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The Route and Bus Stop Plan for Urban Agglomeration Transportation on the Educational Facility in Yogyakarta Urbanized Area

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ABSTRACT Public transportation is important in an urban area to provide better mobility and access to several destinations within the city. Therefore, this research was conducted to improve the Trans Jogja service as an Urban Agglomeration Transportation which is considered appropriate for residents, especially students, to ensure they shift to public transportation. The focus of this study was to develop the plan for the route and bus stop distribution in the educational facility covering high schools and universities in Yogyakarta Urbanized Area (YUA). The bus route network plan was formulated based on the number of student trips, land use, characteristics of the road network, route length, and travel time using multi-criteria analysis while the spatial analytical method was applied to cover the bus stop accessibility to schools and universities through two scenarios. The first was approximately a 200-meters radius while the second scenario was a 500-meters radius of accessibility and the route analysis showed the possibility of having 31 new routes of Yogyakarta Urban Agglomeration Transportation to cover the whole sub-districts in YUA including the Godean and Ngemplak which was not previously served by the Trans Jogja. The new routes consist of three outer city routes (OCR), 23 inner-city routes (ICR), and 5 connecting routes for the suburban and urban areas. Meanwhile, the bus stop was planned to focus on the new route as well as residential land use in a sub-urban area, high schools, and universities and the first scenario with a 200-meter radius has 99 units of the additional bus stop while the second with 500 meters has 66 units. This means the second scenario is better due to its coverage of a larger catchment area and other advantages and both the route network and bus stop addition plan were observed to have the equity concept to increase connectivity and accessibility for students.

KEYWORDS Route Plan; Bus Stop Plan; Urban Agglomeration Transportation; Trans Jogja; Student.

1 INTRODUCTION

Urban development is usually oriented towards private vehicle usage in this part of the world due to the uncontrolled sub-urban development known as the urban sprawl and this is far from the concept of ideal sustainable transportation. Citizens depend highly on cars or motorcycles for their trips and this causes congestion and several other problems (Ariyanti and Sebhatu, 2017). This, however, reflects the level of poor service rendered by urban public transportation (Kwan et al., 2018). Meanwhile, agglomerated urban development leads to the expansion of the urban area and causes bias to the city border (Fang and Yu, 2017).

Yogyakarta City is currently agglomerated with its sub-urban areas such as the Sleman and Bantul Regency and this led to the creation of the Yogyakarta Urbanized Area (YUA) (Devi et al., 2020) which covers 14 sub-districts in Yogyakarta, 6 in Sleman Regency including Depok, Mlati, Godean, Gamping, Ngaglik, Ngemplak, and 3 in Bantul Regency which are Sewon, Banguntapan, and Kasihan (Regional Department Planning Agency, DIY, 2010). The urbanization process started in the city several years ago and its impact is observed from the increase in housing development in the northern and southern part since 1970 with 601 housing units per annum recorded in Sleman Regency and 967 in Bantul Regency and the figure is expected to reach 72.775 units in 2025 (Ritohardoyo, 2016). Moreover, activity centers such as offices, hospitals, malls, schools, and universities are also spread in the city center and urban area to create

a gap between the generation and attraction areas.

Trans Jogja is the only public transportation or bus currently operating in the city center and the surrounding area of Yogyakarta but its service does not cover the whole area of YUA fully and this means the generation and attraction areas are not well connected, thereby, causing an increase in the use of private vehicles as dominated by motorcycles with 85% (Devi et al., 2020). Moreover, the performance of Trans Jogja has been reported to be declining annually in terms of punctuality, waiting time, accessibility, and travel time which are below average (Hidayat, 2018). These problems have been associated with the circular form of route network which leads to inefficiency and the city agglomeration which is not oriented towards public transportation has also been found to be causing traffic congestion in the city (Hagen et al., 2016).

The passengers patronizing Trans Jogja have been statistically reported to be 5,3 million in 2018 and this includes 6,6% of students and 93,4% of other commuters (Regional Transportation Office, 2018). This means a small group of students use these buses as their primary mode of transportation despite the minimum service provided to schools and universities in YUA. Meanwhile, the students have been observed to be half of the population of the school and productive ages and this means they are potential customers of Trans Jogja.

The high number of students is reflected in Yogyakarta City's predicate as an education city as well as a large number of schools, especially senior high schools and universities. The Regional Sport and Educational Office (2018) recorded 156 senior high schools and 110 universities in the city with 80 senior high schools and 46 universities in Yogyakarta City, 50 senior high schools and 40 universities in Sleman, and 26 senior high schools and 22 universities in Bantul District. The students are the major focus of this study due to their population which has been recorded and previously stated to be nearly half of the total school and productive ages in YUA (Regional Population and Civil Registration Office, DIY, 2018). Furthermore, the number increase every year and most of them tend to buy a new vehicle, especially motorcycle and those with the requirement to obtain a driving license also tend to make use of their motorcycles for school activity (Irawan and Sumi, 2011).

Meanwhile, these motorcycles are the most vulnerable vehicles, especially for students between 15 to 20 years old, as observed in their high contribution to the number of death associated with fatal motorcycle crushes. This is related to the transition of maturity experience of this age group physically, psychologically, and socially which influence their decisions while driving (Banz et al., 2019).

This research is expected to improve the Trans Jogja by developing a bus route network and bus stop plan through a student approach to shift from the use of private vehicles to public transportation and also reduce the occurrence of accidents. The plan is also an effort to implement the use of public transportation for the next generation starting from the early stage, especially at the student age.

2 METHODS

Flow diagram of this research can be seen in Figure 1 below.

2.1 Description of Study Area

Yogyakarta Urban Agglomeration Area is formed from Yogyakarta City development with surrounding areas with direct borders such as Sleman and Bantul districts as shown in Figure 2. This area was selected based on 2 criteria which include its urban characteristic and planning area as reported in (Regional Department Planning Agency, DIY, 2010) which consists of the sub-districts of Mantrijeron (MJ), Kraton (KT), Mergangsan (MG), Umbulharjo (UR), Kotagede (KG), Gondokusuman (GS), Danurejan (DJ), Pakualaman (PK), Gondomanan (GN), Ngampilan (NL), Wirobrajan (WB), Gedongtengen (GT), Jetis (JT), and Tegalrejo (TG) in Yogyakarta City, Depok (DP), Mlati (ML), Ngaglik (NG), Ngemplak (NP),

Godean (GD), and Gamping (GP) in Sleman District and Sewon (SW), Banguntapan (BP), and Kasihan (KS) in Bantul District. It has an area of 314,81 km2 land population of 1.249.062 people with one third, 362.980, found to be students (Regional Population and Civil Registration Office, DIY, 2018) which are proven by the 156 schools and 110 universities in the area.

2.2 Route Network Plan

The bus route network in Yogyakarta plays an important role in the development of public transportation due to its ability to provide good urban mobility for people rather instead of using a private vehicle (Ceder and Jiang, 2020) to long distances such as office, school, or tourist areas (Pemberton, 2020). The route network generally aims to minimize trip and travel time in order to reduce traffic (Caceres et al., 2017; Diaz-Parra et al., Nov 2012), and public transportation service is required to be developed with equity concept to reach not only the central city but also the suburban area with high demand (Pemberton, 2020). The bus route network plan was, however, determined based on the SK Dirjen 687/2002 as follows (the Republic of Indonesia, 2002).

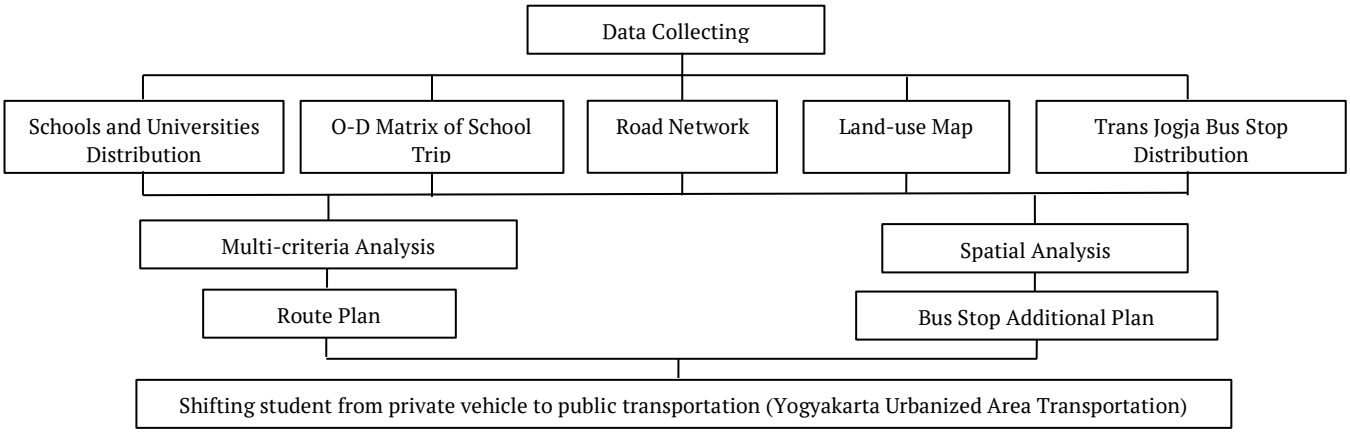

Figure 1. Flow diagram of the methodology

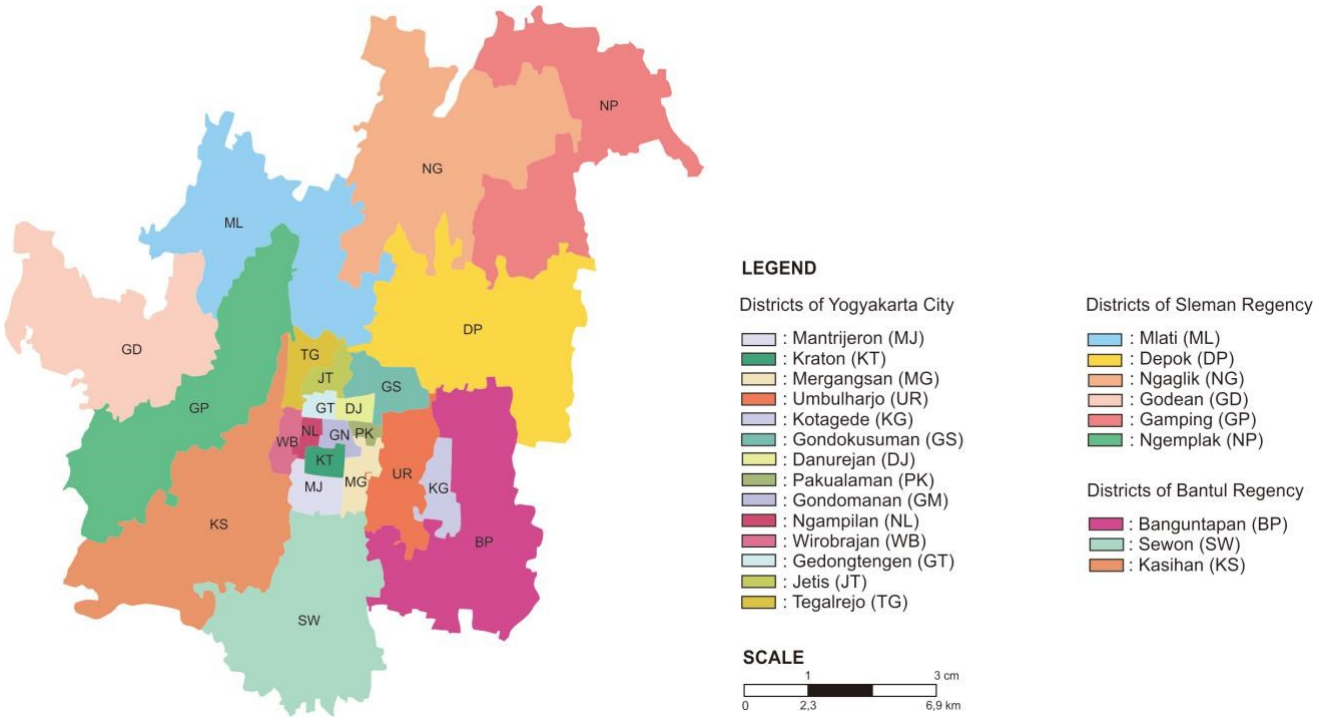

Figure 2. Map of the study area

1. Land use pattern: Public transportation is expected to serve the area with land use planning and a high potential for transport demand and destination.
2. Mobility pattern of public transportation passenger: Public transportation mobility is suitable with the pattern of the population in creating trips and ensuring efficient service.
3. Population density: Area with a high-density population have a high potential to demand public transportation and this means there is a need to create a route as close as possible to the area.
4. Service area: Public transportation service is expected to be rendered with an equity concept in urban and sub-urban areas with the potential for higher trip demand.
5. Network characteristics: Public transportation route is planned by considering the existing route condition in the planning area.

The other attributes required to formulate a route network include the public transportation service, connectivity, fare cost, accessibility, and travel distance (Galdames et al., 2011; Kingham et al., 2001). Meanwhile, the route network is classified into four based on the type of the road network type and they are stated as follows.

1. Route with grid network: It follows the existing road network which passes through a trading or attraction center.
2. Route with a radial network: Most cities use this type of road network to connect the CBD.
3. Route with a circular network: The route network connecting suburban areas.
4. Route with a territorial network: The route commonly used in medium and small cities.

2.3 Bus Stop Plan

A bus stop is defined in SK Dirjen 271/1996 as an infrastructure completed to support good and efficient transportation service. The regulation further shows that the bus stop point consists of a bus station and bus stop with the bus station explained to be a place with a building to take the passenger while the bus stop is a place with the same function but without a building (the Republic of Indonesia, 1996). The objective of the bus stop planning is to guarantee reliable service, safety, and orderliness when the bus is conveying the passengers and considered optimal when it is located in an area which attracts, generates, and accessible to the passengers (Bawana and Rachmawati, 2020). According to Ellegood et al. (2019), the plan is formulated based on a list of potential bus stop points, student residence areas, a list of schools, the distance between the residential area and bus stop, and the maximum distance the students need to walk depending on the land use as shown in Table 1 (the Republic of Indonesia, 1996).

2.4 Multi-criteria Analysis

This is a technique which ranks a list of options from high to low level through the use of several criteria or attributes in the decision-making process which are stated as follows (Communities and Local Government, U K, 2009).

1. Identify the objective: Goals need to be specific, measurable, agreed upon, realistic, and time-dependent.
2. Identify several alternatives to achieve the objective: Develop sensible options and alternatives.
3. Identify the criteria to compare the alternatives: Each criterion needs to be assessable both quantitatively and qualitatively.
4. Analyze alternative options: Provision of the context in the multi-criteria analysis.
5. Making a decision: Selection of the best option.

The multi-criteria analysis assessed each alternative based on the selected criteria or attributes and weighed using the determined score after which the option with the highest score was selected.

2.5 Data Collection

This research used data secondary data obtained directly or online through some related agency or institution as shown in Table 2.

Table 1. Decision of bus stop distance

Zone	Land Use	Location	Bus Stop Distance (m)
1	Very crowded activity center: markets and shops	CBD, Urban	200 – 300 *)
2	Crowded activity center: offices, schools, and services	Urban	300 – 400
3	Residential area	Urban	300 – 400
4	Crowded mixture: residential area, schools, and services	Sub-Urban	300 – 500
5	Sparse mixture: residential area, fields, paddy fields, and vacant lands	Sub-Urban	500 – 1000

Additional Information: *) = 200 mets distance is used when it is only needed while the general distance is 300 meters.

Table 2. The data source for route and bus stop planning

Data	Supplying Agency
Road Network	Regional Development Planning DIY
O-D Matrix of School Trip	Regional Transportation Office DIY
Number of Students	Regional Population and Civil Registration Office DIY
High School and University Distribution	Regional Education, Youth and Sports Office DIY
Bus Stop Number and Distribution	Regional Transportation Office DIY

3 RESULTS AND DISCUSSION

Yogyakarta Urban Agglomeration Transportation was planned to improve the service for students in order to reduce private vehicle usage and traffic congestion easily seen during the rush hour in Yogyakarta Urbanized Area. The focus of this research was to plan the expansion of the bus route network and bus stops in suburban residential areas and educational facilities in the urban area.

3.1 Existing Trans Jogja

According to Regional Transportation Office DIY (2018), Trans Jogja has 17 existing routes serving Yogyakarta City and its surrounding areas. The routes are mostly centralized in inner ring road and prioritized social facilities such as schools, colleges, hospitals, post offices as well as shopping and leisure areas. However, the existing bus routes have not been able to connect the YUA which requires an integrated infrastructure network system as observed in two districts including Godean and Ngemplak. Meanwhile, the districts located in the suburban areas have experienced residential growth but have low Trans Jogja accessibility since most of the bus stops are distributed in central and urban areas when people usually start their trip from the residential area. The distance between the bus stops was also observed to be closer and has high density with 46% recorded in a residential area, 25,5% education, 13,4% government, 7,9% health, 3,3% trade, 2,9% tourism, and 0,8% in built-up areas (Bawana and Rachmawati, 2020).

3.2 Route Plan of Yogyakarta Urban Agglomeration Transportation

The bus route network plan for the Urban Agglomeration Transportation development was by the school trip approach based on OD Matrix transformed into Origin Destination Bar Chart as presented in Figure 3 and Desire Line Map of Figure 4. Moreover, Figure 5 shows nearly all districts in the suburban area are residential while Depok and Umbulharjo Districts have a high number of attraction trips than others.

The network plan was formulated using multi-criteria analysis conducted through several stages as previously explained. The process includes the following:

1. Determination of several alternative routes connecting the generation area in urban and suburban areas with schools and universities
2. Weighting each alternative route on a scale from 1 to 10 based on determined indicators

3. Addition of all the values of indicators at each alternative route
4. Ranking of each alternative route to determine the priority route

The indicators used were obtained from the literature review and empirical conditions and the importance of each from the highest to the lowest was determined by the researcher and they are presented as follows.

1. The number of student trip in YUA
2. Land use map of YUA
3. Characteristics of the road network
4. Route length
5. Travel time

The priority route was determined with calculating all indicators based on percentage of weight and scoring each alternative route with Equation (1) in Table 3.

$$Rn = X1 + X2 + X3 + X4 + X5 \quad (1)$$

Where Rn is the alternative route, $X1$ is the number of student trip in YUA, $X2$ is land use with the routes connecting the residential area and school or university, $X3$ is the characteristics of the road network, $X4$ is the route length, and $X5$ is the travel time

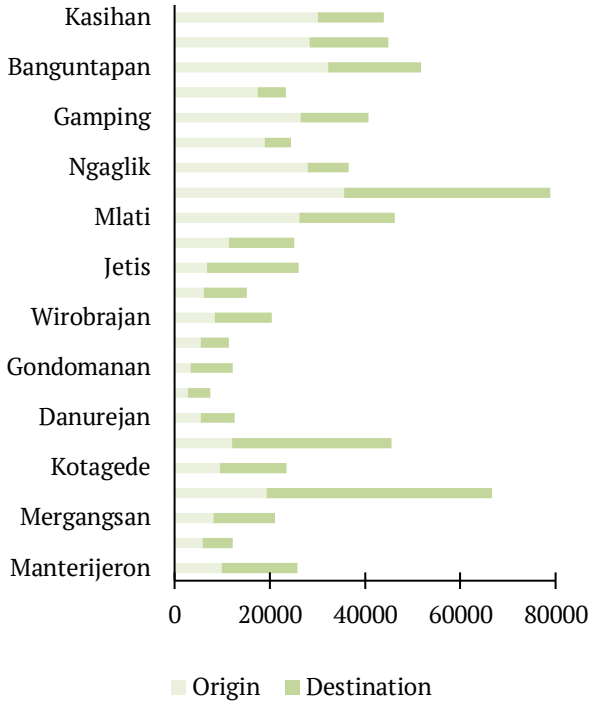

Figure 3. Origin-destination bar chart

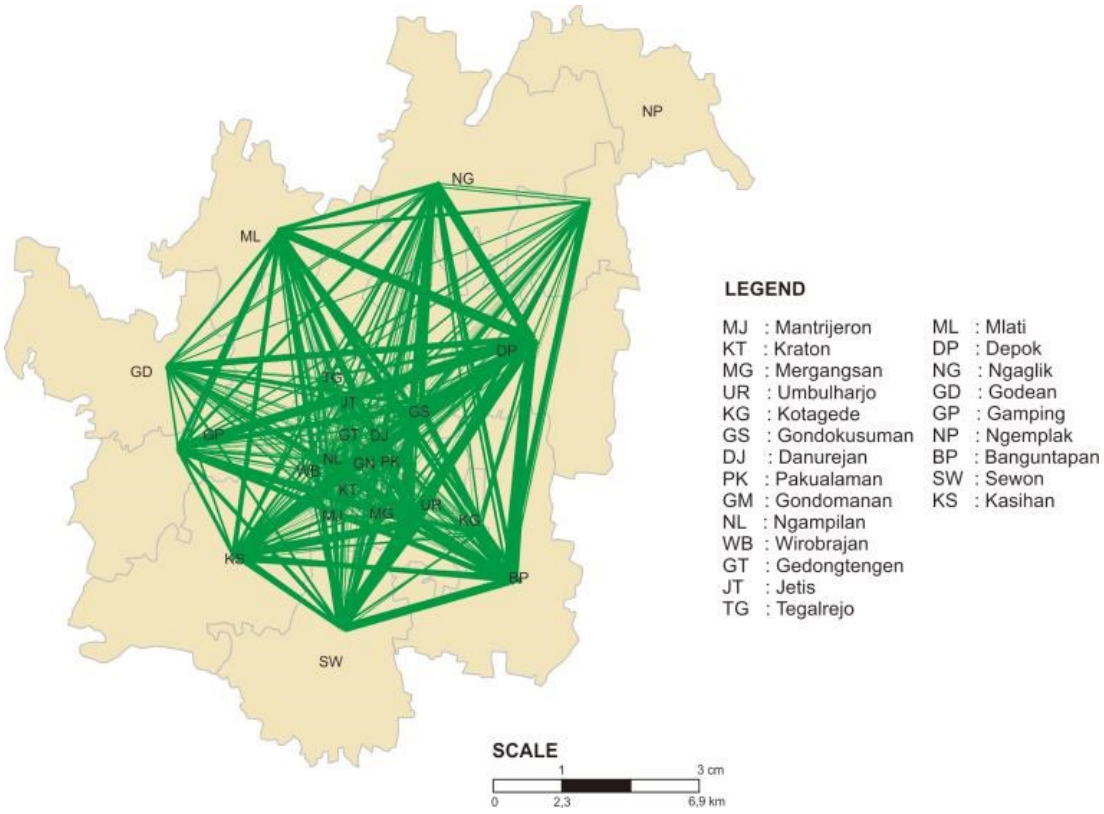

Figure 4. Desire line map

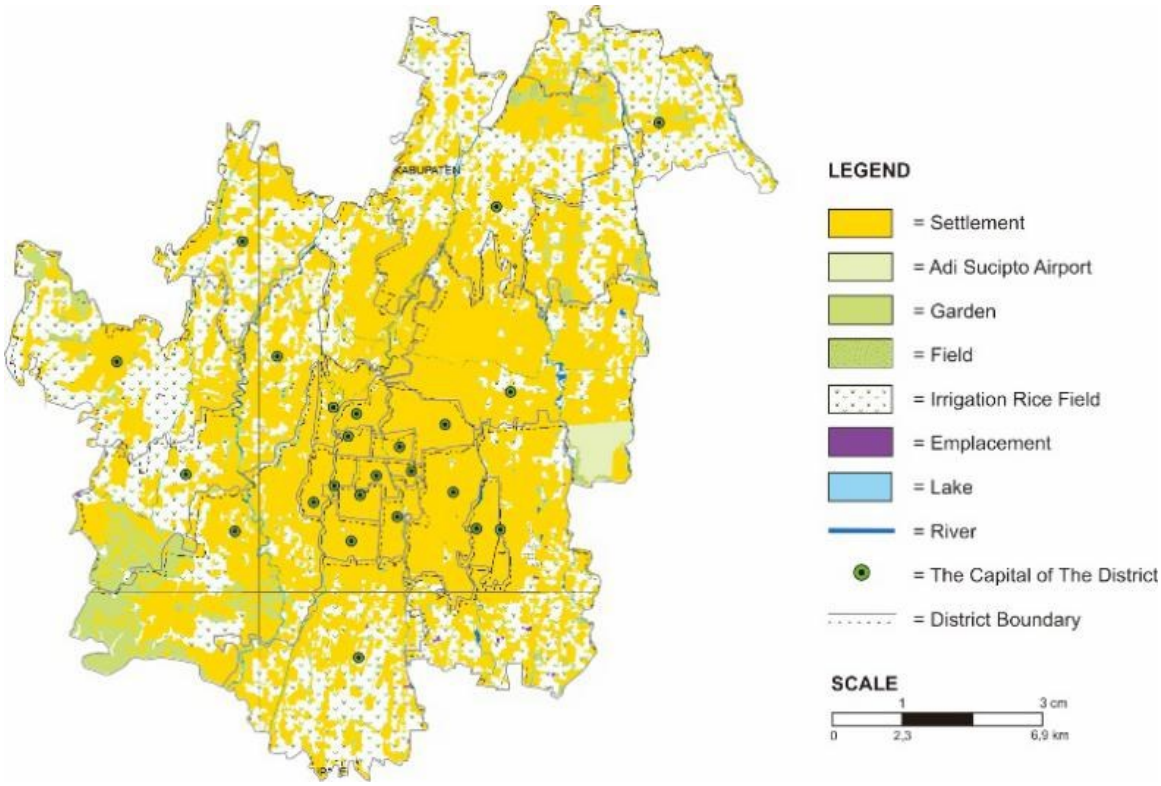

Figure 5. Land use map

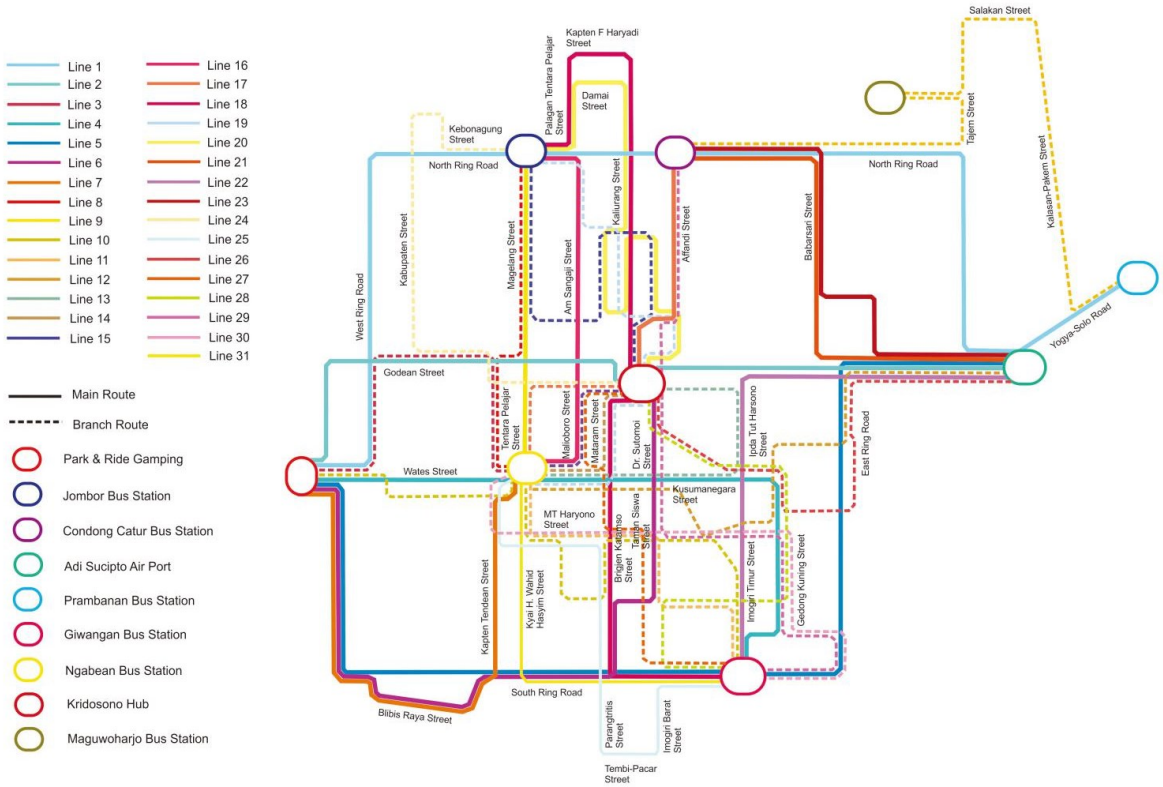

Figure 6. Bus route plan map of Yogyakarta Urban Agglomeration Transportation

The route network plan of urban agglomeration transportation obtained from the calculation is presented in Table 4. The bus route network plan as shown in Figure 6 has 31 routes which are divided based on the service area and hierarchy. Categorized route plan base on service area as

listed in Table 5 consists of 23 routes in the inner city (ICR), 3 at the outer city (OCR), and 5 integrated routes connecting the inner and outer road networks with 4 OCR and 1 ICR. Meanwhile, the hierarchically based routes showed 18 in the first hierarchy and were dominated by the inner-city route while the second has 13 routes. The routes included in the first hierarchy are prioritized as the direct routes which serve the high demand zones.

Table 3. Weighting result

No	Indicators	Score			Weight(%)
		Alternative Route 1	Alternative Route 2	Alternative Route 3	
1.	Number of student trips				30
2.	Land use				25
3.	Characteristics of the road network				10
4.	Route length				20
5.	Travel time				15

Table 4. Route plan of Yogyakarta Urban Agglomeration Transportation

Route	Route Length (km)	Travel Time (minutes)
1	25	85
2	20	60
3	10	30
4	15	45
5	23	75
6	18	54
7	11	33
8	8	24
9	14	42
10	16	48
11	8	24
12	14	42
13	9	27
14	4	12
15	12	36
16	10	30
17	6	18
18	24	72
19	24	72
20	19	57
21	12	36
22	12	36
23	8	24
24	12	36
25	19	57
26	23	75
27	11	33
28	14	42
29	24	72
30	14	42
31	25	85

Table 5. Categorized route plan base on service area

Route	Hierarchy	Service Area
1	2	OCR
2	1	ICR
3	2	ICR
4	1	ICR
5	2	OCR
6	1	ICR
7	2	OCR
8	2	ICR
9	1	ICR
10	1	ICR
11	2	ICR
12	2	ICR
13	2	ICR
14	2	ICR
15	1	ICR
16	2	ICR
17	1	ICR
18	1	OCR
19	1	ICR
20	1	ICR
21	1	ICR
22	1	ICR
23	1	ICR
24	1	OCR
25	2	OCR
26	1	OCR
27	1	ICR
28	1	ICR
29	2	ICR
30	1	ICR
31	2	ICR

3.3 Bus Stop Point Plan of Yogyakarta Urban Agglomeration Transportation

The bus stop plan of Yogyakarta Urban Agglomeration Transportation was formulated with two scenarios based on Table 1 using a general distance of 300-500-meter for urban and 500-1000-meter for sub-urban areas (the Republic of Indonesia, 2002). This means the addition plan for the first scenario used a 200-meter radius as an ideal walking distance while the second used a 500-meter radius which is suitable for crowded mixture land use. The planning was implemented with a spatial method through the design of the basic map of YUA, educational facility, and Trans Jogja bus stop using ArcGis and Corel software. Moreover, the accessibility analysis of the first and second scenarios was conducted to identify the distance between the bus stop and walking distance from the educational facility or residential area to the end of the destination point. Meanwhile, the addition plan for the bus stop was implemented along the new route and in the educational or residential facility without previous access.

The existing bus stop points were analyzed and the location towards the school and university was also overviewed before the additional bus stops were planned. It was discovered that there are currently 113 bus stations and 165 bus stops distributed in the urban area, especially in the inner ring road with 156 schools and 110 universities. However, the spatial analysis showed several schools and universities do not have access to these facilities and these include 45 schools and 46 universities not served by Trans Jogja in the first scenario of 200-meter radius and 18 schools and 19 universities in the second scenario with a 500-meter radius as shown in Figures 4 and 5.

The planning of additional bus stops in Yogyakarta Urban Agglomeration Transportation is to improve the number and accessibility of public transportation service for students in order to reduce private vehicle usage. The plan was based on land use, bus stop distance, and walking distance from the stop point to the end destination. In a similar pattern with the route plan, the land use for the bus stop plan was focused on the use of the educational land for an attraction while the residential land is for generation for the distance of 200-meter in urban and 500-meter in sub-urban areas. The same was observed with the walking distance from the stop point to the end destination at the first and second scenarios and this means the bus stops added in schools and universities using these distances are more than the selected scenarios as shown in Figures 7 and 8.

The first scenario has 99 points of bus stop addition while the second has only 66 points and Figures 9 and 10 show the catchment area of the second scenario is better than the first even though the number of bus stop planned to be added to the first is higher. This means some schools and universities are still not served by public transportation. Meanwhile, the first scenario has better travel time to or from the bus stop with 200 meters distance and this means it is better for the students to walk and it was also empirically discovered that finding the land for an additional bus stop near the city center and urban areas is costly. However, both scenarios are carrying equity concept to increase connectivity and accessibility and this is reflected in the location of almost all the added bus stop in a suburban area not previously served by public transportation. Furthermore, the second scenario bus stop addition plan was discovered to be the best choice due to its more advantages and also realistic to be implemented. This means the students are expected to be more willing to walk as far as 500-meter or use feeder transportation to access public transportation.

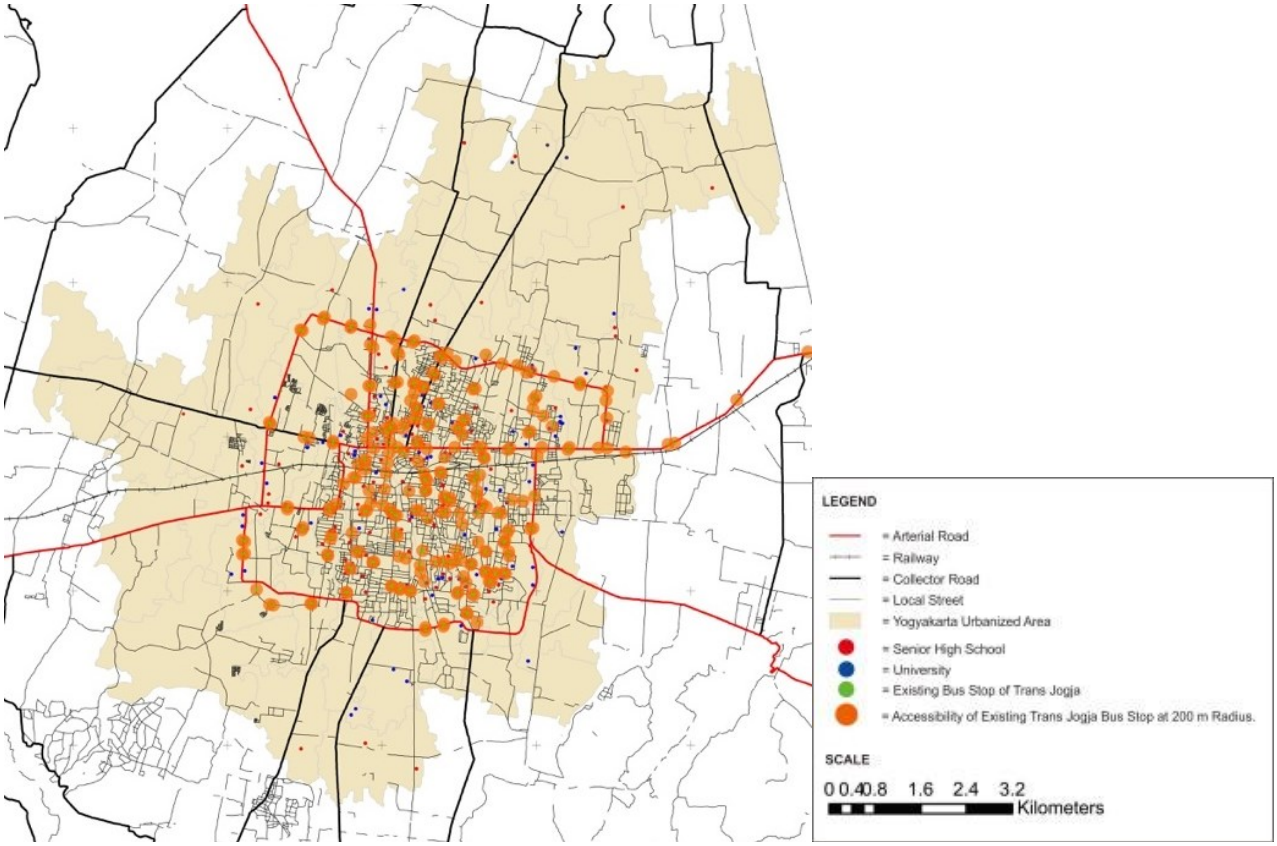

Figure 7. Existing map of Trans Jogja bus stop accessibility with the first scenario

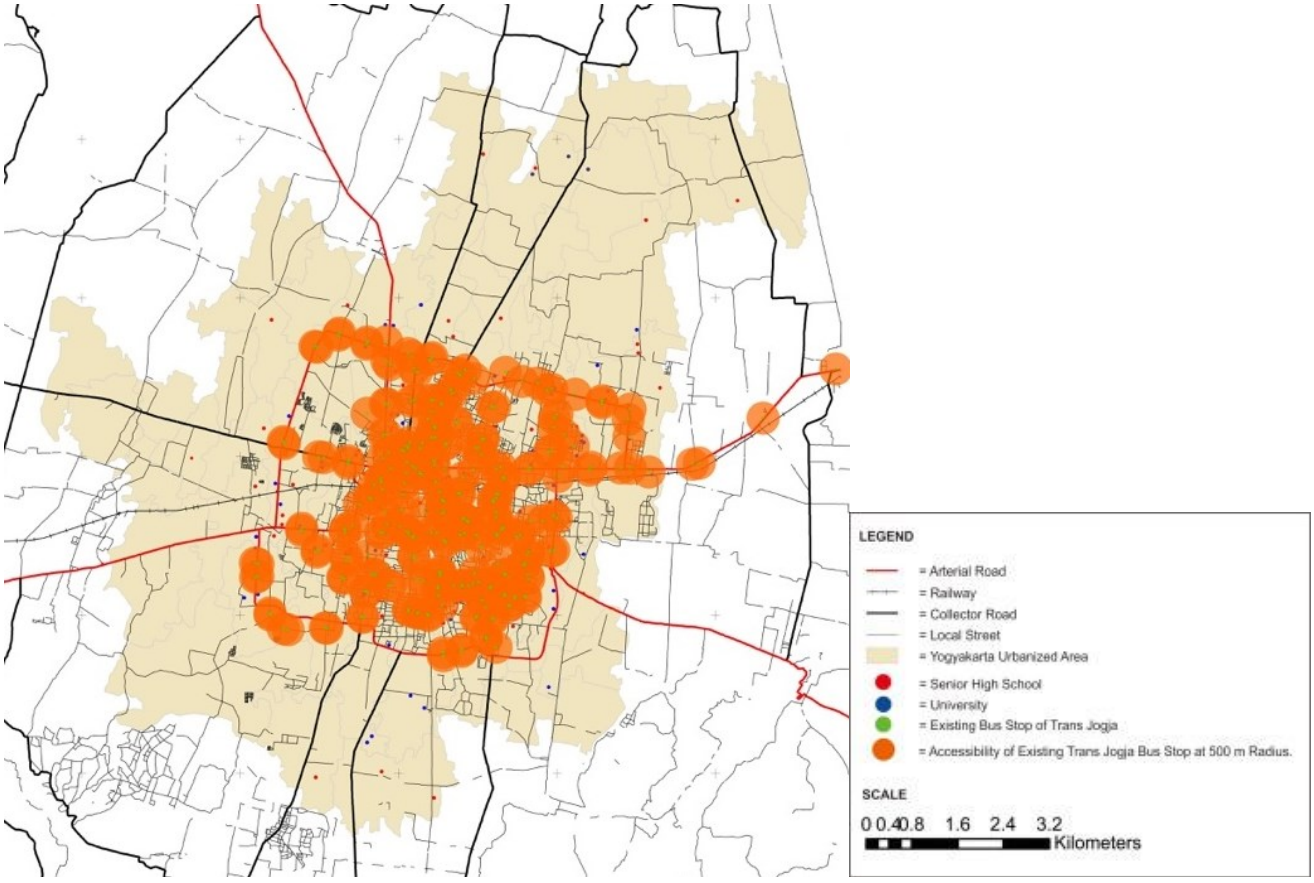

Figure 8. Existing map of Trans Jogja bus stop accessibility the second scenario

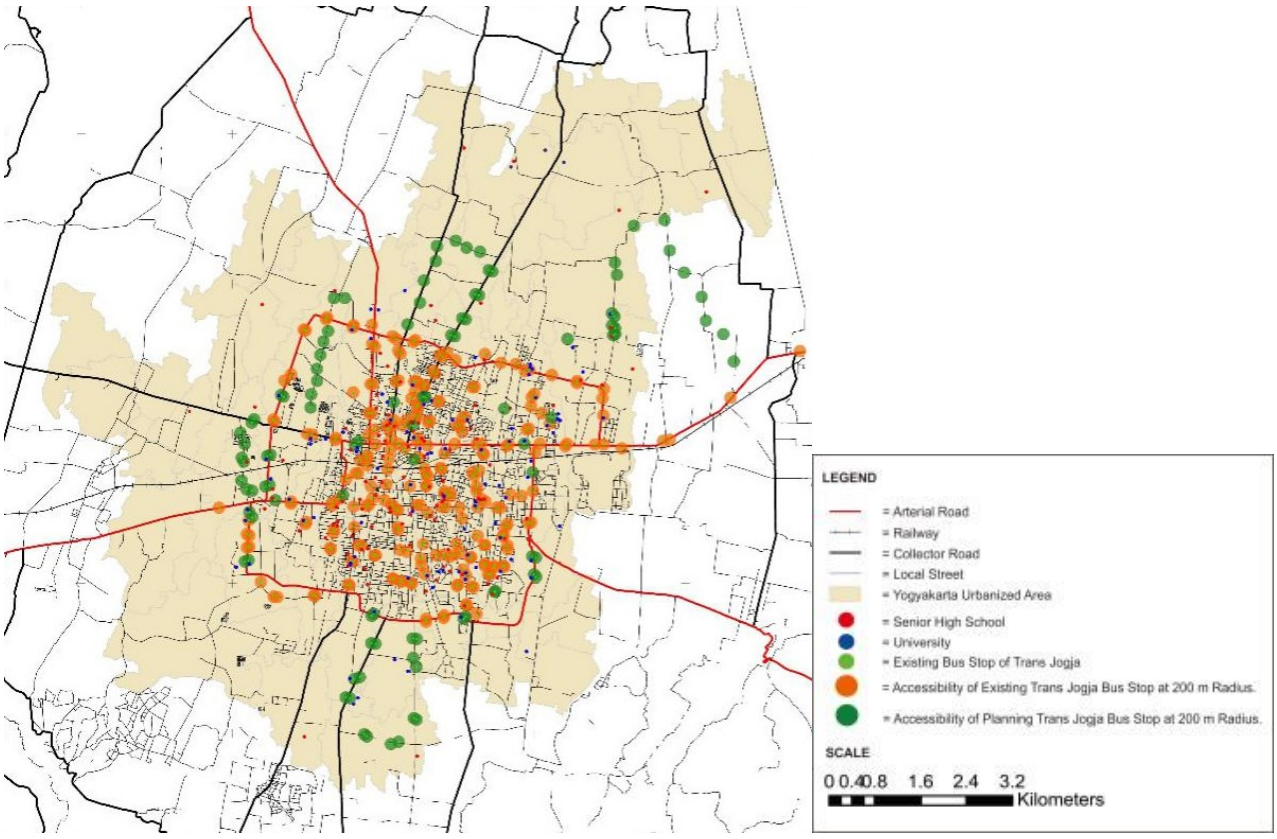

Figure 9. Plan map of bus stop addition on the first scenario

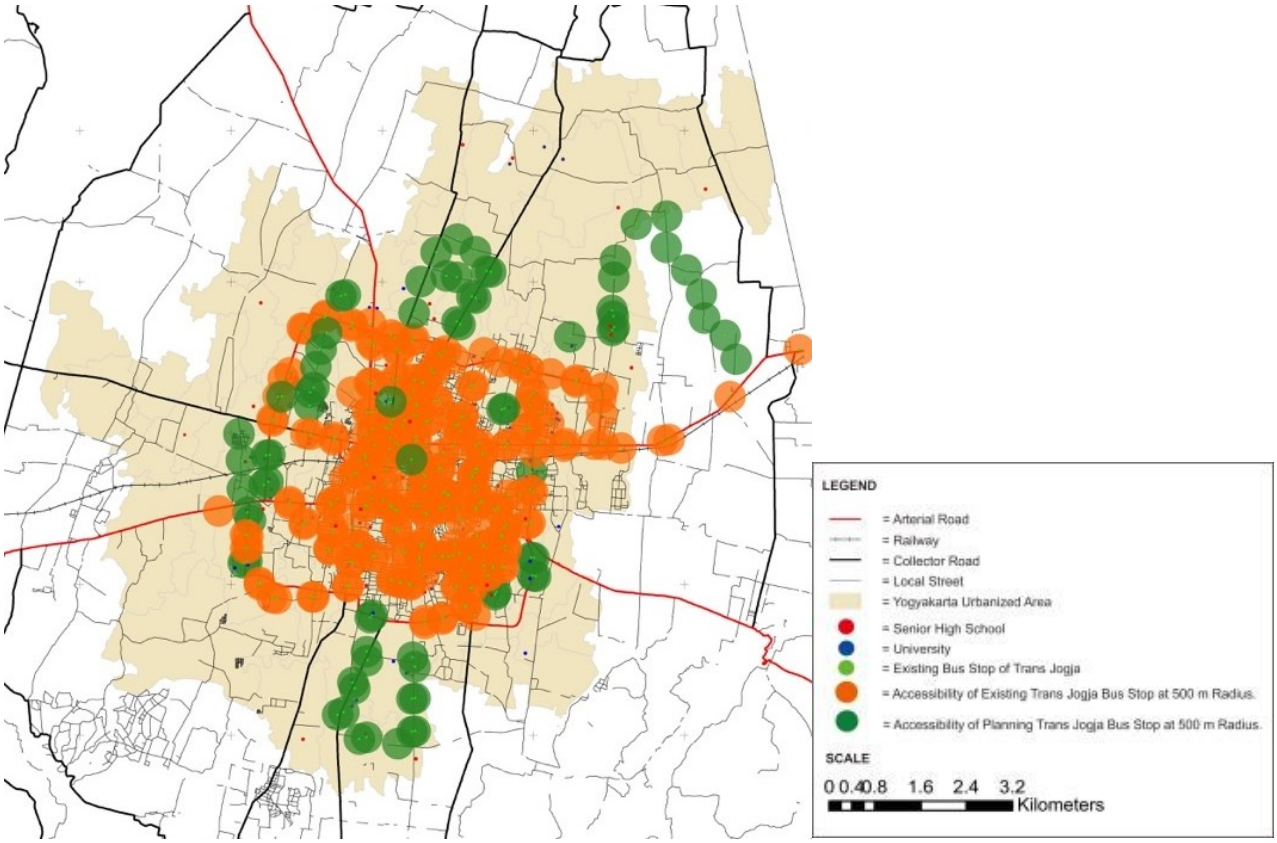

Figure 10. Plan map of bus stop addition on the second scenario

4 CONCLUSIONS

Trans Jogja has not been able to serve the whole of YUA, especially in the context of educational activity and the rapid growth of housing as the generation area in suburban, schools, and universities as increased their attraction. This led to a reduction in connectivity and accessibility, thereby, leading to congestion. Therefore, this study used the student approach to improve the quality of Trans Jogja service in YUA through the concept of Urban Agglomeration Transportation and the bus route network plan was formulated using multi-criteria analysis with simply scoring, and 31 new routes were added to public transportation service across YUA followed by additional bus stop plan using two scenarios and the second with 66 new bus stop points is most likely to be implemented.

DISCLAIMER

The authors declare no conflict of interest.

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