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Research Paper

Potential Development of Trans Central Java Bus Rapid Transit (BRT) Corridor in the Banyumas Area Towards Sustainable Mobility

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Abstract

The Bus Rapid Transit (BRT) in the Banyumas area, Central Java, aims to provide inter-regional connectivity in Purwokerto City and Purbalingga Regency. This is one of the six BRT corridors in Central Java launched in 2018. Therefore, this study aims to examine the development of BRT corridors based on transit-integrated land use along the corridor, after five years of operation. The primary survey was conducted on land use along the corridor at a radius of 200 m and 400 m from the BRT bus stop, which was analyzed using a qualitative descriptive method. As a result, BRT Corridor 1 in Central Java can be identified for bus-based transit development. First, BRT services have connected high to very high populations. Second, BRT shelters have good access to shopping centers, culinary centers, and artificial tourism within a 200 m and 400 m radius. Third, BRT shelters are also connected to other modes of public transportation. However, the results of our study found that the BRT shelters had not been connected to pedestrian facilities. Based on these three criteria, BRT Corridor 1 in Central Java is feasible to be developed as a sustainable public transport service. However, further studies are needed to link BRT shelters with pedestrian facilities, in order to create clean and sustainable mobility.

Keywords: BRT; Public transport; Transit-oriented; Sustainable mobility

1. Introduction

The World Business Council for Sustainable Development defines sustainable mobility as the ability to meet people's needs to move freely, gain access, communicate, trade, and build relationships without compromising current or future human or other important ecological values [1]. The achievement of sustainable mobility in each urban area is assessed by transportation system performance indicators such as social justice, economy, environmental integrity, and the development of multimodal transportation [2], [3]. Therefore, sustainable mobility in urban areas is encouraged to prioritize public transportation [4] and land use [5], which are oriented towards supporting local community businesses [6]–[8].

Developed countries have operated Bus Rapid Transit (BRT) to improve the performance of public transport and are followed by developing countries. For example, Tanzania operated a BRT in Dar es Salaam in 2016 which serves to improve livelihoods, reduce travel time and increase access to primary services [9]. Hanoi inaugurated its first BRT corridor in early 2017 but its initial operation was faced with low capacity and frequency, limited speed, and convenience [10]. In Indonesia, the first BRT was built in 2004 and was operated in Jakarta under the name Transjakarta, which is the first BRT in Southeast and South Asia. This system was designed based on the experience of TransMilenio in Bogota, Colombia [11], [12]. Good practice in Jakarta was later developed in many provinces in Indonesia [13]–[15]. Apart from BRT,

Indonesia is also developing Light-Rail Transit (LRT) for mass transportation [16]–[18].

Behind the success stories of BRT implementation in several countries, problems have also accompanied its development, both technically, user demands, and environmental factors. Technically, an alternative solution in BRT operations is enforced by giving priority to intersections and providing multimodal real-time information and reducing intervals during peak hours [10]. In addition, there is also a need to improve the bus network in areas with extreme vulnerability [9]. During a pandemic, BRT operations are also required to comply with health protocols [19]–[21]. BRT which operates at high levels of congestion is also faced with the number of passengers during peak hours in the morning and evening [22]. In Central Java, especially in Purwokerto City and Purbalingga Regency, BRT (Transjateng Corridor 1) has been operating since 2018. The presence of BRT was welcomed by the community. However, the COVID-19 pandemic in 2020 has caused a drastic reduction in the load factor. The physical distance policy, restrictions on activities in public facilities and schools, as well as the closure of tourist attractions have affected BRT operations. It increases operational costs disproportionately to revenues [21].

In addition, BRT is also reported to have an effect on land values and the urban economy. The BRT infrastructure in Bogota shows that low-income neighborhoods are having a positive impact on land values. However, in middle- and high-income neighborhoods, BRT infrastructure has an insignificant or even negative effect on land value [23]. The impact of Boston Silver Line 4, Line 5, and Seoul BRT on urban development shows that two BRT systems with different performances can affect urban development around the system to different degrees [24]. The BRT system and land use in transit-oriented development (TOD) is efficient and sustainable urban planning [25]. The TOD concept is the management of the public transport system against population density in achieving a balance that supports high-capacity public transport systems.

In Indonesia, the creative economy continues to be developed to improve the regional economy. The purposes of tourist trips include vacations, hotel stays, and culinary [26]. Therefore, the integration of BRT with tourist areas is necessary to achieve sustainable mobility. As it is known that sustainable planning, infrastructure, and mobility add value to the travel and tourism experience [27]. Measuring sustainable mobility is not only from the transportation sector but also the potential for mobility and tourism which can increase sustainable mobility as a whole [28]. Therefore, this research was conducted to evaluate the potential for developing BRT Corridor 1 in Central Java to support sustainable mobility.

2. Methods

This research focuses on examining the accessibility of BRT (Transjateng) Corridor 1 which connects Purwokerto City and Purbalingga Regency. Some photographic view of Transjateng is presented in **Figure 1**. A descriptive qualitative method is used to evaluate the accessibility of BRT Transjateng Corridor 1 in terms of:

(1) the level of population density along the BRT line;
(2) the number of tourist destinations within a radius of 200 m and 400 m from the shelter (including shopping centers, culinary centers, and artificial tourist attractions); and
(3) the accessibility of BRT from other modes of transportation (including intra-city transportation, inter-city buses, motorcycle taxis, non-motorized transportation, and pedestrians).

Furthermore, the spatial and non-spatial data are processed using a geographic information system (GIS) for mapping. Data on population density, tourist areas, and BRT accessibility from other modes of transportation were analyzed using the correlation method to see a significant relationship between these variables. The correlation method was used to measure the relationship between BRT demand and land use patterns [29]. Furthermore, correlation analysis was used to look at the significant factors that influence the sustainability of urban transportation on city characteristics [30] with two-tailed 95% confidence intervals or 5% alpha [31]. For shopping, culinary, and artificial tourism centers in a radius of 200 m and 400 m, the variables considered include:

X1 = Population density per km^2
X2 = Shopping center 200 m
X3 = Culinary center 200 m
X4 = Artificial tourism 200 m
X5 = Shopping center 400 m

X6 = Culinary center 400 m
X7 = Artificial tourism 400 m

Moreover, the shelter data and variables considered are presented in **Table 1**.

Table 1. Location of BRT shelters to population density, shopping centers, culinary, and tourism made by radius 200 m and 400 m

No	Shelter name	X1	X2	X3	X4	X5	X6	X7
1	Bulupitu Bus Station	1842	2	3	1	0	5	0
2	Candimas Gas Station	1842	1	7	0	0	3	0
3	Depo Pelita	1842	2	4	0	1	7	1
4	Sokaraja 1 Middle School	2981	8	15	0	0	15	0
5	Hok Tek Bio Pagoda Sokaraja	2981	1	9	0	0	9	0
6	Sokaraja 1 High School	2981	0	0	0	0	1	0
7	Sokaraja Logistics Agency	2981	0	4	0	0	8	0
8	Banjarsari	2981	1	6	0	0	2	0
9	Yakpermas Banyumas Polytechnic	2981	0	4	0	0	2	0
10	Jompo Bus Station	2981	0	4	0	0	8	0
11	Faculty of Engineering Unsoed 1	2981	0	6	0	0	7	0
12	Faculty of Engineering Unsoed 2	2981	0	6	0	0	5	0
13	Kalimanah 1 Middle School	2981	1	10	0	0	5	0
14	Kalimanah 2 Middle School	2981	1	12	0	0	3	0
15	YPT Purbalingga 1 Vocational High School	2981	1	1	0	0	9	0
16	YPT Purbalingga 2 Vocational High School	2981	1	1	0	0	8	0
17	Purbalingga Bus Station	2981	2	4	0	0	1	0
18	Indokores	2981	3	5	0	1	0	1
19	Yuro T-Junction	2981	4	5	0	0	2	0
20	Usman Junatin Park	2562	2	8	1	0	3	0
21	Gringsing 1 Park	2562	1	7	1	1	5	1
22	Gringsing 2 Park	2562	1	7	1	1	5	1
23	Purbalingga 1 Middle School	2562	0	10	1	0	2	0
24	Purbalingga 2 Middle School	3912	0	10	1	0	2	0
25	Purbalingga 1 Madrasa Aliyah	3912	0	1	0	0	3	0
26	Purbalingga 2 Madrasa Aliyah	3912	0	1	0	0	3	0
27	Kedungmenjangan 2	3912	0	1	0	0	5	0
28	Kedungmenjangan 1	3912	0	3	0	0	7	0
29	Bojong 1	3912	4	6	0	0	1	0
30	Bojong 2	3912	4	6	0	0	1	0
31	Bukateja State Madrasa Aliyah 1	3912	2	3	0	0	0	0
32	Bukateja State Madrasa Aliyah 2	3912	4	3	0	0	0	0
33	Bukateja Bus Station	3912	6	13	1	0	9	0
34	Sokaraja 2 Middle School	3912	1	9	0	1	6	1
35	Campus 2 UMP	2562	0	3	0	0	4	0
36	Orthopedhi Hospital	2562	0	4	0	0	1	0
37	Margono Hospital	2562	2	9	1	0	3	0
38	Pancurawis 4 intersection 1	5258	4	3	0	0	2	0
39	Pancurawis 4 intersection 2	5258	3	3	0	0	2	0
40	Karangbawang 1 Intersection	5258	0	8	0	0	4	0
41	Karangbawang 2 Intersection	5258	0	8	0	0	4	0
42	Andhang Pangrenan 1 Park	5258	0	2	0	1	20	1
43	Andhang Pangrenan 2 Park	6483	6	13	1	0	0	0
44	Rajawali 1 Cinema	6483	0	8	1	0	8	0
45	Rajawali 2 Cinema	6483	0	8	1	0	8	0
46	Mandiri Bank	6483	8	1	0	0	3	0
47	RRI broadcasting station	6483	2	4	1	0	7	0
48	Pratistha Harsa	6483	1	5	0	2	4	2
49	Pasar Manis Shopping Center	6483	1	10	0	0	6	0
50	Bruderan	6483	1	2	0	0	9	0
51	Purwokerto 1 High School	5258	0	4	0	0	3	0
52	Purwokerto 2 Vocational High School	5258	0	7	0	0	0	0
53	Kombas	5258	4	4	0	0	7	0
54	Pasar Wage Shopping Center	5258	16	3	0	0	12	0

Figure 1. Photographic view of BRT Corridor 1: (a) the fleet used and (b) the enthusiasm of the community at the start of BRT's operation

3. Results

3.1. *Map of BRT Route in Population Density*

BRT Corridor 1 in Central Java connects Purwokerto City and Purbalingga District through areas with varying population densities, with routes and shelter availability presented in **Figure 2**. Most BRT routes cross areas with high population density (up to 69%) located in Sub-Districts of Sokaraja, Kalimanah, Bukateja and Purbalingga. Meanwhile, 31% of BRT routes across areas with very high population density in the Districts of South Purwokerto, East Purwokerto and West Purwokerto.

3.2. *The BRT Route as a Buffer for Tourist Destinations*

BRT Corridor 1 in Central Java is also intended to support the affordability of natural tourism, artificial tourism, shopping tourism and culinary tourism within a 200 and 400 m radius, as presented in **Figure 3**. That is the ideal distance for pedestrians after getting off the BRT or will use BRT and suit the Indonesian climate [24]. A radius of 400 m from the bus stop requires a maximum travel time of 10 minutes on foot. The distribution of tourist centers reached by BRT is presented in **Table 2**.

Table 2. Distribution of tourist destinations reached by the BRT shelter

No	Tourism centers	Total destination	Percentage
1	Shopping center	204	26%
2	Culinary center	562	72%
3	Artificial tourism	20	3%
4	Nature tourism	0	0%
	Total	786	100%

BRT Corridor 1 shelters have reached 72% of culinary tourism centers with a radius of 200 m and 400 m. Banyumas culinary tourism is spread along the BRT Corridor 1 route, especially in Sokaraja (**Figure 4a**) at a radius of 200 m. Meanwhile, restaurants and cafes are located in four districts in Purwokerto City up to a 400 m radius from the shelter (**Figure 4b**). In total, the number of culinary spots with a radius of 200 m and 400 m from the shelter accounted for 54% and 46%, respectively.

Furthermore, the reach of BRT to shopping centers reaches 26% and most of it is in Purwokerto City, as presented in **Figure 5**. Shopping centers that are reached by BRT users up to a radius of 400 m reach 51%. Meanwhile, **Figure 6** presents an artificial tourist map traversed by the BRT, which includes city parks, museums, and other tourist destinations. At a radius of 200 m from the shelter it reaches 60% and at a radius of 400 m it reaches 40%.

3.3. *BRT Shelter Coverage from Other Transportation Modes*

The southern region of Central Java province has the potential to be developed to offset economic development in the northern region [32]. In the Purwokerto and Purbalingga regions, tourism has become a flagship program. The tourism industry in the Banyumas area is generally based on nature tourism [33]. However, the BRT Corridor 1 line only passes through the artificial tourism area. Consequently, BRT users need other modes of transportation to reach natural tourist destinations. The data we have obtained shows that BRT shelters are currently connected to other public transportation (see **Table 3**) including urban transportation and inter-

city foam as much as 32-47%. Meanwhile, support from non-motorized transportation (horse carriages and pedicabs) reaches 18-20%. In addition, BRT shelters connected to motorcycle taxis and taxis account for 26-29%. Meanwhile, BRT shelters that are connected to pedestrian paths are still very low, only 3-4%. We found that most of the BRT shelters were not equipped with pedestrian facilities.

Figure 2. Map of BRT Corridor 1 route in Central Java

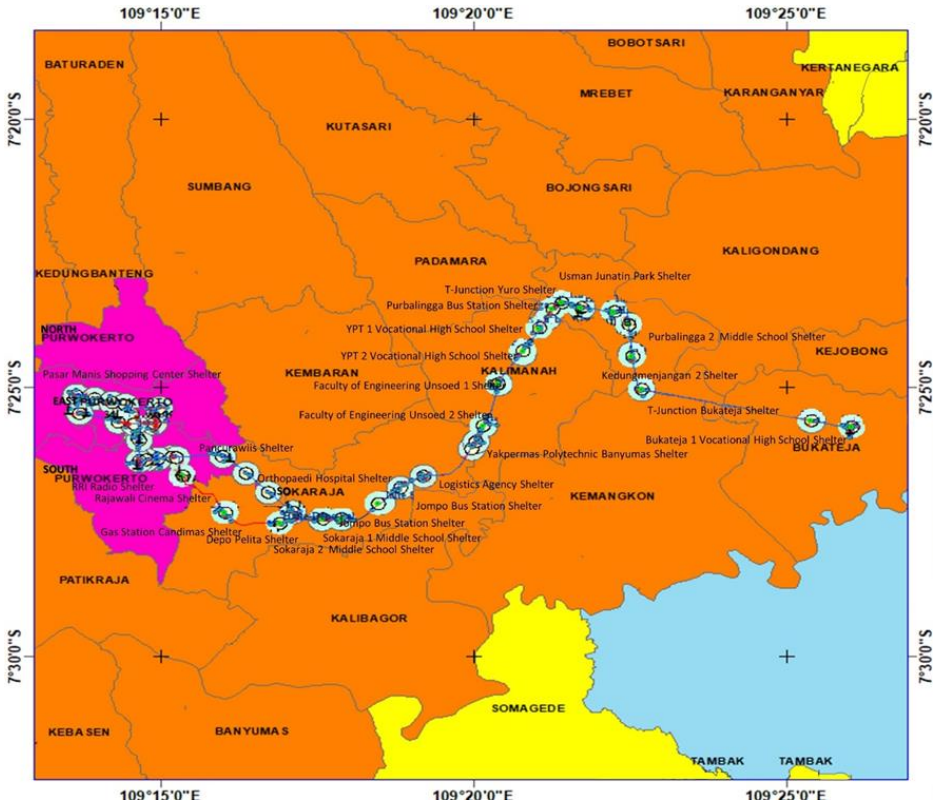

Figure 3. BRT routes toward tourism destinations

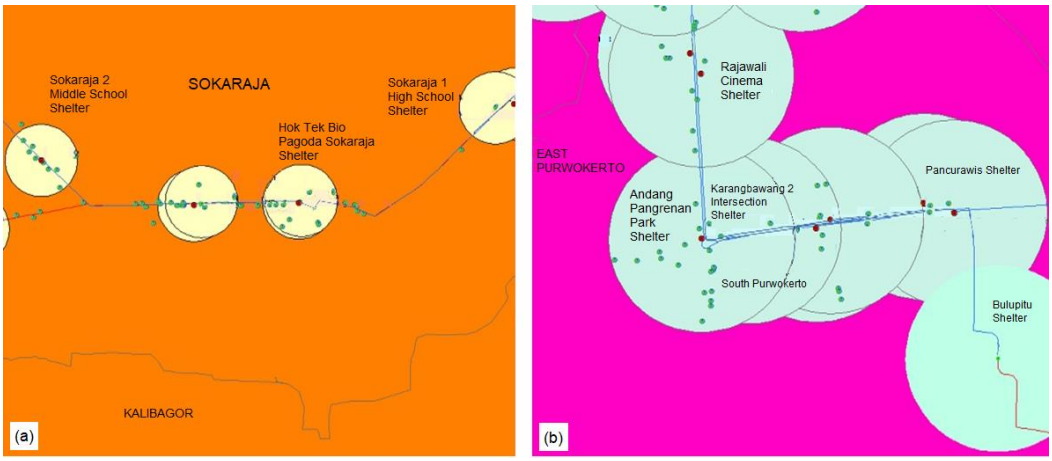

Figure 4. Map of culinary spots from BRT shelter: (a) radius 200 m and (b) radius 400 m

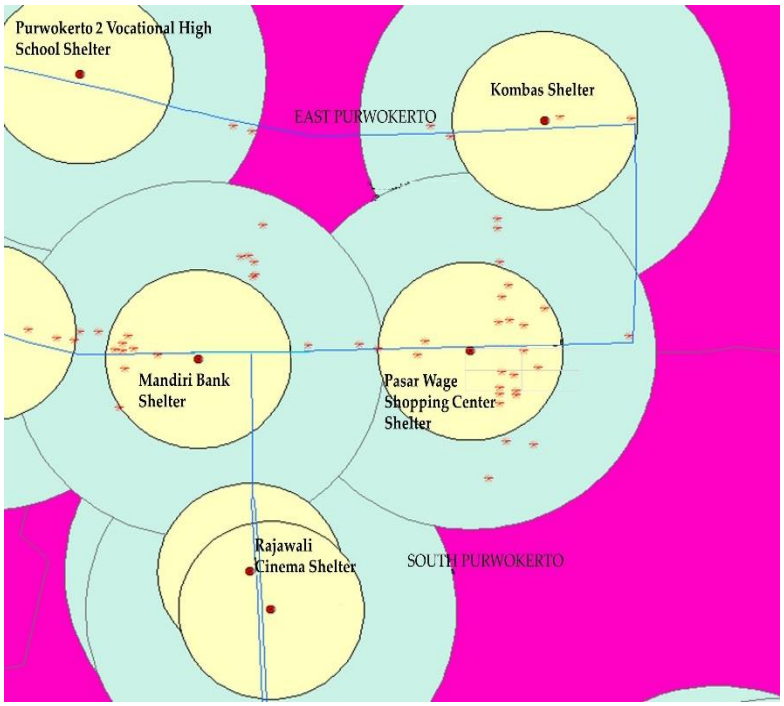

Figure 5. The reach of the shopping center from the BRT shelter

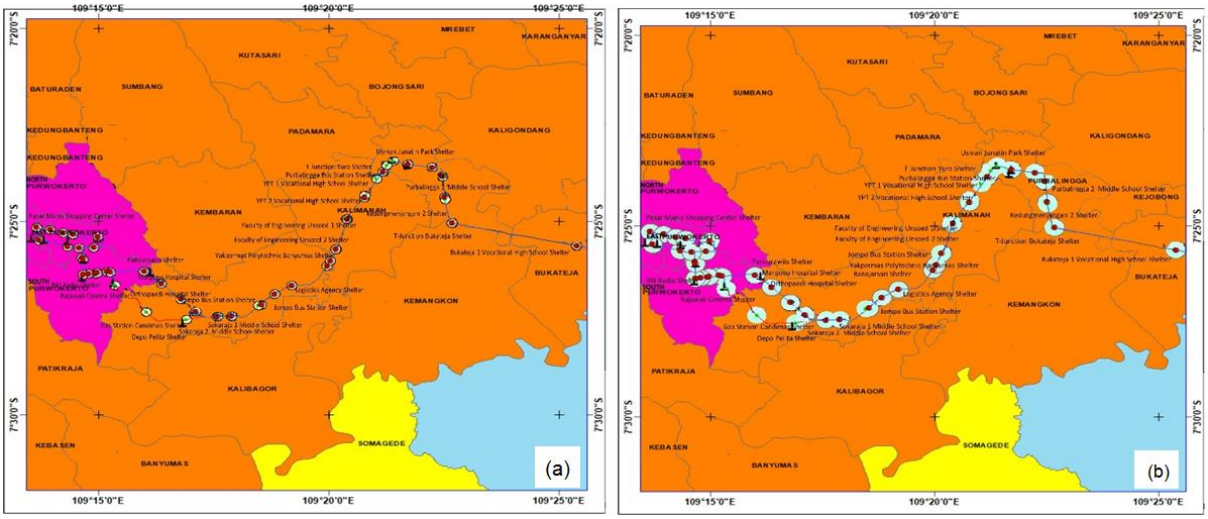

Figure 6. BRT shelter coverage for artificial tourism: (a) radius 200 m, and (b) radius 400 m

Table 3. BRT bus shelter connectivity to other public transportation

No	Public transportation and pedestrian path	Direction	
		Purwokerto to Purbalingga	Purbalingga to Purwokerto
1	Pedestrian path		
	Footpath	3%	2%
	Zebra cross	1%	1%
2	City transport	19%	20%
3	Inter-city buses between provinces	9%	8%
4	Inter-city buses whitin provinces	14%	19%
5	Motorcycle taxi (ojek)	22%	18%
6	Taxi	7%	8%
7	Pedicab	18%	15%
8	Horse-carriage	2%	3%
9	Travel agency	6%	5%

3.4. Results of Correlation Analysis

The potential correlation between population density and the mix-land use of tourism activities which support each other for the development of land use along the BRT corridor at a radius of 200 m and 400 m is presented in **Table 4**. It shows that artificial tourism 400 m from the BRT shelter does not show a correlation to all variables with a Sig value. (2-tailed) > 0.05. The other six variables are correlated or influence each other as indicated by the Sig value. (2-tailed) < 0.05, among others:

- The shopping center 400 m from the BRT shelter has a positive correlation with population density;
- The shopping center 400 m from the BRT shelter has a positive correlation with a shopping center 200 m;
- Artificial tourism 200 m from the BRT shelter has a positive correlation with the culinary center 200 m;
- The culinary center 200 m from the BRT shelter has a positive correlation with artificial tourism 200 m;

Table 4. Correlation between population density and tourism mix-land use

Correlations								
		X1	X2	X3	X4	X5	X6	X7
X1	Pearson Correlation	1	.193	-.014	.031	.322*	.125	.015
	Sig. (2-tailed)		.162	.920	.823	.017	.368	.913
	N	54	54	54	54	54	54	54
X2	Pearson Correlation	.193	1	.102	-.007	.567**	.153	-.081
	Sig. (2-tailed)	.162		.465	.959	.000	.268	.559
	N	54	54	54	54	54	54	54
X3	Pearson Correlation	-.014	.102	1	.419**	-.187	.042	-.012
	Sig. (2-tailed)	.920	.465		.002	.177	.761	.933
	N	54	54	54	54	54	54	54
X4	Pearson Correlation	.031	-.007	.419**	1	-.034	-.006	.024
	Sig. (2-tailed)	.823	.959	.002		.807	.963	.860
	N	54	54	54	54	54	54	54
X5	Pearson Correlation	.322*	.567**	-.187	-.034	1	.386**	.060
	Sig. (2-tailed)	.017	.000	.177	.807		.004	.668
	N	54	54	54	54	54	54	54
X6	Pearson Correlation	.125	.153	.042	-.006	.386**	1	.150
	Sig. (2-tailed)	.368	.268	.761	.963	.004		.280
	N	54	54	54	54	54	54	54
X7	Pearson Correlation	.015	-.081	-.012	.024	.060	.150	1
	Sig. (2-tailed)	.913	.559	.933	.860	.668	.280	
	N	54	54	54	54	54	54	54

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

- Culinary center 400 m, shopping center 200 m, population density per square kilometer from BRT shelter positively correlated to shopping center 400 m; and
- The shopping center 400 m from the BRT shelter has a positive correlation to the culinary center 400 m.

For the development of mix-land use along the BRT corridor, a combination of population density and tourism activities can be considered to attract/add to the demand for BRT users.

4. Discussion

Land use, transportation, and walkability are important indicators in planning for transit-oriented development (TOD) [34]. An important finding in this study is that the BRT corridor I route in Central Java has reached areas with high to very high population densities and that supports TOD. As it is known that high population density within a distance of up to 800 meters is suitable for TOD [35]. High population density has a change in the average vehicle mileage per kilometer, but there is a reduction in driving at very high densities [36]. In addition, BRT as connectivity between regions can play a role in reducing the use of motorized vehicles. BRT has played an important role in limiting the use of private transport, particularly motorbikes [10]. This will reduce fuel consumption and exhaust emissions. In the Dhaka City case study, rickshaws acted as a feeder service to the BRT system [37]. BRT in South Africa is used to drive reforms in the transport sector inspired by cities in Latin America such as Bogotá, Mexico City, and Santiago de Chile [38]. Higher population densities and local accessibility favor BRT occupancy in large cities compared to smaller cities; however, some BRT routes from small and medium-sized cities in North America show passenger rates comparable to those of larger cities [39]. In small towns in North America, the proportion of elderly is superior, so an assessment of the accessibility and attractiveness of the system is required [39], whereas, in Purwokerto and Purbalingga, the ratio between men and women of productive age is around 50% [40].

BRT supports tourist areas in Purwokerto and Purbalingga. Correlation analysis showed a significance value (two-tailed) <0.05. BRT routes from areas with high population density to tourist centers consisting of shopping, culinary and artificial tourism at a radius of 200 m and 400 m are known to have a significant effect on shopping centers at a radius of 400 m. Therefore, regional development based on population density is focused on shopping centers up to a radius of 400 m. The development of shopping centers on the BRT line at a radius of 200 m and 400 m can be combined with culinary centers. A culinary tourism center with a radius of 200 m correlates with an artificial tourism center with a radius of 200 m from the BRT shelter. Meanwhile, a shopping center with a radius of 400 m is connected to a culinary center with a radius of 400 m from the BRT stop. From these data, it is necessary to develop a culinary center with artificial tours within a 200 m radius of the BRT shelter. Transit potential is influenced by economic dynamics [41]. The development of mix-land use based on tourism activities in the corridor I which connects Purwokerto and Purbalingga is needed to increase BRT demand and increase pedestrians. Transit areas with high land use densities with a mix of trade and service land use as well as public facilities that have access to adequate pedestrian pathways (wide and wide) can significantly encourage a high number of public transport users [42]. Furthermore, population density correlates with an increase in the number of passengers [43].

From our mapping, most of the BRT Corridor 1 shelters are connected to various types of public transportation, both city transportation, inter-city buses within the province and between provinces, as well as non-motorized transportation such as pedicabs and horse-drawn carts. The existence of public transportation around the BRT shelter has a positive and significant effect on drivers [44]. However, pedestrian facilities from the shelters along the BRT route are not evenly available. Therefore, it is necessary to build facilities for pedestrians to increase access to BRT shelters. Our analysis shows that the number of public transport and pedestrian routes correlates with culinary centers within a 400 m radius of the shelter. Based on the potential of the BRT route to shopping, culinary, and tourism centers, it significantly increases the number of pedestrians [45]. Road connectivity and mixed land use are the most consistent predictors of pedestrian traffic volume [46]. A pedestrian-oriented environment

creates a higher sense of community [47]. Therefore, the development of BRT Corridor 1 in Central Java requires further studies from relevant stakeholders and policymakers. The TOD areas encourages sustainable urban development and growth [48].

5. Conclusion

BRT Corridor 1 in Central Java which connects Purwokerto City and Purbalingga Regency has the potential for transit-oriented development. The routes currently available are through high population density and mixed land use with shopping, culinary, and man-made tourist centers at a radius of 200 m and 400 m. In addition, BRT Corridor 1 is also easily accessible by various public transportation, including non-motorized vehicles. However, pedestrian facilities at each BRT shelter are still very limited. Further development requires good integration of land use planning (development of mix-land use shopping centers and culinary centers up to a radius of 400 m while artificial tourism is up to a radius of 200 m) with infrastructure for pedestrians along the BRT corridor. Future decision-making requires an in-depth study of pedestrian needs to encourage sustainable and environmentally friendly travel. Integrated planning for land use and transportation, especially BRT Corridor 1 in Central Java, must be considered by operators, regulators, and transportation planners for transit-oriented development, while still integrating the potential of local transportation and pedestrians.

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Author's Declaration

Authors' contributions and responsibilities

The authors made substantial contributions to the conception and design of the study. The authors took responsibility for data analysis, interpretation and discussion of results. The authors read and approved the final manuscript

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Availability of data and materials

All data are available from the authors.

Competing interests

The authors declare no competing interest.

Additional information

No additional information from the authors.

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