surakarta regarding urban spatial structure. However, various studies have shown that no one has discussed the relationship between public transportation services in urban areas and the urban spatial structure. The previous literature still does not cover studies on how transportation services are built concerning population, population density, and the locations of public services and activity centres. Moreover, studies that address the reciprocal relationship between transportation and the urban spatial structure have not been conducted. Previous studies have focused on the effect of one variable on the other

and have not looked at the reciprocal relationship. This indicates a scientific gap that needs to be filled with further studies.

Yogyakarta Urban Area has a public transportation facility called "Trans Jogja." This mode of transportation has been operating since 2008. Data from the Yogyakarta Special Region Transportation Agency shows that in 2024, "Trans Jogja" serves 21 routes with 140 bus fleets and 267 bus stops spread across Yogyakarta and its surrounding areas. In its development, this mode of transportation also serves new routes to several areas that are satellites for Yogyakarta City, including Godean, Ngaglik, Ngemplak, and Bantul. Godean, Ngaglik, and Ngemplak, included in the Sleman Regency area, have been served since 2020, while Bantul has been served since 2022. The existence of "Trans Jogja" as a mode of public transportation amidst the high use of private vehicles or motorcycle taxis is a unique phenomenon to study. In particular, it is interesting to see the relationship between this transportation system and the urban spatial structure. Previous studies by Saputra and Widyasmara have highlighted travel time, bus stop spacing, coverage area, number of passengers, and operating time, concluding that "Trans Jogja" is highly affordable. However, further studies are still needed to see how the reciprocal relationship with the urban spatial structure relates to the population's activities.

In this paper, the reciprocal relationship between the development of public transportation, "Trans Jogja," and the spatial structure of the urban area of Yogyakarta is investigated. There are three more specific objectives in this paper. First, we evaluate the distribution pattern of bus stops and routes of "Trans Jogja." Second, we assess the urban spatial structure's influence on the service of "Trans Jogja," namely by considering the distribution of bus stops and routes to the population, population density, and various centres of population activities. Last, we evaluated the effect of the "Trans Jogja" public transportation development on spatial structure by considering land use changes between the periods before and after being served by this mode of transportation. This paper provides alternative information regarding the relationship between transportation and spatial structure in Indonesia. Also, this paper offers new insights into the relationship between transportation and spatial structure in Southeast Asian cities dominated by private vehicles, especially motorcycles.

Methods

Data Collection and Analysis

This study employs a geographical approach to analyze the problem. The geographical approach includes utilizing spatial approaches and geographic themes to analyze issues. The subject of this study is the Yogyakarta Urban Area, and the object of study is transportation services and the urban spatial structure. The data collected are secondary data obtained from documentation and primary data from observation, including Trans Jogja routes and bus stops, location of population activity centres, land use, and population data (Table 1).

Table 1. Types of data, data collection, and instrument/data sources

Data	Data collection	Instrument/data sources
Bus stop location	Documentation	Yogyakarta Special Region (DIY) Transportation Agency; Geoportal Palapa
	Observation	GPS, digital camera, observation sheet
Bus route	Documentation	Transportation Agency of DIY
Population	Documentation	Statistical Agency of DIY

Population density	Documentation	Statistical Agency of DIY
Landuse	Documentation	Indonesian Topographical Map (Peta Rupabumi Indonesia); Geoportal Palapa
	Remote sensing image interpretation	Satellite imagery provided by Google Earth
Campus location	Documentation	Geoportal Palapa; Google Maps
School location	Documentation	Geoportal Palapa; Google Maps
Hospital location	Documentation	Geoportal Palapa; Google Maps
Government-owned clinic location (Puskesmas)	Documentation	Geoportal Palapa; Google Maps
Mall location	Documentation	Geoportal Palapa; Google Maps
Traditional market location	Documentation	Geoportal Palapa; Google Maps

The data analysis method used in this study is a Geographic Information System (GIS) analysis, and statistical analysis is supported by descriptive analysis. GIS analysis used the average nearest neighbour, buffering, and overlay. Statistical analysis employs simple linear regression. The first step in the analysis was plotting bus stop locations on the study area map. Furthermore, the average nearest neighbour analysis is carried out to determine the distribution pattern of the bus stop and whether it is included in the clustered, random, or dispersed category. The results of this analysis provide an initial picture of the distribution of bus stops as service centres for "Trans Jogja." This analysis is supported by the analysis, which shows the percentage of roads in Yogyakarta City used as "Trans Jogja" routes compared to the total roads in the region. This will provide information on the coverage area of this transportation mode service.

Furthermore, buffering analysis was conducted on the locations of education, health, and shopping centre facilities. Buffering is done to convert location data in the form of points into areas for overlay analysis in the next step. The buffer is determined at 100 meters, assuming a relatively long distance to walk to the bus stop. Overlay analysis determines the number of bus stops 100 meters from the location of educational facilities, health, and shopping centres. This analysis also determines the number of bus stops in areas with specific population densities and land uses. Simple linear regression analysis was used to determine the trend of the number of bus stops against the population in an area.

The Study Area

This study was conducted in the Yogyakarta agglomeration area, covering the city of Yogyakarta and the surrounding urban areas that are administratively included in the Sleman and Bantul regencies. Judging from the city morphology and city-rural interaction, the urban areas around Yogyakarta City are sub-urban and sub-urban fringe areas in the Yogyakarta agglomeration system. Thus, the study area administratively covers the entire area of Yogyakarta City; Sleman Regency in the sub-districts of Gamping, Mlati, Depok, Ngaglik, and Ngemplak; and Bantul Regency in the sub-districts of Banguntapan, Sewon, and Kasihan. With the

addition of the "Trans Jogja" route, the study area also includes three towns that are satellites of Yogyakarta City, including Bantul District in Bantul Regency and Pakem and Godean Districts in Sleman Regency (Fig 1).

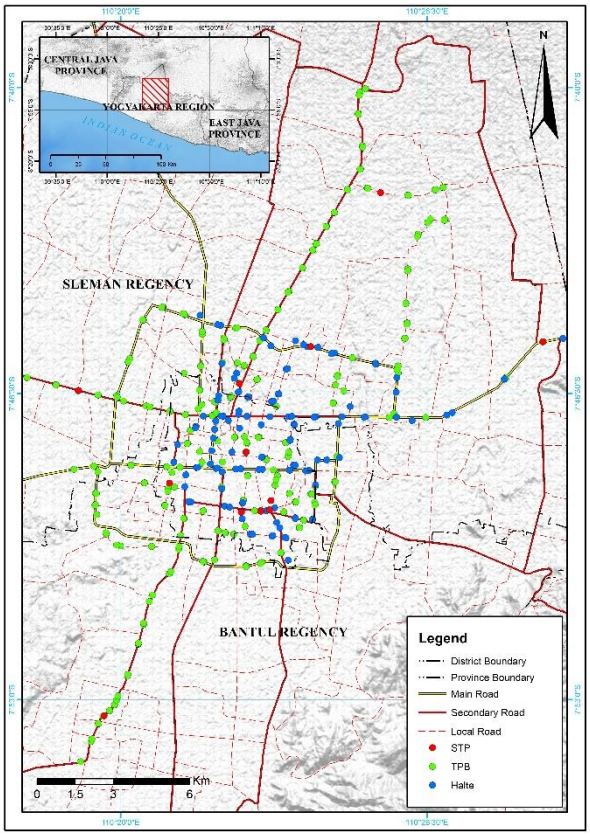

Fig 1. The Study Area

The study area covers an area of 653,89 km^2, with a population of 1.043.702 people. Physiographically, the study area is located in the Merapi volcanic landscape system, starting from the volcanic foot unit in the Sleman area, the volcanic foot plain in Sleman and Yogyakarta City, and the fluvio-volcanic plain in the Bantul area (Ashari, 2017; Ashari & Purwantara, 2022; Purwantara et al., 2021). Geologically, the entire study area is composed of young Merapi activity product material. This volcanic landscape system has good groundwater potential due to the nature of volcanic materials with high permeability and porosity, where slope and foot areas function as infiltration areas (Purwantara et al., 2020; Sutikno et al., 2007).

Result

Distribution pattern of bus stops and routes of "Trans Jogja" in Yogyakarta agglomeration

In this section, we describe the results of evaluating the distribution pattern of bus stops and routes in the research area. The results of GIS analysis using the average nearest neighbour show that the distribution of "Trans Jogja" bus stops throughout the study area is clustered. This is indicated by a Z-score of -28,39 at a significance level of p of 0 (Fig 2). According to Kurniati et al. (2016), there are three distribution patterns: clustered, dispersed, and random. The clustered pattern is indicated by a negative or smaller z-score value. A positive and more significant z-score value indicates the dispersed pattern. In contrast, the random pattern is marked by a z-score value of zero or close to zero.

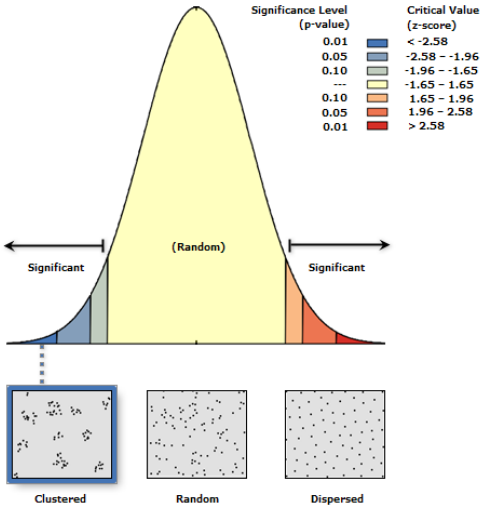

Fig 2. The result of the average nearest neighbour analysis

The distribution of bus stops in the study area obtained a z-score of -28,39, so it is included in the clustered category. This z-score value is minimal, indicating that the pattern formed is very clustered. In the study area, groupings of bus stops are continuously formed. In other words, the level of clustering is firm and far from random but constantly forms aggregate groups between several bus stops. This is because some bus stops tend to be built at a relatively close distance. At least at one location, there are two bus stops in opposite positions. One stop is located across the street from the other.

The total number of bus stops in the study area is 382 (Fig 1). 42% of the bus stops are administratively located in the CBD and the sub-urban regions of Yogyakarta City. Meanwhile, 58% were scattered in urban fringe areas and hinterland areas that became satellites for Yogyakarta. There are three types of "Trans Jogja" bus stops: halte (bus stop with buildings), bus stops non-halte (locally known as *tempat pemberhentian bus* or TPB), and stop points without signage (locally known as *stasiun tanpa plang* or STP). Referring to data from the Yogyakarta Special Region Transportation Agency, the number of each category is not the same. The halte category in the study area has 116 units, TPB has 253 units, and STP has 13 units.

Based on the three types of bus stops, we also conducted an average nearest-neighbour analysis on each type. For the halte type, the z-score is -10.22. For the TPB type, a z-score of -23.32 was obtained. Meanwhile, for STP, a z-score of 3.60 was obtained. Tests on the bus stop and TPB categories also showed clustered pattern results. This is because halte and TPBs are also always built-in pairs. Two bus stops are always placed in pairs across the street. The greater the points tested, the smaller the z-score value obtained. This indicates that the clustered pattern is more robust. The score on TPB of -23.22 shows a more robust clustered pattern than halte, as there are more TPBs than halte. STP is the only category of bus stops that is not clustered but spread dispersed. This is because there are very few of them, and they are usually not built-in pairs. See Fig 3.

According to the data from the Yogyakarta Special Region Transportation Agency, until early 2024, "Trans Jogja" serves 21 routes, namely 1A, 1B, 2A, 2B, 3A, 3B, 4A, 4B, 5A, 5B, 6A, 6B, 7, 8, 9, 10, 11, 12, 13, 14, and 15. The total number of fleets serving all these routes is 140. Line 3A has the most significant number of fleets, with 17 fleets, followed by lines 1A and 15 with 15 fleets, and then line 14 with 14 fleets. The number of fleets is different for all routes, depending on the number of passengers served. In other words, the number of fleets prepared is linear with the number of passengers served. With an unequal number of fleets and route lengths, the waiting time for bus arrival is also not the same. Line 7, which is only served by three fleets, has a waiting time of 35 minutes. Four fleets serve lines 6A and 6B, and the waiting time is 35 minutes. Meanwhile, line 1A with 15 fleets has a waiting time of 10 minutes, and line 3A with 17 fleets has a waiting time of 15 minutes. Table 2 shows the service on all routes.

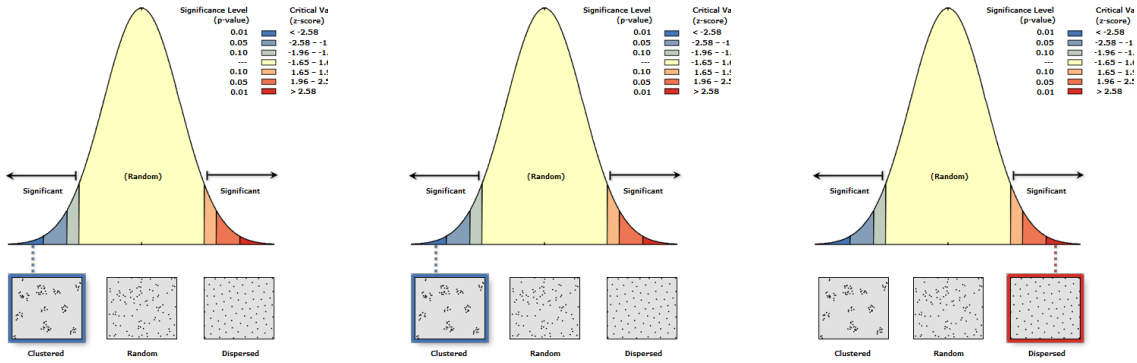

Fig 3. ANN results of bus stop distribution patterns, (A) halte-type, (B) TPB-type, and (C) STP-type

Table 2. "Trans Jogja" service route in the Yogyakarta agglomeration

Route	Number of fleets (units)	Headway (minutes)	Service hours

1A	15	10	05.00-19.00
1B	8	20	05.30-21.30
2A	10	13	05.00-18.45
2B	13	16	05.30-21.30
3A	17	15	05.30-21.30
3B	12	20	05.30-21.30
4A	5	40	05.30-21.30
4B	6	40	05.30-21.30
5A	6	40	05.30-21.30
5B	5	30	05.30-21.30
6A	4	35	05.30-21.30
6B	4	35	05.30-21.30
7	3	30	05.30-21.30
8	8	25	05.30-21.30
9	6	30	05.30-21.30
10	8	20	05.30-21.30
11	4	60	05.30-21.30
12	15	10	05.00-19.00
13	6	41	05.30-21.30
14	14	15	05.30-21.30
15	11	12	05.30-21.30

Influence of urban spatial structure on "Trans Jogja" service

Transportation consists of demand, networks, and nodes as a form of movement of people, goods, and information. As one part of the transportation system, demand is an essential and decisive aspect. Demand includes the volume to be served and the expected service frequency (Rodrigue, 2022). From this, it can be understood that transportation development cannot be separated from demand. The higher the volume and frequency of demand, the more developed the transportation service. The high level of demand will also affect the connectivity of routes connecting between nodes so that transportation will develop further. In the context of the relationship between transportation and spatial structure, transportation facilities will be more developed in areas that many people inhabit and have many population activity centres.

According to this concept, transportation in the urban area of Yogyakarta should also evolve with demand. "Trans Jogja" is a public transportation service that serves passenger transportation, and the demand comes from residents who move between various places in the city. In this section, we evaluate the extent of the relationship between the development of "Trans Jogja" transportation and the demand from residents. The basic assumption is that more routes and bus stops of "Trans Jogja" should be built in areas with high population and population density. Similarly, in areas where there are many centres of population activity, such as education services, health services, centres of economic activity, and leisure centres. The number of routes and bus stops will increase along with the number of population centres. Also, the construction of bus stops should be located relatively close to the population activity centres.

The statistical analysis results show an increasing trend in bus stops relative to population and activities in some variables. However, the relationship between the independent and dependent variables is relatively insignificant. In this study, we analyzed the relationship between population, population density, and area in 26 sub-districts in the study area. Fourteen sub-districts are in Yogyakarta City, eight in Sleman Regency, and four in Bantul Regency. Based on the results of the analysis, it is known that areas with more population also tend to have more bus stops. However, the relationship is not significant with $r^2 = 0.38$.

More densely populated areas also tend to have more bus stops. However, this relationship is much less significant than the population with an r^2 of only 0.10. It can be seen that although these two variables tend not to be significantly related to the number of bus stops, the population in an

area tends to be more of a consideration than population density in building bus stops as transportation service units. An exciting finding was obtained when analyzing the relationship between the area and the number of bus stops. The larger the area, the fewer bus stops there will be. However, the relationship is insignificant, with an r^2 of only 0.10. Thus, a larger area does not necessarily mean more bus stops. Large areas represent suburban areas with fewer people and lower density. Therefore, bus stops are even smaller despite the more extensive coverage area. Table 3 shows the population, population density, area, and number of bus stops of the 26 sub-districts analyzed in this study.

Table 3. Population, population density, area, and number of bus stops in the study area

	Population	Population density	Area (km^2)	Number of bus stops
N	26	26	26	26
Mean	43502,3	8152,8	15,8	14,7
Median	31213,0	7437,7	6,2	11,0
St.dev	36609,4	6769,2	15,3	13,6
Max	131517,0	21442,0	40,1	67,0
Min	6529,0	312,5	0,6	3,0

The relationship between population, population density, and area with the number of bus stops as service units of "Trans Jogja" is very reasonable and clearly understood. However, the insignificant relationship here needs attention. The population, population density, and area variables are not decisive enough to consider building bus stops. Instead of population, population density, and area, bus stops tend to be built following population activity centres such as education services, health services, economic activity centres, and leisure centres.

The analysis results of the number of population activity centres within 100 meters of the bus stop show that each bus stop tends to have at least one population activity centre object. This is based on the initial assumption that the construction of "Trans Jogja" transportation facilities is indeed carried out to serve population demand, reflected in the location of bus stops close to various population activity centres. However, several bus stop locations are built close to several centres of population activity. One example is the Panti Rapih Bus Stop and TPB, which can simultaneously reach three population activity centres, including hospitals, schools and universities. Of the 143 bus stops directly associated with the population activity centre object, 23% serve population activities for universities, followed by 17.5% of bus stops serving school activities. Meanwhile, the bus stops that serve the most minor population activity are bus stops close to malls, which are only 4.2%. The population activity centres analyzed in this study are shown in Table 4.

Table 4. The number of population activity centres covered by bus stops in the study area

Population activity center	Total unit	Bus Stop	Percentage (%)
Universities	54	33	23,1
School	67	25	17,5
Market	49	24	16,8
Mall/Shopping centre	7	6	4,2
Hospital	46	18	12,6
Government-owned clinic	65	14	9,8
Tourism object	74	23	16,1

Effect of "Trans Jogja" public transportation development on urban spatial structure

An essential part of looking at the relationship between transportation and spatial structure is how much influence transportation services have on the development of the spatial structure of an area. In this case, the existence of transportation will encourage the development of an area where transportation will increase accessibility and thus provide opportunities for various new forms of development. Rodrigue (2022) explains that in urban transportation, transportation services will encourage the development of local-scale spatial structure in conventional/classic cities, suburbanization, and exurbanization.

Field observations and observations of temporal land use change in the study area showed that the influence of "Trans Jogja" services on the development of spatial structure in the Yogyakarta Agglomeration is relatively tiny. In other words, the influence of this transportation is feeble on the development of spatial structure. This is because "Trans Jogja" is a mode of public transportation that only serves routes that connect pre-existing nodes. It is different if the transportation here is the construction of a new road or rail system that can encourage the growth of other sectors involved in the transportation service.

Also, "Trans Jogja" functions here as an alternative mode of transportation. The number of public transportation services is relatively small compared to the total mobility in the study area. Like many cities in Southeast Asia, Yogyakarta is dominated by motorized vehicles that fall under the category of private cars. In addition, if residents wish to utilize public transport services, there are still taxis and motorcycle taxis that are widely preferred due to the convenience and efficiency offered, as well as the concept of atomization, which is the choice of many transportation users. Thus, it can be understood that the impact of the existence of "Trans Jogja" on regional development is relatively small due to the intensity of its use, which does not dominate transportation in the Yogyakarta Agglomeration.

Various objects near the bus stop generally exist, such as campuses, schools, hospitals, health centres, markets, malls, and tourist attractions. Bus stops are built close to the centre of the population's activities as nodes, rather than new activity centres appearing due to the public transportation service "Trans Jogja." On all routes served, the condition of the spatial structure has changed relatively little. There is relatively little change, even on the new routes starting to be served.

However, this does not mean that the "Trans Jogja" service has no impact on the spatial structure of the region. The services provided can affect increasing connectivity between nodes that have previously been formed by various other modes of transportation that have been carried out. Referring to the formation of urban landscapes formed by transportation and the use of multiple modes, as stated by Rodrigue (2024), Yogyakarta Agglomeration tends to experience exurbanization, which is the expansion of cities in rural areas, where urban and rural activities are somewhat mixed. This is evident in the satellite areas of the new "Trans Jogja" line, namely in the Town of Bantul and the Town of Godean and Pakem. The "Trans Jogja" service, along with other modes of transportation and even other economic elements, has equally influenced the development of the city's spatial structure.

Discussion

This study's findings indicate a link between the service of "Trans Jogja" as public transportation and the urban spatial structure in the Yogyakarta Agglomeration. This connection is especially evident in the development of transportation infrastructure, especially bus stops and routes that consider the distribution of population activity centres as demand to be served. The study results show that determining bus stop locations is very purposive, and it tends to approach population activity centres, educational facilities, health facilities, economic activity centres, and leisure centres. More specifically, health and education facilities, which are considered the most essential, are prioritized

in building bus stops instead of markets, shopping centres, and leisure and recreation facilities. Population and population density, which represent occupancy, are also influential but very small. On the other hand, transportation services have a relatively weak influence on developing the city's spatial structure.

This finding is similar to a study conducted by Huang et al. (2009) in Wuhan, China. Some similarities include: (1) Bus stop distribution patterns are influenced by urban morphology, land use, road network, and service intensity, and (2) Spatial distribution of bus terminals tends to be complex and is often ignored in transit planning. Public transportation facilities such as "Trans Jogja" are built to serve the needs of residents whose lives have been established first. This causes the distribution of bus stops to follow the existing demand. Bus stops built following demand are complex and not part of transit planning. The findings of this study in Yogyakarta are similar to those in Wuhan. However, the distribution pattern of bus stops in Yogyakarta tends to be clustered because it is purposively designed to have bus stops built in pairs.

The clustering pattern of bus stop distribution in Yogyakarta is similar to that in Ardabil City, Iran, as Mohammadhasan et al. (2019) found. Several factors, including uneven urban development, different population densities, geographic accessibility, and transportation planning policies, influence the clustering pattern in Ardabil. Although they have similar distribution patterns, the factors causing this clustered distribution pattern differ, whereas Yogyakarta tends to be caused by transportation planning policies. Population density has no significant effect in Yogyakarta.

In Indonesia, the distribution pattern of bus stops as an indicator of transportation services was determined by Witjaksono et al. (2018) in the Metropolitan Area of Surabaya (locally known as Gerbangkertosusila). This study's results show that bus stop distribution patterns vary among the regions of the metropolitan system. It turns out that factors such as population density, economic activity, and transportation infrastructure affect the distribution pattern. This condition differs from the findings of the bus stop distribution pattern of "Trans Jogja," which tends to cluster due to transportation planning factors. Different findings were also obtained from a study in the urban area of Lanzhou, China, by Chen et al. (2019). The results of this study show that there are two distribution patterns in one city, namely clustered and dispersed at the same time. Clustering occurs in the city centre, while dispersal occurs in the city's sub-center. Different city morphology is the cause of the difference in findings between Lanzhou and Yogyakarta.

In San Francisco, USA, there are bus stop inequalities where clustering occurs in the northern part of the city and the bus routes with the most extended trips. There is also inequality in the distribution of stop facilities based on demographic composition (Moran, 2022). The study was conducted in San Francisco on a regional scale. Hence, the results differ from those of Yogyakarta, which analyzes the distribution pattern of bus stops locally in Yogyakarta City and its satellite areas. However, the similarity between San Francisco and "Trans Jogja" in Yogyakarta is that most bus stops are not equipped with facilities such as seats, shelters, or clear barriers. This is the same as the TPB and STP in Yogyakarta.

Conclusion

Transportation is closely related to the spatial structure of an area. Transportation is closely related to the city's spatial structure on a local scale. This study proves that the public transportation service "Trans Jogja" follows demand and forms a bus stop distribution pattern that tends to follow the centre of population activity. Ideally, transportation development also affects the spatial development of an area. Transportation services will encourage new business opportunities so that the city's spatial structure will develop. This study found minimal influence of public transportation services in a town that uses motorcycles as private vehicles. However, transportation has an impact that has created an exurbanization system in Yogyakarta agglomeration.

As an evaluation, this study has some limitations. This study is still limited to bus stop

distribution patterns as an indicator of transportation services. Bus routes have also been discussed but in a minimal portion. Due to these limitations, future studies are highly recommended to explore bus routes further concerning transportation and the spatial structure in a motorcycle-dominated city like Yogyakarta.

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