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Wheels of Progress: Investigating Factors Shaping Yogyakarta's Low Carbon Transformation via Bicycle Usage

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ABSTRACT: Utilizing bicycles as a mode of transportation is pivotal for transitioning towards a low-carbon city. It is essential to explore the factors that influence bicycle use to help provide regulatory recommendations and plan the implementation of bicycle transport. This study extensively examines the factors impacting bicycle usage to propose policies to facilitate bicycle transport implementation. Based on survey data collected from public transport and bicycle users, the research highlights two predominant factors shaping bicycle use in Yogyakarta: individual travel characteristics, particularly first-mile needs and mileage, and a positive correlation between income and bicycle adoption. Conversely, distinct external land uses offer varying incentives, notably favoring high-density areas like trade and service zones, further supported by proximity to bicycle parking facilities. These findings empower urban planners and policymakers to craft effective policies and utilize the potential of a bicycle transportation system.

KEYWORDS: Influencing factors; bicycle-public transport integration; low-carbon cities; land use

1. INTRODUCTION

Currently, big cities face transportation problems which continue to exacerbate environmental problems. Traffic jams, increasing air pollution, and greenhouse gas emissions have now become a "vicious triangle" of global environmental problems. Yogyakarta, one of the metropolitan cities in Indonesia, is also experiencing similar problems. Known as a city of tourism, education, and culture, and having an iconic area, Yogyakarta is a favorite destination for the people. The high rate of population growth is in line with the increase in private vehicle ownership, which is increasing by 6 % per year (Badan Pusat Statistik, 2023). The increase in private vehicle ownership shows the increasing dependence of the community on private vehicles. This exacerbates global environmental problems, including increased CO2 emissions (Schiller, & Kenworthy, 2018). Referring to this phenomenon, research conducted by the Institute for Essential Services Reform (IESR) states that of the 600 MtCO2-eq GHG emissions from the energy sector in 2021, 23 % come from the transportation sector. Emissions from the transportation sector are expected to increase by 53 % in 2030 compared to 2015 and almost double between 2030 and 2060 (IESR, 2023). This fact is exacerbated by the urban growth structure in Yogyakarta which develops organically, but the availability of land is limited.

Development that is increasingly being carried out and is not balanced with adequate land availability will be an ongoing problem. In overcoming this problem, big cities are competing to find the right way to develop a sustainable transportation system. For example, the Beijing Government China, proposed implementing eco-friendly travel in large cities by development in the form of bike sharing to reduce carbon emissions (Chen, Zhou, Zhao, Wu, Wu, & 2020). The Copenhagen government also supports including bicycle transportation in the city's development planning system by dividing the percentage of bicycle trips by 50 % from 75 % of non-motorized vehicle trips (Braun et al., 2016). Yogyakarta is also taking action through the Transport Demand Management (TDM) approach. This approach is carried out by attracting people to use public transportation and suppressing the use of private vehicles (Kresnanto 2022). According to Kresnanto (2022), the priority strategy for implementing TDM in Yogyakarta can be carried out by integrating public transportation services and improving non-motorized infrastructure. Previously, the Transport Demand Management scheme was implemented in a city in Indonesia, Bandung, which shows that the TDM approach through providing adequate public transportation and encouraging people to use this mode is very important in improving transportation services. In this case, public transport lanes or lanes are discussed with other transport connections, including bicycles. The application of TDM also indirectly supports the integrated bicycle and public transport (BPTI) scheme.

Bicycle transportation is part of a sustainable transportation system (Autelitano, & Giuliani 2021). The benefits of using bicycles as a mode of travel can be felt, such as reducing congestion, reducing road loads, protecting the environment, and preventing certain diseases (Dargay, Gately, Sommer, 2007; Fishman, Washington, Haworth, Watson, 2015; Yang, Chen, Zhou, & Wang, 2015). The increase in bicycle transportation has been increasingly felt since the development of the bicycle-sharing system program. In most cities around the world, especially in bike-friendly countries, bike sharing has become an important mode of transportation. The development of bike sharing was first initiated by Western countries in the late 1960s (Fishman, et al., 2015). This development was followed by countries in Asia, especially parts of East Asia. Beijing launched the public bicycle project in 2005, followed by Hangzhou in 2008 (Zhang, Shaheen & Chen, 2014). In 2017, Shanghai also launched a bike-sharing project known as Mobike. Until now, the bike-sharing system has become a necessity for China's urban communities.

Bicycles as a mode of transportation offer benefits in improving the quality of life in urban areas, for example by reducing problems related to the environment and air pollution

(Zhang, Zhang, & Wang, 2015), improving the health of users and functioning as transportation; recreational and flexible movement tools (Winters, Teschke, Grant, Setton, & Brauer, 2011). The development of bicycle use has also facilitated public transportation and reduced travel costs (Yi, Li, & Gan, 2019). This of course brings new solutions for the development of low-carbon and environmentally friendly urban transportation. Apart from that, the use of bicycles as a mode of transportation also varies, for example the use of bicycles with a bike sharing system or the use of bicycles with a public integration scheme for bicycle transportation. The goal is the same, namely improving urban transportation and solving the "first mile" and "last mile" problems when citizens use public transportation to travel (Zuo, Wei, Chen & Zhang, 2020). In addition, research supporting the adoption of bicycle use also shows that the implementation of bicycle sharing projects reduces energy use and carbon emissions (Zhang, & Mi, 2018).

In Indonesia, programs related to bicycle use are linked to the integration of bicycles with public transportation in line with low-carbon transportation programs. This implementation is part of the Indonesia-UK cooperation agreement program, namely the transition towards inclusive low-carbon transportation. Based on this phenomenon, the minimum effort that can be made to achieve inclusive transportation is to switch to using sustainable and environmentally friendly transportation. Yogyakarta has the potential to utilize bicycles as transportation that can collaborate with public transportation in the form of BRT, whose service coverage currently reaches the outskirts of the city. However, the problem lies in the operational implementation, there is no full support and regulations so only a few people use it. This combination of bicycles with BRT is only carried out by a few people who are aware of the dangers of pollution caused by transportation. The results of interviews with the cycling community show that apart from being aware of the dangers of pollution, they are also aware of the health reasons for cycling. This shows that the successful implementation of integration must be balanced with the active role of the community and community understanding. Several previous studies support this view; the community as users of transportation is one of the determining factors for the success of transportation (Panchal, Majumdar, Ram, & Basu, 2020).

Based on previous research, we found that characteristics related to gender, income, transportation costs, and bicycle parking location (distance to bus stops, stations, and residential areas) were associated with higher perceived bicycle use. Most studies address individual and city characteristics that influence bicycle use. However, only a few of these studies discuss how these two factors also influence bicycle use when added to other variables in the form of trip characteristics. Previous research also shows several factors that influence bicycle use, including road density and connectivity (El-Assi, Mahmoud, & Habib, 2017), demographic characteristics, certain weather and climate conditions (Bergström, & Magnusson, 2003), the proximity of bicycle stations to bus stops (Rixey, 2013), and placement locations, bicycle (Yang, Ding, Qu, & Ran, 2019). Some of the results of this research indicate that several steps must be taken to encourage bicycle use, such as increasing the length of bicycle lanes or reducing the number of road intersections (El-Assi et al., 2017), increasing vegetation (Lusk, Wen, & Zhou, 2014), and increasing road coverage, public transport network (Noland, Smart, & Guo, 2016).

This research is a complement to previous research, especially from the perspective of utilizing bicycle public transport integration schemes to contribute to the realization of low-carbon transportation programs. In previous studies, trip characteristics were often considered not to influence user decisions, but we tried to examine whether something similar happened in Yogyakarta. In the process of selecting target sources, we recognized that the transformation under consideration is significantly contingent on societal contributions, particularly from key stakeholders. Consequently, we have designated Bus Rapid Transit (BRT) users and bicycle users as the primary sources for this research. To gain insight into user preferences and characteristics, we employ questionnaires and surveys. In constructing these questionnaires, we have thoughtfully included a selection of pertinent characteristics tailored to the practical circumstances of our research setting. Yet, our comprehension extends beyond internal factors, as we diligently explore external variables that impact this context. Our initial hypothesis posits that in addition to internal characteristics, external factors, such as the individual's place of origin and the presence of specific amenities, play a pivotal role in shaping an individual's inclination toward bicycle usage as a mode of transport. This suggests that individuals tend to favor bicycle usage in regions endowed with comprehensive bicycle infrastructure and mixed land-use developments. In terms of land use characteristics and provision of facilities, we identify whether user trips have a relationship with these characteristics based on considerations through trip characteristics. We also offer an open discussion about why this scheme has not been realized in big cities in Indonesia, especially Yogyakarta which has high potential for bicycle use.

2. LITERATURE REVIEW

2.1 Bicycle-Public Transport Integration

The integration of various modes of transportation is a critical concern for ensuring the safety and sustainability of urban transportation systems. This integration involves coordinating all modes, including pedestrians, bicycles, motorized vehicles, buses, and trains (Saplıoğlu, & Aydın, 2018). In both developing and developed countries, transportation planning aims to promote bicycle and pedestrian transport while reducing car usage. Bicycle-public transport integration is a crucial alternative, especially at intersections with other modes of public transportation, for commuters continuing their journeys. Coordinating bicycle use with public transport can enhance safety and convenience for cyclists (Pucher, & Buehler, 2008).

In the past, bicycle integration systems were explored by introducing coordinated bicycle parking programs within the public transportation system. Several studies have also investigated bicycle-on-bus services implemented in Germany and bicycle-on-rail services in parts of California. These examples highlight the dominance of bicycle ownership, where cyclists need to bring their bicycles onto buses. However, this process, particularly embarking and disembarking at each stop, can be challenging. Nevertheless, convenience has been enhanced, especially with the introduction of public bike-sharing systems (PBSS). PBSS supplements existing public transportation services and helps establish new mobility options (Midgley, 2009).

Previous research has demonstrated that using bicycles for both access (home to station/stop) and egress (station/stop to destination) trips significantly reduces door-to-door travel time (Saplıoğlu, & Aydın, 2018). Furthermore, the integration of bicycles and public transport proves advantageous for motorists, particularly in adverse weather conditions, challenging terrain, or gaps in the bicycle lane network (Pucher and Buehler 2009). Other studies have also emphasized the importance of lane availability in bicycle integration with public transportation.

2.2 Factor Influencing cycling and use of public transport

Sustainable public transportation plays a pivotal role in the transition towards low-carbon transportation (Li, He, Luo,

Zhang, & Dong, 2018). However, limited fleet sizes and stops can hinder the optimization of public transportation usage. Similarly, bicycle systems have shown potential in reducing carbon emissions. Various studies have explored the relationship between bicycle use and its influencing factors. These factors encompass age, gender significance (Gu, Kim, & Currie, 2019), income, demographic elements, education, environmental quality (Caulfield, O'Mahony, Brazil, & Weldon, 2017), and weather (Helbich, Bocker, & Dijst, 2014).

Several studies have also delved into this topic by combining individual characteristics with city characteristics. Research on internal factors influencing bicycle use has highlighted the significance of demographic characteristics (Gebhart & Noland, 2014; Noland, et al. 2016) and the proximity of bicycle stations to bus stops in encouraging bicycle use (Noland, et al., 2016). Furthermore, Yang, et al., (2019) revealed that the placement of bicycle facilities also influences the inclination to use bicycles. Another perspective, concerning bicycle use in the context of a city's structure, has been explored. It suggests that demand for bicycle use is higher in larger areas with increased per capita income and population density. Additional research has emphasized that areas with higher density and mixed land use encourage greater cycling (Pucher, & Buehler, 2006).

It is evident that both individual characteristics and city characteristics alone cannot fully explain the factors motivating transportation mode choices. Notably, city characteristics, such as land use, have a profound connection with transportation organization. Specific land uses, such as trade and services, typically exhibit higher mobility compared to other land uses. We will also explore the relationship between this land use and the provision of bicycle facilities as a driving force behind bicycle use.

3. METHODS

3.1 Data Source

The data utilized in this research consists of questionnaire responses collected from late 2022 to early 2023, distributed to users of Bus Rapid Transit (BRT) and bicycles. On a daily basis, we reached a total of 8,144 bicycle and BRT users. Following the Slovin formula with a 5% error tolerance, we derived a sample size of approximately 380 respondents. These questionnaires were distributed at various BRT bus stops and bicycle parking points throughout Yogyakarta.

Subsequently, we conducted data cleaning on the original dataset. Initially, we removed any aberrant data, including (1) entries with repetitive patterns or careless entries and (2) data from users located outside the study area, i.e., beyond the boundaries of the Special Region of Yogyakarta. This process led to the elimination of approximately 40 data points, including outliers, leaving us with 340 usable data points. We then grouped and sorted these 340 data points based on specific criteria and predetermined intervals. To explore the multifactorial influences on the desire to use bicycles, we employed a statistical data processing application. Given that the dependent variable, i.e., the desire to use a bicycle, is categorical and marked with a value of 1, we utilized the logit model for analysis. The resulting numbers represent specific categories derived from the calculated probabilities of each category's occurrence.

In addition to the questionnaire data, we conducted surveys and spatial analyses to map the availability of bicycle facilities. Specifically, we documented the locations of bicycle parking points, incorporating land use data to represent city characteristics. We also collected data on the origin and destination of user trips. This survey was conducted in parallel with the questionnaire distribution and involved recording the coordinates of bicycle parking locations and measuring the distance from these locations to the nearest bus stop. In this study, land use data is crucial for characterizing the city due to its significance in addressing land use limitations in the research area. Land use data reveals the distribution of bicycle stops or parking locations, helping us assess whether the availability of bicycle services supports environmentally friendly transportation and contributes to the realization of a low-carbon city.

3.2 Construction of a multi-factor influence model of using bicycles

3.2.1 Selection of Influencing Indicators

Previous research has established that individuals' travel behavior is shaped by a range of factors, including demographic characteristics (Gebhart & Noland 2014; Noland, et al. 2016) and proximity to the nearest public transportation network (28) (Fuller, Sahlqvist; Cummins, & Ogilvie, 2012; González, Mělo-Riquelme, & de Grange, 2016). In this context, we categorize these factors as population characteristics and travel characteristics variables. Beyond demographics and distance, the type of land use (Wu, Kang, Hsu, & Wang, 2019) and the placement of bicycle facilities (Yang, et al., 2019) are additional indicators that can promote bicycle usage, and we classify them as external variables.

Eight out of ten indicators will undergo analysis through a logit model to create a comprehensive model of factors driving bicycle use. Within the age category, we exclusively consider individuals aged 15 to 65, subdivided into three distinct age groups. Income is stratified into three groups: income below the average minimum wage, income equivalent to the minimum wage, and income exceeding the minimum wage. In the occupational section, we employ multiple classifications, taking into account previous research highlighting the influence of working hours and job type on individuals' modal choices.

Moreover, we gauge respondents' willingness to use a bicycle by providing various response options through a Likert scale. This variable serves as a dummy, with a value of one if the response indicates a high or very high willingness to use a bicycle; otherwise, the value is zero. Table 2 offers a summarized overview of respondents categorized as either willing to use bicycles as a mode of transportation, both as feeders and the primary mode or those not inclined to use bicycles as a means of transportation.

Variable	Indicator
Individual Characteristics	X1 : Age, X2: Gender, X3: Occupation, X4: Income, X5: Vehicle Ownership
Travel Characteristics	X6: Travel Purpose, X7 : Distance between origin and bus stop; X8: moda first mile
City Characteristics	X9 : land use (recreation/sport/culture area; tourism area;education area; trade and service area;office area; housing area)
Bike Facility	X10 : bicycle parking

Table 1. Variable of the Research

3.2.2 Logit Models

To examine the multifactor influences on the desire to use a bicycle, we employ the logit model. Given that the dependent variable, the desire to use a bicycle, is categorical and represented by a value of 1, we utilize the logit model for analysis. The resulting numerical output signifies a specific category, derived from the calculated probability of that category occurring. In this model, we denote the dependent variable as Y, symbolized by "wtu" (want to use) for the bicycle, while X represents the independent variable(s).

To study the relationship between individual characteristics and the desire to use a bicycle,

$$Ywtu = \beta_1' \text{ Individualwtu} + \beta_2' \text{Travelwtu} + \varepsilon wtu(1)$$

Y is a dummy variable with a value equal to 1; if individual I travels, then t wants to use a bicycle. β1 represents an indicator that measures the relationship between individual factors and bicycle use. Individuals represent gender, age, income, occupation, and vehicle ownership. For example, users with a younger age range are more likely to use bicycles than users with an older age range. People with higher incomes tend to use private transportation compared to people with lower incomes. B2 is an indicator that measures the relationship between travel and bicycle use.

The trip represents the destination of the trip, the first mile, and the distance from the nearest bus stop. This means that Y represents the factors that encourage bicycle use based on the value of X; if the value of X is negative, then the factor is in contrast to Y; conversely, if the value of X is positive, then the factor is in line with Y or can be said to be a factor that supports Y. Table 2 shows the Statistical Summary of the variables used in the logit model. The mean value in Table 2 is obtained from a questionnaire that has been processed, and the average value of each category is sought. The results of measuring this relationship will be associated with other variables, such as the characteristics of the city and the origin of the user's trip.

Variable	Want to use	Do not want to use	Total
	Mean	Mean	Mean
Age[1]	1.78	1.37	1.65
Young (< 30)	**0.83**	**0.62**	**0.76**
Middle Aged (30-50)	0.1	0.125	0.11
Aged (>50)	0.05	0.25	0.11
Gender[1]	0.54	0.69	0.59
Woman	**0.54**	**0.69**	**0.59**
Man	0.45	0.3	0.40
Occupation[1]	1.23	1.22	1.23
Student	**0.59**	**0.44**	**0.54**
Worker	0.32	0.38	0.34
Unemployment	0.08	0.16	0.11
Income[1]	0.81	0.81	0.82
Low Income	**0.4**	**0.43**	**0.41**
Middle Income	0.36	0.31	0.34
High Income	0.22	0.25	0.23
Vehicle Ownership[1]	0.94	0.81	0.90
Car	0.1	0.02	0.08
Motorcycle & Bicycle	**0.744**	**0.73**	**0.74**
None	0.15	0.22	0.17
Purpose to go[2]	1.1	1.3	1.23
Work. School	**0.4**	**0.48**	**0.43**
Tourism	0.37	0.33	0.35
Others (Shopping. Friendship)	0.21	0.18	0.20
Distance[2]	1.4	1.43	1.44
< 1 km	**0.57**	**0.15**	**0.57**
1-5 km	0.29	0.29	0.28
6-10 km	0.13	0.02	0.13
First Mile[2]	1.7	1.5	1.67
Walking	**0.72**	**0.59**	**0.68**
2 Wheeler	0.25	0.37	0.29
4 Wheeler	0.01	0.02	0.01

Note: Characteristic 1 indicates individual characteristics and characteristic 2 indicates travel characteristics. This data was obtained through a questionnaire conducted in the 2022-2023 interval for the people of Yogyakarta.

Table 2. Statistical summary

4. RESULTS

4.1 Baseline results

Table 3 reports the results of the logit model estimation. As with the linear regression model using the OLS method. we tested the overall model significance using the g test. In testing the model, the value entered is the variable's value with the highest average value (Table 2). The results of column 4 are the benchmark against which we model the equation as a factor driving bicycle use.

Even so, we try to model the logistic regression model which can be written as follows:

$$Ywtu = \beta_1' \text{Individualwtu} + \beta_2' \text{Travelwtu} + \varepsilon wtu(1)$$
$$Ywtu = 1.734 + 0.904\chi_1 - 0.535\chi_2 - 0.065\chi_3 + 0.369\chi_4 - 0.282\chi_5 - 0.002\chi_6 + 0.571\chi_7 + -0.016\chi_8$$

The results obtained from the logit model highlight the key factors influencing a user's decision to opt for bicycle use. Among these factors, age (χ_1), gender (χ_2), first-mile mode (χ_7), vehicle ownership (χ_4), and trip purpose (χ_5) play the most significant roles in shaping this decision. Specifically, individuals under the age of 30 (χ_1) and males (χ_2) show a higher inclination to use bicycles as their mode of transportation. Moreover, those without personal vehicles or owning four-wheeled vehicles (χ_4) are more likely to express a desire to use bicycles.

Variables	Logit (1)	Logit (2)	Logit (3)	OLS
Age χ_1 (Young < 30)	0.802	0.899	0.904	0.904
Gender χ_2 Woman	-0.414	-0.537	-0.535	-0.535
Occupation χ_3 Student	-0.055	-0.064	-0.065	-0.065
Vehicle Ownership χ_4 2 Wheels	0.313	0.367	0.369	0.369
Purpose to go χ_5 School. Work	-0.223	-0.278	-0.282	-0.282
Distance χ_6 < 1km	-0.009	-0.003	-0.002	-0.002
First Mile χ_7 Walking	0.480	0.566	0.571	0.571
Income χ_8 Low Income	0.018	0.016	0.016	0.016
R-squared				0.161

Table 3. Factors that encourage bicycle use

This category of users commonly commutes on foot from their point of origin to the nearest bus stop (χ_7) for purposes unrelated to work or school (χ_5). Age stands out as the most influential factor, emphasizing the importance of targeting planning efforts toward this age group. Typically, individuals within the 30-year-old age range include students and private workers. This aligns well with Yogyakarta's status as a national and internationally recognized educational hub,

making it an appropriate location to implement bicycle use as a transportation mode for this demographic.

Conversely, indicators related to employment (χ_3), income (χ_8), and distance from the origin to the bus stop (χ_6) demonstrate minimal impact, with values close to zero. These factors exhibit little to no correlation with a user's decision to employ bicycles as a mode of transportation. This suggests that individuals with employment status outside of student or private worker roles, along with lower income levels, exhibit reduced interest in bicycle usage. This trend may be attributed to longer distances between their origin locations and bus stops, reducing their inclination to consider bicycles as a viable transportation mode. Further exploration of this phenomenon reveals that safety and comfort are critical factors that influence these decisions. The presence of supporting bicycle facilities, such as bike paths and greenery, significantly contributes to the perception of safety and comfort. Although individuals in this group may have limited travel expenses and physical fitness suitable for bicycle use, their reluctance stems from concerns about transportation safety. This observation aligns with previous research indicating that the aesthetics of the environment, including bike paths and green spaces, impact bicycle usage (Kyle Gebhart & Robert B. Noland 2014). Additionally, both men and women have specific criteria influencing their decisions regarding bicycle use.

For employed individuals who are the target audience for bicycle use, there is a tendency to agree with using bicycles as a transportation mode, especially when commuting to work. Short interviews with some respondents revealed that they seek a quick mode of transportation to reach their workplaces, thus agreeing to bicycle use for this purpose. Nonetheless, various underlying reasons affect these preferences, including weather conditions, safety concerns, and individual cycling abilities.

4.2 External Factors

Previous research shows that apart from individual factors, city characteristics also affect the willingness to use bicycles. In this section, we will discuss the characteristics of land use as one of the urban characteristics that influence the willingness to use bicycles. Apart from the characteristics of the city, we will also analyze whether the presence of bicycle parking facilities can also encourage public interest. These two factors were taken based on the consideration that land use in areas with high levels of activity usually has a high level of mobility. In line with that, one of the reasons for the high level of mobility is the availability of supporting infrastructure. To analyze these factors, we use point-of-origin data for user journeys. Travel origin is an essential factor in a person's decision to choose transportation. Then we combine the data for the point of origin of this trip with the use of the surrounding land to determine whether a particular land use affects the starting point of the user's movement. As usual, the trips taken by people usually start from home. Therefore, we identified whether these results also apply to this study. Furthermore, we also combine the trip's point of origin with the availability of bicycle use facilities. On this occasion, we also want to prove whether the availability of bicycle facilities can influence the willingness to use bicycles by comparing the point of provision of bicycle facilities with the point of origin of the user's journey.

4.3 Travel Origin

This section will present spatial data on the point of origin of the respondents' trips. Figure 1 shows that more than 25 % of the respondents' trips came from outside the city. We present the distribution of the points of origin of the respondents' trips identified based on their willingness to use bicycles. Most respondents who do not want to use bicycles are outside the Yogyakarta urban area. This unavailability can be caused by several factors, one of which is related to the distance traveled by the respondent being too far so that it is not possible to use a bicycle either as a feeder or the primary mode. Another factor that causes this is the topography of areas outside urban areas with a non-sloping topography like urban areas, so it requires more effort to use a bicycle.

4.4 Land Use

Yogyakarta's land use is mainly characterized by a prominent trade and service area, especially following the main road.

Nmb	Land Use	Area (Ha)	Percent
1	Recreation/Sport/Culture Area	260.2	8%
2	Tourism Area	815.579	24%
3	Education Area	76.962	6%
4	Trade and Service Area	1284.172	38%
5	Office Area	174.245	5%
6	Housing Area	725.532	22%
	Total	3336.69	

Table 4. Land Use in Yogyakarta

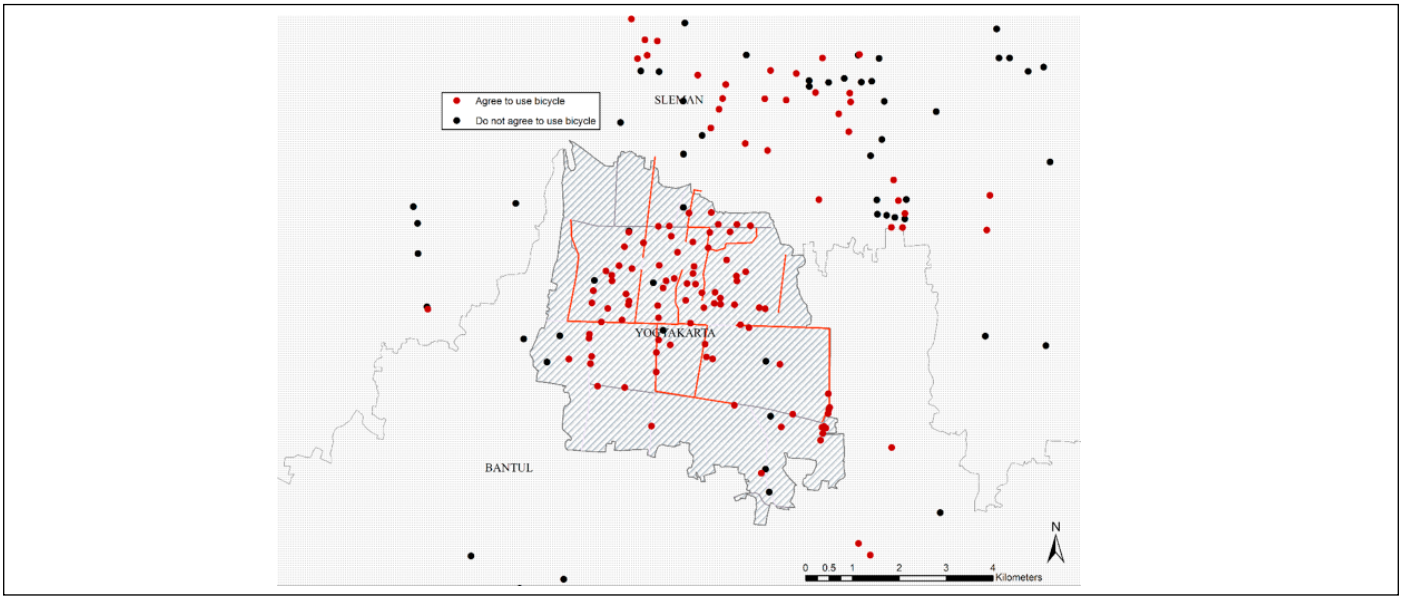

Figure 1. Distribution of Points of Origin for User Trips

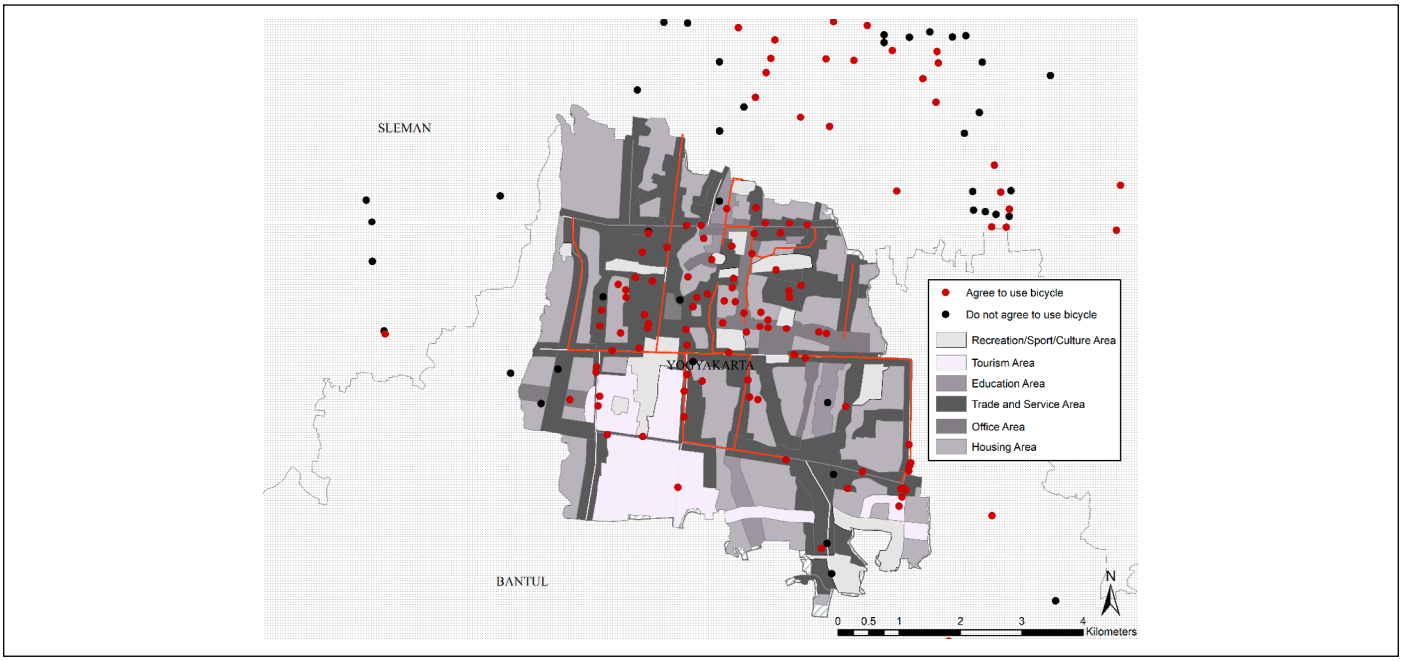

Figure 2. Yogyakarta Land Use.

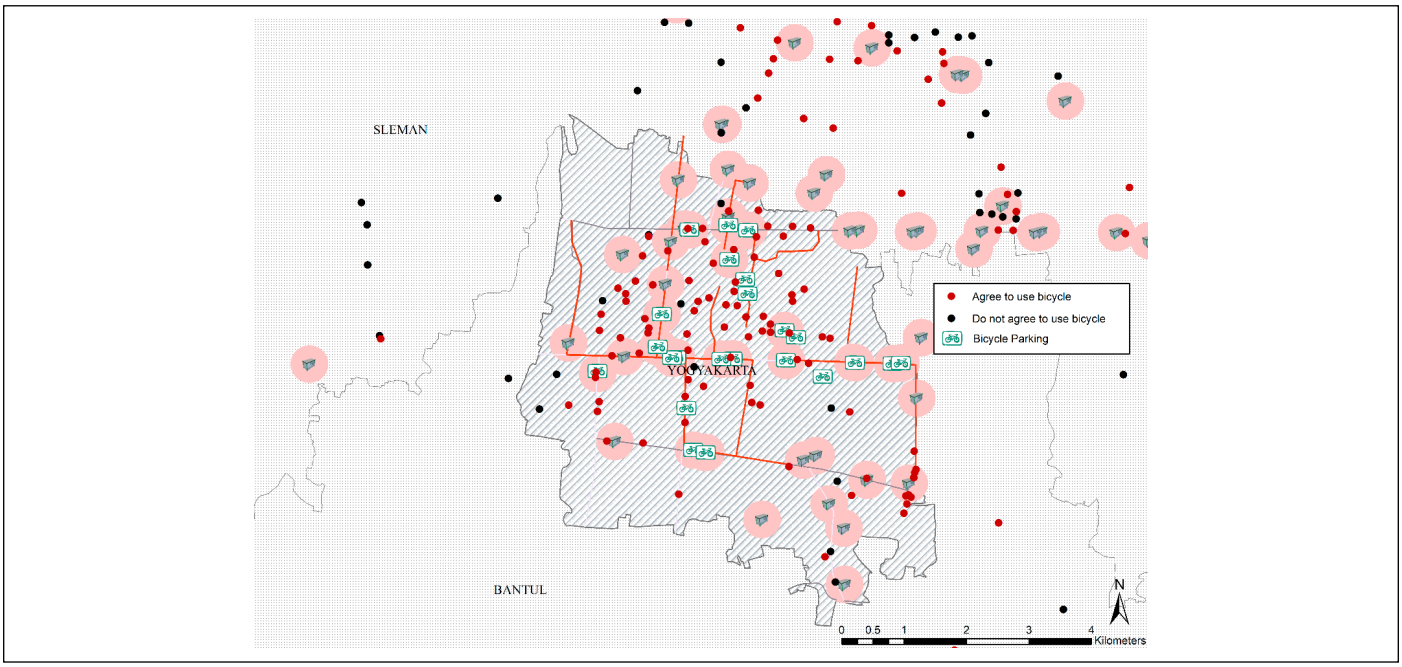

Figure 3. Bicycle Parking Locations

Research conducted by Rakhmatulloh, Dewi, & Nugraheni (2021) shows that usually the area has the highest balance because it is a function of the area that combines residential land with trade and services. This is supported by the fact that trade and services in Yogyakarta are mostly household-based. If seen based on observations of the point of origin of the user's trips, most of them come from the outskirts to outside the city of Yogyakarta. In contrast, for the origin of trips from within the city, most of the users come from the use of land for trade and services, and housing. This shows that trade and service land use have a high level of mobility, both as a source of travel and trade and service activities. Based on this fact, it was found that the highest mobility was assessed from the origin of the journey of users from commercial and service land uses. In this case, land use in Yogyakarta is not purely trading, service, or settlement activities. Communities tend to build houses in shophouses, resulting in a duality of land functions, namely residential and commercial areas.

4.5 Bicycle Facilities

Then we also see whether there is a relationship between the willingness to use bicycles and the availability of bicycle facilities. Figure 3 shows that users willing to use bicycles are mostly scattered at points with bicycle facilities such as bicycle parking. Most of these points are within reach of the nearest bus stop with a radius of less than 300 meters, according to travel guidelines for getting to the nearest bus stop. In this case, when traveling, the location of origin encourages using bicycles as a mode of transportation. The location of origin is within the city and is on land use with high mobility, which encourages bicycle use. In addition, the existence of bicycle facilities also has an important influence in encouraging the use of bicycles; this can be seen in the locations where the facilities are placed at the points where users originate. In addition, the bicycle facility point has also reached public transportation with a radius of 300 meters. This makes it easier for users to shift

in mode use to encourage the use of bicycles with public transportation (BRT).

5. DISCUSSION

This section delves into a more detailed discussion of the factors that encourage bicycle use in Yogyakarta. We'll begin by examining user characteristics based on the processed questionnaire results (Table 2). Users who express a willingness to use bicycles as a mode of transportation typically fall into the following categories: they are under 30 years old, male, students or individuals with below-average incomes, and they own motorized vehicles like motorcycles and bicycles. Moving on to the characteristics of user trips, we find that users predominantly travel for work and school purposes. Their average distance from their starting point to the nearest bus stop is less than 1 kilometer, and they often complete this first leg of their journey by walking. We proceed to analyze this frequently occurring data using a logistic model to uncover factors that positively influence the desire to use a bicycle. The results of this model indicate that user age, gender, vehicle ownership, first mile and travel purpose most significant roles in shaping this decision. Specifically, individuals under the age of 30 and males show a higher inclination to use bicycles as their mode of transportation. Moreover, those without personal vehicles or owning four-wheeled vehicles are more likely to express a desire to use bicycles. Notably, young users under 30 years old, often students or private workers, exhibit a strong tendency towards bicycle use. In terms of income, employment and distance traveled, users with low income have a fairly low desire to use a bicycle. This is in line with research by Zhao, Li, Li, Liu, & Long (2018) which states that compared to usage costs, users prioritize performance comfort and accessibility when using a bicycle. This shows that there is a similarity of opinion among the public in determining the use of transportation. In this study, for people with low income groups, had minimal correlation in choosing the use of a vehicle.

Furthermore, we identify user travel characteristics, particularly the first-mile mode and the purpose of the trip. This category of users commonly commutes by walking from their point of origin to the nearest bus stop for purposes unrelated to work or school. Users who choose to walk to their stop typically cover distances of less than 1 kilometer. This makes sense because the average travel distance for users to reach public transportation is around 300 meters (Rakhmatulloh, et al., 2021). This result is also in line with research by Zhu (2022) that most bicycle trips are short-distance trips with Euclidean distances of less than 1 km. Previous research also stated that the maximum distance covered when using a bicycle is three kilometers (Meng, 2019). However, some users opt for walking even when the distance is greater, possibly combining walking with other modes such as city buses, rickshaws, or trams to reach the BRT. This suggests that they engage in multimodal trips, often traveling from outside the city to the city center.

These results indicate that users with the aforementioned profiles are key drivers for the increased adoption of bicycle use. They are typically concentrated in educational and trade/service areas. Therefore, it's crucial to conduct awareness campaigns and promote bicycle usage at educational hubs within Yogyakarta, given the city's reputation as an education center. A bicycle use campaign in support of a low-carbon transformation is feasible, considering that educational area users are more likely to grasp the importance of such programs. Additionally, the placement of bicycle shelters in educational areas can further facilitate bicycle usage, given the high willingness among respondents to adopt bicycles as a mode of transportation.

In addition to internal factors linked to user characteristics and trip specifics, we've identified external factors that are vital for the success of bicycle usage in Yogyakarta, namely land use and infrastructure provisions. Our analysis shows that besides city residents, there are also many users from outside the city, with trip origins primarily in trade and service areas, office districts, and educational zones. This indicates that bicycle users are often clustered in areas with diverse land uses, aligning with previous research that underscores the importance of mixed land uses in promoting cycling (Pucher, & Buehler, 2006). Furthermore, we assessed the availability of bicycle parking facilities in the area and found that while bicycle parking is widespread, some facilities are classified as basic (and not well-maintained). This highlights the need for proper monitoring, as even when facilities exist, their effectiveness can be compromised without adequate maintenance. A pleasant environment is another factor influencing satisfaction with bicycle use (Gebhart & Noland, 2014), and the location of bicycle parking can significantly impact users' choices (Yang, et al., 2015). Moreover, previous research that expanding bicycle lanes and reducing road intersections can encourage bicycle commuting (El-Assi, et al., 2017).

These findings reveal several opportunities for implementing transportation transformation towards a low-carbon city. Previous research (Li, Xiao, Zhang, & Ji, 2021) has discussed three other factors that encourage bicycle use, one of which is related to the geographic environment. The results show that cities with slopes of less than two degrees positively encourage bicycle use. Besides user preferences and infrastructure availability, geographical factors, such as Yogyakarta's flat topography, can further support bicycle usage. The city's slope range of 0-2 % is conducive to cycling, presenting an additional opportunity for promoting bicycle use.

The current bicycle use system offers convenience and significant benefits for the social and environmental environment of its users. The use of bicycles promises to reduce greenhouse gas emissions (Shaheen, Guzman, & Zhang, 2010) minimize air pollution and car use (Fishman, Washington, & Haworth, 2014), reduce traffic congestion (Fan, & Zheng, 2020) and regular bicycle use can improve users health (Otero, Nieuwenhuijsen, & Rojas-Rueda, 2018). Given the growing congestion and declining air quality in Yogyakarta, this transformation is increasingly imperative. It serves not only commercial purposes but also raises public awareness about the importance of environmental conservation. Additionally, regular bicycle use can improve users' health.

6. CONCLUSION

These findings underscore the significance of user characteristics in determining the propensity to use bicycles as a mode of transportation. These users understand them into several groups and have different characteristics. In particular, users who have a high desire to use bicycles have special characteristics with a tendency to belong to the young age group and travel by walking as their first mode. Conversely, when examining external factors influencing bicycle usage, we observe a desire for bicycle adoption in trade and service areas, driven by the presence of bicycle parking facilities. This second finding highlights that certain regions, notably educational and trade and service hubs, exhibit a high propensity for bicycle usage. Given Yogyakarta's status as a prominent educational hub with institutions of international repute, targeting bicycle usage as a transportation mode in areas aligning with user characteristics holds great promise.

Considering these observations, we propose several recommendations to support the transition to bicycle usage within the context of low-carbon cities:

1. Outreach and Awareness Campaigns: Initiatives aimed at reminding the public of the significance of bicycle usage in building a low-carbon city should be prioritized. These efforts should primarily target educational institutions and trade and service sectors, given their emergence as focal points for bicycle usage interest, both among users and in terms of infrastructure availability. Furthermore, individuals with reservations about adopting bicycles should be educated about the advantages of transitioning to low-carbon transportation.
2. Active Facilitation of Bicycle Usage: Encouraging bicycle adoption necessitates the provision of knowledge and information underscoring its importance. This can be accomplished through the establishment of bicycle shelters in critical areas such as educational campuses and commercial zones.
3. Expansion of Bicycle Facilities: To promote widespread bicycle adoption, the expansion of bicycle facilities throughout urban areas is essential. This expansion should cater to users from areas outside the city. Implementation of a bike-sharing system or integration between motor vehicle, bus, and bicycle rental users can help achieve this goal. The incorporation of GPS-based technology can enhance safety and service by tracking shared bicycles.
4. Integration of Public Transport and Bicycles: Enhancing collaboration between bicycle usage and public transportation can address concerns related to longer travel distances. This includes the enlargement of bicycle parking areas, especially at public transport stops, and the augmentation of their capacity. Additionally, facilitating bike-sharing programs, particularly in areas with inadequate facilities, is crucial.

The findings and insights from this journal underline the significance of promoting bicycle use as an integral part of sustainable transportation development. Considering the environmental benefits and the potential to enhance public health, it is highly recommended that communities and transportation authorities embrace a collaborative approach. This approach should prioritize the active involvement of the local community, considering their unique socio-cultural conditions and respecting their voices.

For successful implementation, it is crucial to conduct surveys and engage with the primary stakeholders, particularly bicycle users and public transportation users. These surveys can help identify varying perspectives and opinions, offering a comprehensive view of the community's needs and concerns. Initiatives should be designed with the goal of ensuring a shared understanding between the authorities and the community.

Moreover, this research highlights the importance of tailoring programs to align with local culture, especially in regions with strong cultural characteristics like Yogyakarta. Instead of imposing generic global programs, a more effective strategy would be to develop initiatives that resonate with the local culture and customs.

Furthermore, this recommendation suggests expanding research efforts to encompass additional variables, such as road safety and cultural factors. Road safety variables should be considered globally, while unique cultural variables should be explored in regions like Yogyakarta. These insights can provide a more comprehensive foundation for enhancing bicycle use worldwide and within specific cultural contexts.

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