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# Comparing Transit-Oriented Development (TOD) Views between Providers and Passengers of BRT Trans Banyumas Based on TOD Standard 3.0

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**Abstract**

An efficient transportation system will positively impact economic growth and equitable social development. Sustainable transportation policies aim to address adverse environmental impacts, such as pollution, congestion, and reduced accessibility. Trans Banyumas acts as a transportation system that facilitates the movement of Banyumas residents by connecting them to several points. The existence of Trans Banyumas should be able to encourage the increased use of public transportation as a solution to overcome transportation problems in Banyumas. This study aims to examine and measure the extent of the service of the Trans Banyumas transit-oriented development concept. This research emphasises passengers' views of transit-oriented development (TOD) services and the operator's views. This research method used GLM ANOVA to test the hypothesis, with quantitative data collection from 375 respondents. The results show that the four reference bus stops showed different scores. Pasar Pon, Bulupitu Bus Station, and Tanjung bus stops reached the bronze standard, while Rita Super Mall bus stop reached the silver Standard. The GLM ANOVA analysis results show that passengers' socio-demographic characteristics significantly affect the service of the eight TOD principles, except densify and shift. The recommendations for improving the Trans Banyumas bus stops include establishing proper pedestrian and bicycle lanes, road infrastructure, and bus stop infrastructure, including proper lighting, cleanliness, and proximity to residential areas. In addition, the operator can establish an open space and retail stores to enhance economic and mobility activities around the TOD.

**Keywords**

BRT, Standard 3.0, sustainable transportation system, transit-oriented development, Trans Banyumas

## 1 Introduction

Development is a process of continuous change towards better conditions to achieve a just, competitive, advanced, and prosperous Indonesian society within the framework of the Unitary State of the Republic of Indonesia (Handrian and Indrajaya, 2019) and there is a direct influence between population growth and the level of public welfare (Didu and Fauzi, 2016). The hierarchy of cities is a crucial issue due to the different social, economic, and environmental impacts they generate. The size and spatial structure of cities, involving human populations and economic activities, lead to variations in impact management and the provision of necessary infrastructure. Therefore, it is essential to understand the changes in urban planning and urban systems and develop appropriate strategies to deal with the challenges faced by cities in the future (Hu et al., 2022). Transportation mobility is an integral part of modern society, playing a role in ensuring prosperity and well-being. Most projections indicate that the coming decades will see continued global population growth, increased prosperity, and further changes in mobility and transportation patterns. The world of transportation is constantly evolving, and mobility will continue to increase as more people and goods move (Cattaneo and Foreman, 2023).

Banyumas Regency is one of the regencies in Central Java with the third-highest population density despite its large area of 1,328 km$^2$ (Rosiyanti et al., 2022). The growth

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of the centre of activity is intensifying, causing an increase in traffic density until there is congestion on several roads in Purwokerto at certain times (Ningsih and Andani, 2023). High population density significantly impacts the transportation system's ability to meet the community's needs and requires the government and related agencies to consider developing transportation infrastructure (Din et al., 2022). In addition, an efficient public transportation system will help achieve the goals by supporting clean energy and promoting sustainable lifestyles (Corchado et al., 2021), accommodate the population density, and provide solutions for efficient mobility (Anggraeni et al., 2021).

In December 2021, the Ministry of Transport of Banyumas Regency announced the launch of a Buy the Service (BTS) program called Trans Banyumas. Trans Banyumas acts as a transportation system that facilitates the movement of Banyumas residents by connecting them to several important points (Prasojo et al., 2023). The operation of Trans Banyumas still faces several challenges, including suboptimal access to some bus stops due to their distance from residential areas (Ningsih and Andani, 2023). One of the alternative solutions that can overcome the problem of bus stops or transit places for Trans Banyumas is the expansion of transit-oriented development (TOD) (Iamtrakul and Chayphong, 2024).

Banyumas Regency was chosen to establish the TOD concept because it is a regional activity centre destination for the surrounding regency, so mobility and traffic are high (Ayuningtias, 2020). TOD is a strategic choice that involves the development of an area where transit points become the primary focus of the development process (Yip et al., 2024). TOD areas usually range from 400 to 800 meters from transit stops. This distance is chosen because it is suitable for pedestrians to overcome the distance barrier between stations and residential areas (Somenahalli et al., 2024). The lack of connections to tourist destinations from public transportation, such as trains, buses, and aeroplanes, makes tourists to refrain from using public transport, and some rely on private vehicles (Arini et al., 2024). It is also supported by the strategic plan from the Ministry of Transport in Banyumas, 2024-2026, to establish people's mobility to support pioneer transport services (Ministry of Transport, 2023).

Transit-oriented development (TOD) involves eight principles that can serve as variables or criteria to assess how the TOD concept can be implemented in an area. The eight principles include walk, cycle, connect, transit, mix, densify, compact, and shift (Hardi and Maatouk, 2023). Based on observations from several Trans Banyumas routes, several transit points can potentially apply the TOD concept. These transit points consist of Pon Market, Bulupitu Bus Station, Rita Super Mall, and Tanjung Nirwana, which need to be evaluated. It can be determined how much these Trans Banyumas transit points comply with TOD principles (Azzahrah et al., 2022). This should align with local regulations that emphasise the application of TOD principles to improve transportation availability and mobility and optimise accessibility to public transportation systems in the area (Yu et al., 2023). Therefore, the aim is to develop sustainable transportation policies so that those responsible can find solutions to address negative environmental impacts, such as pollution and noise, congestion, accessibility, health, safety, and security (Prior Filipe et al., 2024)

According to a preliminary survey, it was found that Pon Market, Bulupitu Bus Station, Rita Super Mall, and Tanjung Nirwana need an improvement in the implementation of the eight concepts of transit-oriented development (TOD), including inadequate levels of accessibility of sidewalks, bicycle lanes, access for disabilities, and buildings around transit places have not implemented transit-oriented development, which prioritises pedestrian access. This assessment can be done by analysing the services around the Trans Banyumas transit area (Romadlon and Saintika, 2020). Therefore, the maximum implementation of the TOD concept will create a more sustainable, efficient, and human-focused city regarding mobility and land use (Ibraeva et al., 2022).

The lack of supporting facilities at transit stops can create an unpleasant experience for transit users, potentially affecting their perception of public transportation and encouraging them to choose private vehicles (Li et al., 2024). It is crucial to develop a spatial planning framework that integrates transportation and land use planning into an integrated whole to reduce the use of private vehicles and switch to environmentally friendly vehicles (Su et al., 2021). In a theoretical framework, TOD is developed based on regulation, planning, design, organisation, and investment (Rosalin, 2021). Those aspects are the operator's responsibility. Therefore, to improve service and accessibility at Trans Banyumas, a study is needed to determine the extent of the TOD concept's implementation based on passengers' and operators' views. The passenger views focus on shifting and connecting to other public transports, and the operator views emphasise TOD planning.

According to the condition, this study aims to examine and measure the extent of the service of the Trans

Banyumas transit-oriented development concept. This research emphasises passengers' views or perceptions of transit-oriented development (TOD) services as well as the operator's views. This research can add new recommendations for improving the Trans Banyumas transit place based on the TOD concept. The implementation of TOD provides significant benefits for individual passengers and the government. For passengers, the optimal application of the TOD concept will improve accessibility, reduce transportation costs, and improve quality of life and health. Implementing the TOD concept is also expected to help the government create a more structured regional development by improving efficient mobility. This will reduce the number of private vehicles, overcome congestion problems, and lead to better regional development planning.

### 1.1 Literature review and hypotheses development

Creating and measuring a TOD area can be done by applying the eight principles of Transit-Oriented Development (Uddin et al., 2023). Four significant TOD principles include transit, connect, walk, and cycle (Liu et al., 2020). However, remember that the importance of the indicators used may differ depending on the location and situation of the application (Khare et al., 2020). In addition to the principles, there are three categories of TOD standards used in implementing TOD principles: Gold Standard, Silver Standard, and Bronze Standard (ITDP, 2017). TOD development is assisted and guided by incentives, such as FAR (Floor Area Ratio), which are expected to fulfil specific requirements that can be used as a reference to improve the overall efficiency of TOD development, or can help the development of TOD in various regions (Yen et al., 2023).

In Indonesia, the selection of BRT Trans Jateng stop locations is influenced by several factors, including pedestrian convenience, presence in densely populated neighbourhoods, use of unused areas (without impeding public utilities), and the ability to connect the central business district with the industrial zone of primary focus (Romadlon and Saintika, 2020). In Bangkok, Thailand, gender, age, education, and income have a significant effect on walking distance to TOD (Seehamart et al., 2025). Walking contributes to spatial perception and gains physical and mental health (Toralles, 2023). This is important because the quality of walking is one of the factors that determine the level of accessibility of using public transport (Kapoor et al., 2023). Therefore, the hypothesis is set below.

*H1: Sociodemographic characteristics affect the preference for walking criteria*

Bus stops must be integrated with densely populated areas and close to work locations to improve accessibility (Ashour and Tarawneh, 2023). Therefore, the location planning of Trans Banyumas bus stops should consider pedestrian-friendly aspects, population density, connections with industrial areas, and evaluate public facilities that are frequently used by the community (Romadlon, 2020). In Sydney, Australia, bicycle accessibility and cycling infrastructure are required to improve transport capacity and enhance attractiveness (Zhang and Lee, 2023). Therefore, TOD involves a high-quality process of planning and designing spaces to support, facilitate, and give priority not only to the use of public transit but also to the primary modes of transportation, such as walking and cycling (Wang and Xia, 2024), thus the hypothesis is set below.

*H2: Sociodemographic characteristics affect preference for cycle criteria*

In TOD areas, connecting bus routes has an impact on trip frequency, and people who live around the TOD area are more dependent on public transport (Li et al., 2022). When choosing BRT bus stop locations pedestrian-friendly aspects, population density, connections to industrial areas, and public facilities frequently used by the public must be considered (Romadlon, 2020). Active community participation as users aims to support sustainable urban development, especially in transportation and TOD development (Azmi et al., 2021). Therefore, the hypothesis is set as follows.

*H3: Sociodemographic characteristics affect the preference for connect criteria*

To improve passenger satisfaction with Trans Banyumas services, one of the strategies that can be applied is to allocate a certain amount of resources for bus travel time and focus on improving services related to the availability, comfort, safety of sidewalks, and transit (Salamah et al., 2023). The transit criterion aims to make better connections between jobs and housing, highlighting public and transit passengers, and creating opportunities for affordable housing (Shamskooshki, 2012). The transit area from TOD can be reshaped based on mobility culture by considering land use, housing, and transport (Hasibuan and Permana, 2022). Therefore, the hypothesis is set below.

*H4: Sociodemographic characteristics affect the preference for transit criterion*

In Jakarta, Indonesia, some TODs are equipped with retail stores to serve economic activity and improve the quality of life for passengers (Harmain et al., 2020). The primary variables of mixed-use for TOD are leave time, return time,

offline activity, and weekly mobility (Hasibuan et al., 2025). The mixed-use development can be enhanced by prioritising land use diversity to attract passengers (Berawi et al., 2020). Therefore, the hypothesis is set below.

*H5: Sociodemographic characteristics affect the preference for mixed criteria*

Passenger experience is a benchmark for assessing service quality, considering factors such as maintaining average waiting times at bus stops and considering BRT capacity. Bus stops need to be integrated with densely populated areas and close to workplaces to improve accessibility (Marsikun et al., 2023). In China, TOD is relevant to urban vitality, which can be closer to dense roads, and it will enhance offline consumption (Li et al., 2023). The development of TOD can create highly dense communities differently, and land gentrification (Fang, 2023). Therefore, the hypothesis is set below.

*H6: Sociodemographic characteristics affect the preference for density criteria*

One of the strategies of planned TOD areas is to promote social, economic, and environmental benefits by utilising serviced land to create a more compact area (Shamskooshki, 2012). The land use can impact passengers who use TOD because of concerns about health, residential, and industrial places (Gu et al., 2024). Some passengers in the Jabodetabek area, Indonesia, need mixed-use housing, but they prefer to rent rather than buy because they perceive transit as not for long-term residency (Hasibuan et al., 2025). In Naples, Italy, the diversity of land-use and public spaces design can play a role in sustainable public transport (Tiwari et al., 2023).

*H7: Sociodemographic characteristics affect the preference for compact criteria*

Walking and cycling have the potential to reduce emissions, and sociodemographic factors can trigger it (Mun Ng et al., 2024). In Bangkok, Thailand, some passengers who own vehicles mostly walk to public transport (Iamtrakul et al., 2021). Thus, the planned TOD can increase travel options for those who do not own a private vehicle. (Shamskooshki, 2012). But those who live in suburbs, TOD is not likely to affect their transportation ways (Fang, 2023). Therefore, the hypothesis is set as follows.

*H8: Sociodemographic characteristics affect the preference for shift criteria*

## 2 Methods

The method used is quantitative. This method compares the views of BRT operators and the Department of Transportation with those of passengers. The data that has been obtained is then analysed using the Multi-Criteria Evaluation (MCE) method with calculations using Microsoft Excel software. This research was conducted by distributing a questionnaire to 375 Trans Banyumas passengers. For passengers, the questionnaire contained questions about sociodemographic attributes and eight Transit-Oriented Development variables.

The sociodemographic aspects of the passengers included age, gender, occupation, residence, travel frequency, and walking time to the bus stop or transit point. The answers obtained were then recorded through Google Forms to make them easier to process. TOD has eight variables: walk, cycle, connect, transit, mix, densify, compact, and shift. The Standard was created based on the knowledge gathered over the years from various organisations worldwide, including ITDP. This document formulates a development model that optimally capitalises on the success of public transportation systems by focusing development on the end passenger (ITDP, 2017) (Table 1).

TOD evaluation and readiness focus on Pon Market, Bulupitu Bus Station, Rita Super Mall, and Tanjung Nirwana bus stops. This readiness assessment aims to ensure that corrective measures can be taken to improve the quality and success of the TOD project. This research used the General Linear Model ANOVA method with data processing using Minitab 21 software.

## 3 Results and discussion

### 3.1 Readiness of Trans Banyumas to implement TOD Standard 3.0

The value of the Trans Banyumas bus stop suitability indicator in this study was obtained from a survey of ten respondents from both the Banyumas Regency Transportation Agency and the Trans Banyumas operator, as shown in Table 2 and the results of the assessment of several bus stop points by the TOD Standard 3.0 can be seen in Table 3.

Table 3 shows that Pasar Pon, Bulupitu Terminal, TMP Tanjung Nirwana Bus Stop, and Rita Super Mall bus stop met the transit principle, a mandatory TOD concept implementation requirement. Even though they have met the transit principle, the four bus stops get different total scores, including Pasar Pon, Bulupitu Terminal, and TMP Tanjung Nirwana Bus Stop getting scores of 56-70, which shows the bronze standard, which means that the bus stop development project has fulfilled most of the goals of optimal implementation of the TOD principle. Meanwhile, the Rita Super Mall bus stop falls into the silver Standard because it gets a total

**Table 1** Variables of transit-oriented development (Source: ITDP, 2017)

| Variable | Explanation | Code |
|---|---|---|
| Walk | Pedestrian path segments with safe and accessible paths. | Q1 |
| | Intersections with safe and accessible crosswalks in all directions. | Q2 |
| | Minimum 50% active pedestrian walkway (building frontage). | Q3 |
| | The average number of shops, building entrances, and pedestrian access per 100 meters of building frontage. | Q4 |
| | Walkway sections provide sufficient shading or protective elements. | Q5 |
| Cycle | Availability of access to safe and complete cycling infrastructure. | Q6 |
| | Adequate and secure bicycle parking facilities are available at each transit station. | Q7 |
| | Availability of sufficient and secure bicycle parking in the building. | Q8 |
| | Availability of bicycle access to the building. | Q9 |
| Connect | Pedestrian path block length is less than 150 meters. | Q10 |
| | Prioritise connectivity. | Q11 |
| Transit | Walking distance to the nearest public transit station. | Q12 |
| Mix | Complementary land use. | Q13 |
| | Availability of access within walking distance to public/local services. | Q14 |
| | Access to parks and playgrounds within 500 meters. | Q15 |
| | Affordable housing units are available. | Q16 |
| | Preservation of housing or lodging. | Q17 |
| | Businesses and services are available within walking distance. | Q18 |
| Densify | Non-residential density against baseline in transit service areas. | Q19 |
| | Residential density against baseline in transit service areas. | Q20 |
| Compact | The number of sides of the development that adjoin previously developed areas. | Q21 |
| | A diverse number of public transit options can be accessed on foot. | Q22 |
| | The total off-street area is no more than 40%. | Q23 |
| Shift | The average number of motor vehicle accesses is a maximum of 2 driveways per 100 meters of block frontage. | Q24 |
| | The total road area is used for motorised traffic. | Q25 |

**Table 2** Sociodemographics of representative respondents

| Name | Age | Gender |
|---|---|---|
| Ministry of Transport Officer 1 | 24 | Female |
| Ministry of Transport Officer 2 | 28 | Male |
| Ministry of Transport Officer 3 | 25 | Male |
| Ministry of Transport Officer 4 | 26 | Female |
| Ministry of Transport Officer 5 | 25 | Male |
| BRT operator 1 | 21 | Male |
| BRT operator 2 | 30 | Male |
| BRT operator 3 | 27 | Male |
| BRT operator 4 | 22 | Male |
| BRT operator 5 | 23 | Female |

**Table 3** TOD scores

| Variable | Code | Score acquisition | | | |
|---|---|---|---|---|---|
| | | Pasar Pon | Bulupitu | Tanjung | Rita Super Mall |
| Walk | Q1 | 2 | 3 | 3 | 3 |
| | Q2 | 2 | 3 | 3 | 2 |
| | Q3 | 3 | 4 | 4 | 3 |
| | Q4 | 1 | 2 | 1 | 2 |
| Cycle | Q5 | 1 | 1 | 1 | 1 |
| | Q6 | 1 | 1 | 1 | 1 |
| | Q7 | 1 | 1 | 1 | 1 |
| | Q8 | 1 | 1 | 1 | 1 |
| | Q9 | 1 | 1 | 1 | 1 |
| Connect | Q10 | 6 | 5 | 5 | 6 |
| | Q11 | 3 | 3 | 3 | 3 |
| Transit | Q12 | Fulfilled | Fulfilled | Fulfilled | Fulfilled |
| Mix | Q13 | 5 | 5 | 5 | 5 |
| | Q14 | 2 | 2 | 2 | 2 |
| | Q15 | 1 | 1 | 1 | 1 |
| | Q16 | 6 | 6 | 6 | 5 |
| | Q17 | 2 | 3 | 2 | 2 |
| | Q18 | 2 | 2 | 2 | 2 |
| Densify | Q19 | 4 | 4 | 5 | 5 |
| | Q20 | 6 | 5 | 5 | 6 |
| Compact | Q21 | 5 | 5 | 6 | 6 |
| | Q22 | 2 | 2 | 1 | 2 |
| Shift | Q23 | 5 | 5 | 5 | 6 |
| | Q24 | 1 | 1 | 1 | 1 |
| | Q25 | 3 | 4 | 4 | 4 |
| Total Score | | 66 | 70 | 69 | 71 |
| Standard | | Bronze | Bronze | Bronze | Silver |

score of 71. This means that TOD has achieved almost all the maximum TOD principle implementation goals.

TOD score of Rita Supermall shows that it supports pedestrians with a length of less than 150 meters compared to the others. It also supports residential density surrounding the TOD and many development areas supporting department store activities. However,

the surrounding Rita Supermall has less affordable housing, and only old residents lived there before the TOD was developed. Therefore, mixed-use housing can be built near Pasar Pon, Bulupitu, and Tanjung to support passengers.

### 3.2 Sociodemographic of respondents

Data on the sociodemographic characteristics of respondents in this study were obtained from distributing questionnaires to 375 Trans Banyumas passengers.

According to the data on the sociodemographic characteristics of respondents presented in Table 4, most Trans Banyumas passengers are aged 18-27 years, with a percentage of 64%, followed by passengers aged less than 17 years, with a rate of 14%, and the rest are aged greater than 27 years. Most Trans Banyumas passengers are women, reaching 76%, while male passengers only have a percentage of 24%. Based on the type of occupation, Trans Banyumas passengers are dominated by students with a rate of 52%, followed by private employees or entrepreneurs with 22%; the rest consist of civil servants / Indonesian National Army / Indonesian National Police / State-Owned Enterprise, employees, traders, not working, and others with the smallest percentage of 4% each. 56% of Trans Banyumas passengers live in Purwokerto; the rest live in the Banyumas Regency and surrounding areas. The frequency of travel of respondents who use Trans Banyumas 2-6 times per week reaches 36%, those using Trans Banyumas every day account for 27%; the rest use Trans Banyumas only once a month, once a week, and some even for the first time. 48% of Trans Banyumas passengers take 6-15 minutes to walk to the nearest bus stop, followed by 34% of passengers taking less than 5 minutes to walk to the bus stop, with another 18% taking more than 15 minutes.

**Table 4** Sociodemographics of passengers

| Variable | Indicator | N | % |
|---|---|---|---|
| Age | Less than 17 years old | 53 | 14 |
| | 18-27 years old | 241 | 64 |
| | 28-38 years old | 49 | 13 |
| | 39-49 years old | 21 | 6 |
| | More than 50 years old | 11 | 3 |
| Gender | Male | 90 | 24 |
| | Female | 285 | 76 |
| Occupation | Students | 194 | 52 |
| | Civil servants | 15 | 4 |
| | Govt. corp. employee | 28 | 8 |
| | Self-employed | 83 | 22 |
| | Merchant | 19 | 5 |
| | Not working | 16 | 4 |
| | Others | 20 | 5 |
| Residence | Purwokerto | 211 | 56 |
| | Baturraden | 57 | 15 |
| | Ajibarang | 73 | 20 |
| | Others | 34 | 9 |
| Travel frequency | First time | 33 | 9 |
| | Every day | 102 | 27 |
| | 2-6 times/week | 135 | 36 |
| | Once a week | 45 | 12 |
| | Once a month | 54 | 14 |
| | Others | 6 | 2 |
| Walking time to bus stop | <5 minutes | 127 | 34 |
| | 6-15 minutes | 178 | 48 |
| | 16-25 minutes | 47 | 12 |
| | >26 minutes | 23 | 6 |

### 3.3 Classical assumption test

The classical assumption test processing of 375 respondents was conducted to ensure that the data met the criteria needed for the final analysis stage. This classic assumption test involves a validity test, a reliability test, and a normality test. Processing of classical assumption test data was carried out using Minitab 19 software with a confidence level of 95% and an error rate of 5%, as shown in Table 5.

The validity test results show that the *p*-value of each statement item in the questionnaire is 0.000 or less than 0.05, indicating that the data is considered valid. Furthermore, the reliability test results resulted in a Cronbach Alpha value of 0.9551, indicating that the data is deemed reliable because the value exceeds 0.6. The next stage is the normality test using the skewness and kurtosis method because it is suitable for data with a mean smaller than the standard deviation. The results of the normality test calculation show that the skewness value is in the range of –2 to +2, and the kurtosis value is in the range of –7 to +7, and it can be concluded that the data obtained is usually distributed.

### 3.4 GLM-ANOVA test

The General Linear Model, commonly called the GLM ANOVA test, is used to evaluate whether there is an influence between the factors of passenger sociodemographic characteristics on bus stop facilities based on the TOD concept at Trans Banyumas bus stops. These sociodemographic characteristics include age, gender, travel frequency, walking time to the bus stop or transit point, and the vehicle used before or after using Trans Banyumas. This study also consists of several variables: walk,

**Table 5** Classical assumption test results

| Code | Validity | Reliability | Normality (Kolmogorov-Smirnov) | |
|---|---|---|---|---|
| | *P*-value | Cronbach's Alpha | Skewness | Kurtosis |
| Q1 | 0.000 | 0.9551 | −2.11 | 4.80 |
| Q2 | | | −1.94 | 4.50 |
| Q3 | | | −0.62 | −0.08 |
| Q4 | | | −0.49 | −0.19 |
| Q5 | | | −1.64 | 2.40 |
| Q6 | | | −0.47 | −0.34 |
| Q7 | | | −0.62 | 0.27 |
| Q8 | | | −0.34 | −0.07 |
| Q9 | | | −0.12 | −0.62 |
| Q10 | | | −0.61 | −0.35 |
| Q11 | | | −1.36 | 2.19 |
| Q12 | | | −1.91 | 4.44 |
| Q13 | | | −0.79 | 0.09 |
| Q14 | | | −1.26 | 1.93 |
| Q15 | | | −0.47 | −0.55 |
| Q16 | | | −0.18 | −0.90 |
| Q17 | | | −0.47 | −0.24 |
| Q18 | | | −0.52 | −0.32 |
| Q19 | | | −0.44 | −0.24 |
| Q20 | | | −0.76 | 0.42 |
| Q21 | | | −1.56 | 2.60 |
| Q22 | | | −1.47 | 2.78 |
| Q23 | | | −0.13 | −0.64 |
| Q24 | | | −0.40 | −0.28 |
| Q25 | | | −0.61 | 0.11 |

**Table 6** Results GLM-ANOVA test

| Variable | Code | Significance factor | *P*-value |
|---|---|---|---|
| Walk | Q1 | Age | 0.000 |
| | | Gender | 0.013 |
| | | Walking time to bus stop | 0.002 |
| | Q2 | Age | 0.002 |
| | | Walking time to bus stop | 0.014 |
| | Q3 | - | - |
| | Q4 | Age | 0.016 |
| | Q5 | Age | 0.010 |
| | Q6 | - | - |
| Cycle | Q7 | - | - |
| | Q8 | Age | 0.012 |
| | Q9 | Age | 0.005 |
| | Q10 | - | - |
| Connect | Q11 | Age | 0.020 |
| | | Gender | 0.024 |
| | | Walking time to bus stop | 0.008 |
| Transit | Q12 | Age | 0.040 |
| | | Frequency of travel | 0.042 |
| | Q13 | Age | 0.034 |
| | | Walking time to bus stop | 0.040 |
| | Q14 | Age | 0.006 |
| | | Walking time to bus stop | 0.048 |
| Mix | Q15 | Age | 0.000 |
| | Q16 | Age | 0.000 |
| | | Gender | 0.022 |
| | Q17 | Age | 0.003 |
| | Q18 | - | - |
| Densify | Q19 | - | - |
| | Q20 | - | - |
| | Q21 | - | - |
| Compact | Q22 | Age | 0.001 |
| | | Walking Time to Bus Stop | 0.014 |
| Shift | Q23 | - | - |
| | Q24 | - | - |
| | Q25 | - | - |

cycle, connect, transit, mix, densify, compact, and shift. The GLM ANOVA test in this studyshows the significant difference between the sociodemographic characteristics factor and the sample group, as shown in Table 6.

Table 6 shows the hypothesis result. The results show that sociodemographic factors affect walking criteria. Regarding gender and age, it shows that female passengers, especially those aged 18-27, feel comfortable and safe using Trans Banyumas services because the bus stops and sidewalks are equipped with supporting facilities. The facilities are shade trees or canopies that are accessible to all groups, including the elderly, people with disabilities, and pedestrians carrying items such as canes, wheelchairs, and strollers, with sidewalks approximately 2-3 meters wide (Apriliyani and Mardiansjah, 2020). Walking time to the bus stop provides a good perception because it allows pedestrians to cross safely and efficiently without competing with passing vehicles. Walking is an essential part of every journey through transit points, making travel more comfortable, safe, and productive when the available lanes are narrow (Agustin and Hariyani, 2022). Based on analysis and survey results, passengers' sociodemographic perceptions of the walking aspect are positive.

Sociodemographic factors affect cycle criteria. It shows that only the age factor significantly influences perceptions of Trans Banyumas passengers. It is because the

primary goal is to provide environmentally friendly transportation. It encourages mobility with a primary focus on non-motorised transportation, especially bicycles, which are well-equipped and safe, and provide comfort for cyclists (Bagus et al., 2023). Furthermore, regarding the cycle aspect, special attention must be paid to dedicated bicycle parking areas and a safe bicycle network, spatially separated from vehicles on roads with speed limits exceeding 30 km/h, and equipped with signage.

Sociodemographic factors affect connect criteria. It shows that gender and age factors significantly influence the connectivity aspect. 76% of Trans Banyumas passengers are women who choose bus stops with adequate pedestrian facilities, such as crosswalks for pedestrians and evenly distributed shade and protection in the bus stop area. In addition, intersections for motorised vehicles equipped with adequate sidewalks and crosswalks are considered pedestrian-friendly intersections (Agustin and Hariyani, 2022). Based on observations, several users complained that there were no sidewalks near the bus stops, with a distance of less than 150 meters between each sidewalk.

Sociodemographics significantly affect transit criteria. It shows that age and walking to the bus are the factors that influence this. In addition to availability, easy access from transit points is also essential to reach all segments of society (Bagus et al., 2023). This has been implemented at several Trans Banyumas bus stops in the city centre and busy areas. Unfortunately, some Trans Banyumas bus stops, such as those leading to the Baturraden terminal, are still inaccessible.

Sociodemographic factors affect mix criteria. It shows that gender, age, and walking to the bus stop are influential factors. Passengers consider Trans Banyumas bus stops easily accessible because they can be accessed at public service locations such as schools, hospitals, offices, and shopping centres. The availability of various public transportation options should improve accessibility and efficiency of travel time to the bus stops. The mix, or integration, combines diverse land uses within a single area, brings various activities closer together, and makes them easily accessible by walking, cycling, or public transportation (Apriliyani and Mardiansjah, 2020). The mix concept has several key elements, such as diverse land uses within an area, local service centres and public spaces easily accessible from residential areas, and land and housing prices that align with residents' economic capabilities. These components provide the foundation for the success of the TOD concept in creating a diverse and integrated environment (Bagus et al., 2023).

Sociodemographic factors affect compact criteria. It shows that age and travel time to the bus stop influence this. To assess the implementation of the compact principle, attention is paid to aspects such as the availability of additional public transportation, the presence of bicycle systems in the bus stop area, and the characteristics of buildings in the area (Bagus et al., 2023). Most Trans Banyumas bus stops are accessible by public transportation, car, motorcycle, or bicycle. However, some Trans Banyumas bus stops are standalone or far from residential areas, making them vulnerable to crime.

Sociodemographics do not affect densify and shift criteria. In summary, it shows that there is less residential density around TOD. Most of the passengers come from suburban and rural areas. The shift criteria show that Trans Banyumas uses the same route as other vehicles.

### 3.5 Implication and recommendation

The comparison between the evaluation results of the TOD 3.0 standard and passenger perceptions involves two different dimensions. A representative Trans Banyumas operator conducted the assessment of the TOD variables. This assessment was based on the TOD Standard 3.0 metrics. On the other hand, passenger perception reflects the viewpoints, opinions, or direct experiences of individuals or groups who use or live around Transit-Oriented Development (TOD) areas. This perception can be influenced by subjective factors such as convenience, safety, quality of transportation services or bus stops, and availability of other public facilities.

In operator assessment, the results show that the evaluation results of the TOD 3.0 standard at the Trans Banyumas bus stop show a non-optimal performance. It shows that Rita Supermall achieved the highest TOD score, since it supports pedestrian and surrounding resident density. Rita Supermall is close to department stores, offices, schools, and hospitals compared to other TODs. At the TOD, walking and cycling activities are supported with a car-free day every Sunday morning. Therefore, other TODs such as Bulupitu, Pasar Pon, and Tanjung can be developed so that all criteria can be achieved and passengers can increase mobility and reduce their own-vehicle use.

However, Pasar Pon is highly possible to be improved because it is close to the train station that connects provinces. The improvement can be started by establishing a pedestrian path from the station to the bus stop to support walking and cycling criteria. Pasar Pon can also be developed into retail stores to support economic activities (Harmain et al., 2020).

Therefore, the TOD principles can be achieved with a walkable distance to essential services and infrastructure to minimise own-vehicle use (Chuang et al., 2023).

According to passenger perceptions, passengers still feel dissatisfied with several aspects, such as pedestrian facilities, shade and protective facilities, and cleanliness around the bus stop area. Passengers aged 50 years and above consider accessibility in the TOD area, especially in the walk variable, inadequate for older adults or those with limited mobility, and sidewalks and public facilities are still not friendly to older adults and people with disabilities. Female passengers also consider that the density variable is still not optimally implemented, and safety in the TOD area is less guaranteed. It happens mainly at night, because bus stops are still in quiet residential areas or far from other public facilities. In the compact variable, students have difficulty transferring from Trans Banyumas to other public transportation because the number of public transportation options accessible on foot around the bus stop is still limited.

Moreover, the alignment of operator assessments and passenger perceptions may also indicate that the evaluation standard needs to be improved to reach passenger satisfaction. The operator can follow up on the recommendations to improve the TOD score for Bulupitu, Pasar Pon, and Tanjung. It aims to create better accessibility, comfort, and safety for passengers and support sustainable development around the TOD. The explanation of each criterion can be seen in the following paragraph.

The walking aspect and the availability of pedestrian paths around Trans Banyumas bus stops significantly impact passenger perceptions. Walking is an integral part of any journey through transit points to make the trip more comfortable, safe, and productive, especially if the available paths are small in size (Naharudin et al., 2013; Kapoor et al., 2023). Adequate facilities increase the comfort, safety, and attractiveness of the environment, encouraging more passengers to walk. Conversely, inadequate facilities may discourage passengers from using available pedestrian facilities. Therefore, improvements and maintenance of pedestrian facilities are essential to support the TOD concept.

In regard to the cycling criteria, using bicycles as a mode of transportation will reduce air pollution and be a more flexible and efficient alternative, especially in dense urban environments. However, if cycling is not taking place in a designated bicycle lane, other road passengers may lack awareness of the rights and presence of cyclists. In that case, there will be concerns for the safety of cyclists due to unfriendly road infrastructure or the presence of other vehicles that do not pay attention to cyclists, which can cause conflicts on the road. Therefore, improving road infrastructure by providing separate and safe bicycle lanes from motorised traffic is necessary. Other supporting facilities, such as secure bicycle parking, must also be supplied around bus stops.

In regard to the connect criteria, the availability of good connections between modes of transportation makes travel time more efficient because there is no need to make complicated transfers or wait too long between modes of transportation (Yang et al., 2023). For the connecting principle to be achieved, there should be an intersection every 200 meters, and each block should be about 100 meters apart, so that there are more pedestrian paths and the paths are shorter than those for motor vehicles (Juliana and Lo, 2022). However, there are still limitations in the availability of transportation modes that connect a transit point with the passenger's destination, such as low service frequency or too long a distance. Moreover, there are still Trans Banyumas bus stops with inadequate facilities that discourage passengers from using public transportation such as Trans Banyumas. Therefore, the manager is expected to pay attention to, repair, and improve the quality and safety of Trans Banyumas bus stops, including adequate lighting, cleanliness, and security supervision.

In a transit system, it can improve travel comfort and efficiency for passengers by offering faster, more efficient, and more structured travel options (Dumedah et al., 2023). Converting an uncoordinated paratransit system to a coordinated service can increase the regularity of service frequency and reduce average waiting times, even without the addition of vehicles (Jaiswal et al., 2022). It can also eliminate the prolonged waiting times that sometimes occur in paratransit services (Garnier et al., 2022). There are still some passengers who feel uncomfortable and unsafe using the transit system because there are still Trans Banyumas bus stops that are far from residential areas and prone to crime. Poorly maintained bus stop facilities also cause passengers to feel uncomfortable. Thus, the manager is expected to conduct further investigations to improve and maintain the existing transit system, such as strengthening security in the bus stop area, increasing the number of security officers, installing surveillance cameras (CCTV), and increasing lighting in vulnerable areas.

The mix criteria can be evaluated through the variety of functions that pedestrians can access within a short distance, and through the array of land functions (Fadilla et al., 2022). With facilities and easy access to

nearby and diverse local services, people are more likely to use public transportation on foot, reducing the need for private vehicles. However, high density without proper management can result in congestion, noise, and reduced quality of life for residents. Therefore, it is necessary to develop adequate transportation infrastructure and public facilities, such as retail stores, to enhance economic and passenger mobility. The government can build a new bus stop near a high-density residential area.

The compact criteria show that diverse public spaces are developed near each other, while towers are built around them. This minimises the time and energy required to move from one activity to another (Sulaiman, 2023). Clustering land use makes it easier to build infrastructure and services that better meet the community's needs, such as better accessibility and access to public transportation. However, high density will also lead to congestion. Therefore, it is desirable to develop alternative transportation such as bicycles, walking facilities, or efficient and environmentally friendly public transit to reduce dependence on private vehicles.

In regard to densify and shifting criteria, there is no relationship with sociodemographics. It is an opportunity for the operator to establish the system. It can be applied by maximising the use of space, matching high-quality public transportation capacity, local services, and activities in public spaces (Pelczynski and Tomkowicz, 2019) such as lighting, fresh air circulation, and access to parks (Allan et al., 2022), recreational areas, nature preservation, and preservation of the historic and cultural environment (Pelczynski and Tomkowicz, 2019). Compacting settlements and activities make building infrastructure and services that meet the community's needs more accessible. However, inappropriate and uncontrolled densification will result in losing open and green spaces important for people's physical and mental health. Managers are expected to conduct more targeted and sustainable urban planning to control population density by considering the needs of public transportation infrastructure, open space, and environmental sustainability in living and mobility.

In regard to shifting criteria, the operator can increase movement through parking and land use policies to reduce dependence on private vehicles by strengthening public transport mobility and regulating parking and road use (Antonson et al., 2017). The existence of shift aspects can help promote sustainable mobility in the city so that there will be a shift from private vehicles to public transportation. However, many passengers still feel inconvenienced or uncertain in using public transportation, such as schedule uncertainty, delays, or inconvenience during the trip. It is, therefore, necessary to improve the frequency and quality of public transportation services and provide more accurate and up-to-date information on schedules and routes to improve the reliability and convenience of public transportation through a digital application. The recommendation can be summarised as shown in Table 7.

## 4 Conclusions

This study examines and measures the extent of the service of the Trans Banyumas transit-oriented development concept. This research emphasises passengers' views or perceptions of transit-oriented development (TOD) services and the operator's views. The evaluation

**Table 7** Recommendation summary

| Variable | Factor | | | |
|---|---|---|---|---|
| | Age | Gender | Walk to the bus stop | Freq. of travel |
| Walk | Improve pedestrian facilities. | | | |
| Cycle | Adding a bicycle lane and improving road infrastructure. | | | |
| Connect | Increase the bus schedule, proper lighting, and cleanliness at the bus stop. | | | |
| Transit | The bus stop is closer to the residential area. | | | Installing CCTV and proper lighting at the bus stop. |
| Mix | Establish more stores to enhance economic business and mobility. | | The bus stop is close to a high-density residential area. | |
| Densify* | Adding new bus stops, establishing open spaces, and conducting environmental sustainability in living and mobility. | | | |
| Compact | Improving bicycle lanes and walking facilities to reduce own-vehicle use. | | Improve public transit. | |
| Shift* | An app to provide more accurate route, bus position, and bus capacity information. | | | |

*: Insignificant, but it needs improvement.

of the transit area shows that the area is still in the low to medium accessibility category. Pasar Pon Bus Stop, Bulupitu Terminal, and Tanjung Bus Stop achieved bronze, while Rita Supermall achieved silver classification. Improvement points can be made by completing bus stop facilities that fully adopt the TOD concept.

Passenger views of Trans Banyumas passengers showed that sociodemographic factors affect TOD criteria except densify and shift. Passengers' primary focus is on establishing proper pedestrian and bicycle lanes, improving road infrastructure, and improving bus stop infrastructure, including proper lighting, cleanliness, and being close to residential areas. In addition, the operator can establish an open space and retail stores to enhance economic activity around the TOD.

However, this study has limitations. Digital app technology helps passengers get real-time information about transit and bus schedules. The improvement of the TOD concept for all bus stops needs support to cover all demographic segments and collaboration among stakeholders. Therefore, future research can investigate how the design and accessibility provided by Trans Banyumas bus stops meet the needs of all levels of society, including individuals with disabilities, older people, and other vulnerable groups. The use of digital applications and design for retail stores can be initiated so that people's mobility and the reduction of own-vehicle use can be achieved.

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