

Evaluation of the Operational Effectiveness and Services of Bus Rapid Transit (BRT) in Mamminasata Metropolitan Area (MMA), South Sulawesi, Indonesia

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ABSTRACT

Rapid urbanization has increased the demand for efficient transportation systems in Indonesian cities, including the Mamminasata Metropolitan Area (MMA). To address persistent congestion, the government implemented the Bus Rapid Transit (BRT) system under the Buy The Service (BTS) scheme. This study investigates the characteristics of Corridors I and II users, analyzes mode choice behavior using a conditional logit model, and conducts sensitivity testing. A quantitative survey of 250 respondents revealed that reductions in travel time and cost significantly increased BRT usage likelihood, with an estimated modal shift of 14.19% from private cars to BRT. The mode preference rates reached 63.38% (Corridor I) and 88.96% (Corridor II). These findings underscore the role of the BRT system in fostering sustainable urban mobility.

Keywords-*effectiveness; bus rapid transit; public transportation; Mamminasata*

I. INTRODUCTION

Transportation refers to the movement of people and goods from one location to another. A well-developed transportation system enables various human needs to be fulfilled efficiently and effectively [1, 2]. In this context, public service involves assisting others in ways that require sensitivity and interpersonal engagement to ensure satisfaction and successful outcomes. Transportation is a crucial element of the daily life that supports human interaction and facilitates the movement of goods across different areas [3]. Smooth mobility is a significant factor in transportation service delivery, as it helps to prevent severe traffic congestion. The Mamminasata

Metropolitan Area (MMA) is a strategic region connecting suburban and urban areas. Severe traffic congestion has frequently occurred, particularly at access points leading to the MMA, with an average travel speed of only 9.4 km/h. This situation is further exacerbated by damaged road segments, which diminish road service performance, along with the dominance of private vehicle usage and the absence of public transportation services [4].

The Indonesian government has undertaken efforts to reform the public transportation sector by promoting a modal shift from private to public transit, primarily through the development of Bus Rapid Transit (BRT) systems under the

Buy The Service (BTS) scheme. In 2020, the Ministry of Transportation initiated the implementation of public transport services in MMA with free-of-charge services at first [5]. Existing studies on BRT services have mainly focused on evaluating operational performance, emphasizing improvements in service quality through enhanced infrastructure and the adoption of digital technologies [6]. In addition to improving public transport quality, BRT systems enhance road performance and play a significant role in mitigating traffic congestion [7].

While assessing the effectiveness of BRT services in the MMA, it is essential to move beyond operational metrics and consider demand forecasting, particularly a mode choice behavior from the users' perspective. Despite its importance, empirical studies examining BRT as an alternative within mode choice frameworks remain limited. Mode choice analysis is a significant component of transportation planning and policy development, as it reflects the preferences of travelers among a variety of available transport options [8].

The MMA, with Makassar as its urban core, serves as the primary center for governance, economy, and socio-cultural activities in the South Sulawesi Province. Its high population density and strategic location underscore the importance of understanding user preferences, especially regarding public transport, in order to inform accurate demand forecasting and support sustainable urban mobility. The concentration of urban functions has led to increased travel activity and a high degree of population mobility within and around the metropolitan area [9]. However, to support the mobility that connects the suburban area and Transit Oriented Development (TOD) area, the existence of BRT and the effectiveness of services are crucial for sustainable transport services.

At the initial stages of implementing public transportation services in MMA, the Ministry of Transportation, in collaboration with local transportation authorities, introduced the Trans Mamminasata Bus system. This BRT service connects the core city of Makassar with the surrounding regions, including the regencies of Maros, Gowa (Sungguminasa), and Takalar. Since the fare policy was officially enforced on November 14, 2021, the BRT system has been operating along two primary corridors: Corridor I, which connects Panakukang Mall to Galesong (Takalar Regency), and Corridor II, which runs between Panakukang Mall and Sultan Hasanuddin International Airport (near Maros Regency). A total of 87 buses were deployed across these routes. The operation of the BRT has expanded the available mode choices beyond the informal paratransit services that have long dominated the Mamminasata area [10, 11]. For both Corridors I and II, travelers now have access to various transport modes, including BRT buses, ride-hailing services, and private modes (cars and motorcycles). The level of user satisfaction associated with each mode is subject to change over time, mainly due to shifts in travel mode characteristics. For example, fluctuations

in travel costs, such as those resulting from fuel price increase, can significantly influence individual mode choice decisions [12, 13]. These dynamic characteristics serve as indirect indicators of each mode's effectiveness within the broader urban mobility system.

Research on travel behavior in relation to demand forecasting for the Mamminasata's BRT system remains limited. Evaluating BRT performance from the user's perspective, particularly in terms of mode choice, requires an understanding of the conditions, characteristics, and reliability of the available transport modes [14-16]. The present study aims to estimate travel demand based on user behavior and to assess its influence on mode preference. Specifically, it examines the probability of selecting BRT over other modes of transportation. A sensitivity analysis was employed to forecast changes in demand and user preferences in response to variations in key travel attributes.

The findings of this study are expected to provide valuable insights for policymakers and stakeholders, particularly in promoting the sustainability of public transportation and addressing congestion issues caused by the high dependence on private modes in the Mamminasata area [17].

II. METHODOLOGY

A. Research Framework

The research framework is presented in Figure 1, showing the research stages followed in this study: preliminary studies, preparation stages, data collection, data analysis, and modeling stages. The Conditional Logit Model (CLM) was employed to analyze mode choice behavior, as it offers methodological advantages over standard logit models, such as the Multinomial Logit Model (MNL). One key advantage of the CLM lies in its ability to incorporate alternative-specific attributes as explanatory variables [18]. In contrast to the MNL, which uses only individual-specific variables that remain constant across alternatives, the CLM enables the inclusion of variables that vary across alternatives, such as travel time, cost, comfort, and accessibility, allowing for a more precise estimation of the influence of these attributes on individual choices.

The model assumes that the utility of each alternative is a function of its specific attributes, making it ideal for transportation studies where each mode presents different service levels. By capturing the trade-offs users make between competing alternatives, the CLM provides richer behavioral insights into mode preference.

Furthermore, CLM structure allows for conducting a sensitivity analysis to simulate changes in mode-specific attributes and observe their effects on the probability of choice. This feature enhances its applicability for policy evaluation and demand forecasting, especially in assessing the potential impacts of fare adjustments or service improvements on modal shifts.

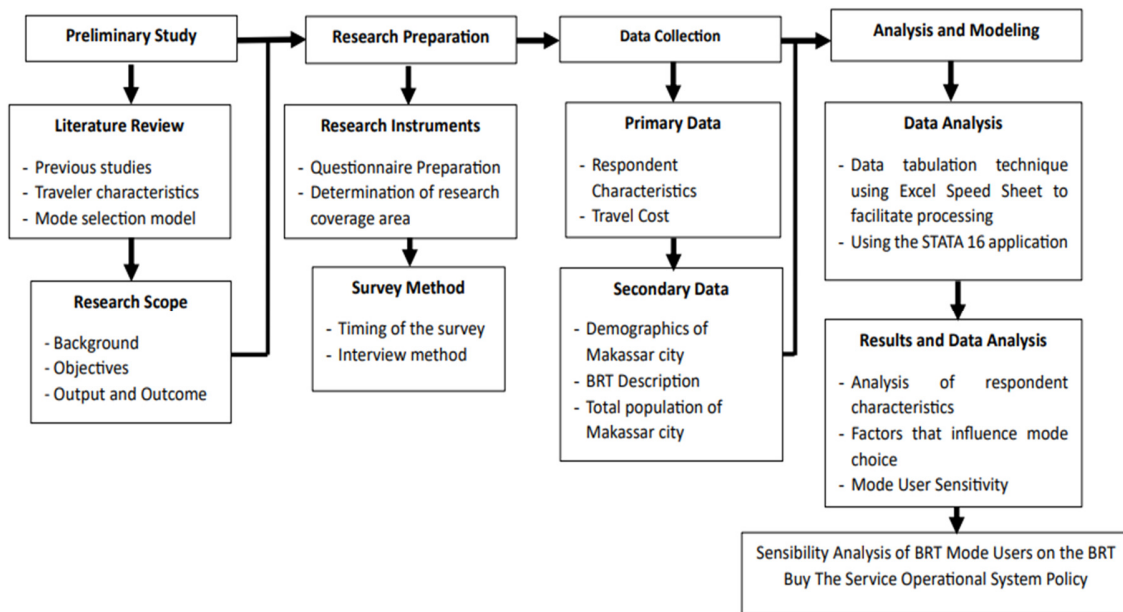


Fig. 1. Research flow.

B. Study Area

This study focuses on the MMA, which administratively comprises Makassar City, Maros Regency, Gowa Regency, and Takalar Regency. Data collection was carried out through the random distribution of questionnaires, targeting users of the Mamminasata BRT system. Sampling was conducted not only at designated bus stops, which directly capture active users, but also within residential areas located in proximity to the BRT service routes, in order to include potential users and capture a broader range of travel behavior. As part of the research preparation stage, preliminary interviews were conducted to gain a contextual understanding of user characteristics and travel behavior related to the BRT service. The primary purpose of these interviews was to identify the key factors influencing mode choice and to develop a more structured survey instrument. The interviews were designed to explore the users' perceptions of travel time, cost, service reliability, and accessibility.

Respondents were selected using a random sampling technique, targeting individuals residing in neighborhoods near bus stops and Transit-Oriented Development (TOD) terminal areas along BRT corridors. This approach ensured the inclusion of actual and potential BRT users, thereby capturing a representative range of travel experiences and preferences of the respondents. Interviews were conducted in residential zones surrounding major BRT access points, allowing for direct engagement with participants familiar with the service environment.

The insights obtained from the interviews played a significant role in refining the research design, particularly in formulating relevant survey questions and determining the appropriate model variables. Moreover, the interview results helped validate the assumptions regarding user sensitivity to travel time and cost, which were subsequently tested through quantitative analysis using CLM.

C. Data Collection and Data Sources

The data collected were categorized as primary and secondary:

1) Primary Data

Primary data refer to information collected directly by researchers for the specific purpose of addressing/to address the research problem. Primary data were obtained through the offline distribution of questionnaires, conducted by visiting both residential areas and locations served by the BRT system (Tables I and II). Face-to-face interviews were conducted with respondents using a set of pre-structured questions designed to align with the objectives of the study. The questionnaire focused on collecting data related to socio-demographic characteristics, travel preferences, and travel behavior.

2) Secondary Data

Secondary data were obtained or collected by researchers from various existing sources/data obtained indirectly. Secondary data include the spatial plan, land use, traffic and road performance in MMA, the satisfaction of the operational of BRT, the infrastructure service from authorities' reports, and documentation from the ministry and transportation authorities.

D. Types of Variables

1) Independent Variables

The independent variables were based on BRT user characteristics (individual characteristics), trip characteristics, and sociodemographic characteristics. The independent variables used are displayed in Table III. As exhibited in Table III, the questionnaire was designed based on the Stated Preference (SP) approach. The dataset comprises both alternative-specific independent variables and case-specific independent variables, in accordance with the data structure requirements for analysis using the CLM in the STATA statistical software environment.

TABLE I. QUESTIONNAIRE OF THE RESPONDENTS' CHARACTERISTICS AND TRAVEL PREFERENCES

No	Characteristics of respondents	Category characteristic
1	Gender?	a. Male b. Women
2	Age?	a. 20–30 Years b. 31–40 years old c. 41–50 Years d. 51–60 years e. 61–70 Years
3	What was your last education?	a.Elementary school, b. Junior high school, c. High school, d. Diploma, e. Bachelor, f. Postgraduate
4	What is your average monthly income? (IDR)	a. < 1,500,000 - 7,500,00 b. 1,500,001 – 3,000,000 c. 3,000,001 – 5,000,000 d. 5,000,001 – 7,500,000 e. > 7,500,000
5	Your job?	a. Civil servant/State-owned enterprise b. TNI/POLRI c. Teacher/Lecturer d. Entrepreneur e. Private employee f. Other
6	What is your marital status?	a. Not married (single) b. Married c. Widow/Widower
7	How many times do you travel in a month?	a. 1x b. 2x c. 3x d. 4x e. 5x f. 6x / 7x
8	What is your purpose for traveling?	a. Work/business trip/school/campus b. Visiting family/relatives Others:..... c. Recreation d.
No	Characteristics of travel	Category characteristic
1	Do you have a private vehicle?	a. Yes b. No
2	Travel companion?	a. Brother b. Family members c. Alone d. Friends e. Cowokers/Colleagues
3	How often do you travel?	a. Every day b. Several days a week c. On weekdays only d. On weekends e. Other
4	What modes of transportation do you use besides private vehicles?	a. Public transportation b. Taxi/Motorcycle taxi c. Employee bus d. Others
5	How often do you use other transportation?	a. Every day b. Several days a week c. On weekdays only d. On weekends e. Others
6	What is the main mode of transportation used in your family?	a. Car b. Motorcycle c. Bicycle d. Walking e. Others
7	How much do you spend on transportation per month? (IDR)	a. < 500,000 b. 500,001 - 750,000 c. 750,001 - 1,000,000 d. 1,000,001 - 2,500,000 e. > 2,500,000

TABLE II. QUESTIONNAIRE OF THE STATED PREFERENCES METHOD

No	Travel cost (IDR)		Travel time (min)		Travell frequency (times/h)		Choice
	BRT	Car	BRT	Car	Travel frequency (Times/hour)	Car availability	
1	4.6	50	1 h 10 min	1 h 30 min	2	At all times	
2	4.6	50	1 h 10 min	1 h 30 min	5	At all times	
3	4.6	50	1 h 40 min	1 h 30 min	2	At all times	
4	4.6	50	1 h 40 min	1 h 30 min	5	At all times	
5	50	50	1 h 10 min	1 h 30 min	2	At all times	
6	50	50	1 h 10 min	1 h 30 min	5	At all times	
7	50	50	1 h 40 min	1 h 30 min	2	At all times	
8	50	50	1 h 40 min	1 h 30 min	5	At all times	

TABLE III. LIST OF INDEPENDENT VARIABLES

No	Independent variables	Symbol
	Alternative specific independent variables	
1	Travel cost attribute [19]	X ₁
2	Travel time attribute [19]	X ₂
Case-specific independent variables		
3	Age [20]	X ₃
4	Trip frequency [21]	X ₄
5	Number of car vehicles [20]	X ₅
6	Number of motorcycle vehicles [20]	X ₆
7	Family size [20]	X ₇
8	Daily activity [22]	X ₈
9	Trip purpose [21]	X ₉
10	Employment status [20]	X ₁₀
11	Educational background [20]	X ₁₁
12	Income in Indonesian Rupiah (IDR) [20]	X ₁₂

2) Dependent Variables

The dependent variables used in this study include the existing private mode (cars) and the BRT mode, which is considered an alternative. The selection of these mode dependent variables was based on the results of a preliminary survey. Respondents were selected based on their experience using the BRT system repeatedly, indicating their familiarity

with the service. Consequently, the analysis focused on individuals who were considered potential users of BRT, thereby allowing for a realistic assessment of their mode choice behavior when presented with alternative transport options.

3) Sampling Method

The sampling process began with determining the total number of respondents using a quota sampling technique. The total sample size was derived based on information obtained from a preliminary survey. In cases where the population size (n) was unknown, the minimum required sample size was calculated using the formula proposed by Lemeshow:

$$n = \frac{Z^2 \alpha / 2 \cdot p \cdot q}{d^2} = \frac{1.96^2 \cdot 0.5 \cdot (1 - 0.5)}{0.05^2} \approx 385 \tag{1}$$

where n is the minimum number of samples/respondents, $z^2 \alpha / 2$ is the standard value (degree of freedom)², p is the probability, which is 0.5 (maximum estimate for unknown data), q = 1-p = 1-0.5 = 0.5, and d is the tolerable error (determined) = 0.05.

III. RESULTS AND DISCUSSION

The characteristics of the respondents traveling along Corridors I and II were analyzed based on several socio-demographic and travel-related variables. These included

gender, age, travel frequency, trip purpose, daily activities, travel companions, number of family members, level of education, and monthly income.

A. Characteristics of Users on Corridors I and II

1) Corridor I: Age

As illustrated in Figure 2, the age profile of people using Corridor I (N = 250) is dominated by the 31–40 age group, which accounts for 49.6% of the total respondents. This is followed by the younger demographic group of 18–30 years at 40.8%. In contrast, older age groups represent a much smaller portion of the sample, with only 7.2% in the 41–50 range and 2.4% in the 51–60 range.

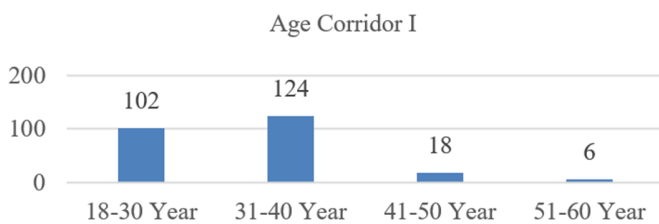


Fig. 2. Age characteristics of Corridor I users.

2) Corridor II: Age

As depicted in Figure 3, in Corridor II (N = 250), the 31–40 age group is the majority (55.6%). However, unlike Corridor I, the second-largest group consists of older individuals aged 41–50 years, representing 23.2% of the respondents. The younger 18–30 age group accounts for 18.8%, while the 51–60 age category remains the smallest at 2.4%.

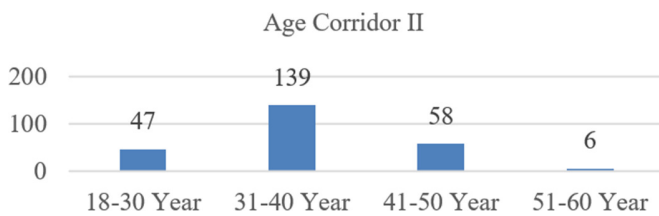


Fig. 3. Age characteristics of Corridor II users.

3) Educational Background of Corridor I Users

Figure 4 shows that the educational profile of the respondents using Corridor I is prominently led by those with a Bachelor (S1) degree, accounting for 53.6% of the sample. The second-largest group consists of individuals with a Senior High School (SHS) education at 25.2%, followed by Diploma (D3) holders at 16.4%. Lower educational levels, including Elementary and Junior High School (ES and JHS, respectively), represent a minority with a total of 3.2%, while Master's (S2) graduates constitute the smallest segment at 1.6%. This indicates that more than half of the potential commuters in this corridor are highly educated professionals or students.

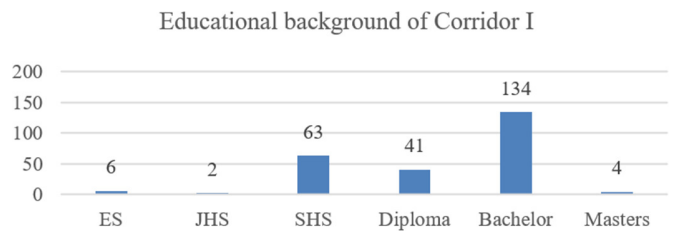


Fig. 4. Educational background of Corridor I users.

4) Educational Background of Corridor II Users

Figure 5 displays the educational background of Corridor II respondents and reveals an even stronger concentration of highly educated individuals compared to Corridor I. Respondents with a Bachelor (S1) degree are the majority, accounting for 66.4% of the total. This is followed by those with an SHS education (18.4 %) and Diploma (D3) holders (9.2 %). Master's degree graduates represent 2.8% of the sample, while basic educational levels, including ES and JHS, account for a combined 3.2%. These results indicate a highly educated user base, which is a critical factor in understanding the mode choice preferences within this specific corridor.

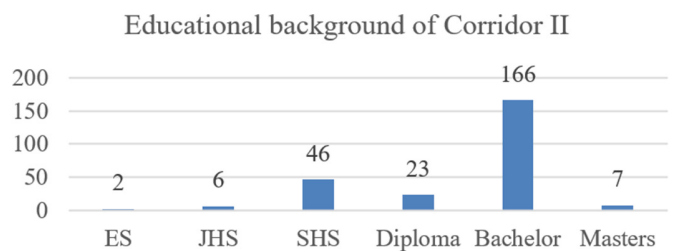


Fig. 5. Educational background of Corridor II users.

B. Analytical and Modeling Approach

The analytical framework of this study was structured into a multi-stage econometric evaluation, beginning with a granular segmented estimation of utility parameters across two primary transit corridors. In the initial phase, CLMs were deployed to examine mode-choice preferences by categorizing respondents into key socio-economic cohorts: educational background, age groups, and occupational types. By isolating these segments for both Corridors I and II, the model captures the heterogeneity in sensitivity to alternative-specific attributes, such as travel cost (X₁) and travel time (X₂), as well as case-specific characteristics (X₃-X₁₂). This study focused on respondents with higher education backgrounds (Diploma, Bachelor, and Master's), and the age cluster above 28 years is justified by the need to capture the preferences of primary decision-makers in urban mobility. These groups represent the most economically active demographic with stable commuting patterns and higher access to private vehicles, making them a significant target for modal shift interventions. Furthermore, focusing on these clusters ensures statistical robustness, as they constitute the majority of the sampled population in both corridors, thereby providing more reliable estimates of the mode choice model.

Within this framework, the Alternative-Specific Constant (ASC) for the car alternative is represented by the intercept (cons) in the model estimation, with BRT serving as the

reference base category. This approach allows the model to capture the inherent preference for private cars, which is not only explained by travel time or cost alone, but also by the socio-demographic characteristics specific to the conditions of each preference mode choice for capturing travel behavior. The utility functions (V) for the two alternatives in the MMA are expressed as:

$$V_{BRT} = \beta_1 X_1 + \beta_2 X_2 \quad (1)$$

$$V_{Car} = ASC_{Car} + \beta_1 X_1 + \beta_2 X_2 + \sum_{k=3}^{12} Y_k X_k \quad (2)$$

where V_{BRT} and V_{Car} are the systematic utilities of choosing BRT and private cars, respectively. The ASC_{Car} is the alternative specific constant for the car (relative to BRT), represented by the const in the STATA output. Moreover, β_1 and β_2 are the estimated coefficients for the alternative-specific attributes, and Y_k is the estimated coefficient for the case-specific characteristics.

Following the segmented parameter estimation, the study transitions into an integrated mode choice probability assessment. This phase synthesizes the empirical coefficients from the previous steps to calculate the mathematical likelihood that commuters choose BRT over private cars. By aggregating the utility functions across the operational landscape, the model provides a quantitative benchmark for the current market share of the Mamminasata's BRT system.

The final stage involves a robust sensitivity analysis to assess the service's operational effectiveness and future resilience. By systematically varying travel time and travel cost levels, the framework simulates policy scenarios to identify the critical thresholds that trigger a modal shift. This elasticity testing reveals how improvements in transit efficiency or fare restructuring influence the perceived utility of BRT relative to private cars. Ultimately, this comprehensive analytical sequence provides a review as an evidence base for optimizing transit service delivery and fostering sustainable urban mobility in South Sulawesi province and in MMA.

The total sample consisted of 250 respondents. However, for the segment-specific analysis (clustering by age, education, and employment), only respondents belonging to each respective cluster were included. In the CLM framework, the total number of observation samples (N) is defined as the total number of samples in the cluster multiplied by the number of alternatives.

C. Mode Choice Preference Estimation Between BRT and Car

The survey data obtained through the SP method were analyzed using a conditional logit choice model in STATA 16. To determine the appropriate mode choice model, the statistical significance and overall model fit were evaluated, particularly using the chi-squared probability value (Prob > Chi²).

1) Mode Choice Preference Model Between BRT and Car Based on Type of Educational Background at a Higher Education Level for Corridors I and II

Table IV illustrates the model of preference for choosing a transportation mode between BRT and cars based on the type

of higher education level. The travel cost variable produced a negative coefficient of -0.00027 with high statistical significance (P = 0.000), confirming that financial expenditure is a determinant factor in mode choice.

Additionally, travel time shows a statistically significant influence (0.173, P = 0.036), suggesting that temporal efficiency is a prioritized factor for this demographic. Regarding the respondents' characteristics, the number of vehicles is statistically significant (P = 0.013) with a negative coefficient of -0.596. The ASC (cons) of 2.848 reflects a baseline preference for private car usage not captured by cost and time, with marginal significance (P = 0.086). The model is based on 358 observations from 179 individual respondents (each facing 2 alternatives), with a Prob > chi² value of 0.0000.

TABLE IV. ESTIMATION RESULTS OF THE MODE CHOICE PREFERENCE MODEL FOR EDUCATIONAL BACKGROUND OF CORRIDOR I

Set selection Variable	Type of educational degree level	
	Coef.	P> Z
Independent		
Travel cost (X ₁)	-0.00027	0.000
Travel time (X ₂)	0.173236	0.036
Base category	BRT	
Category	Car	
Variable	Coef.	P> Z
Independent		
Age	0.003543	0.911
Number of vehicles (Cars)	-0.5962	0.013*
Income dummy	0.000105	0.572
Expenditure dummy	0.000536	0.598
Trip purpose	-0.72321	0.113
Trip frequency	0.554231	0.295
cons	2.848311	0.086
Prob > chi ²	0.0000	
Number of observations	358	

Note : * Significance level more than 95%.

Table V demonstrates the model of preference for choosing a transportation mode between BRT and cars based on the higher education level in Corridor II. The travel cost variable produced a negative coefficient of -0.0000851 with high statistical significance (P=0.000), indicating that financial expenditure is a determinant factor in mode choice. Moreover, travel time shows a statistically significant influence (-0.0432372, P=0.013), indicating that temporal efficiency is a prioritized factor for this demographic. However, the cons value of 2.839258 reflects a baseline preference for private car usage not captured by cost and time, with a statistical significance of P=0.015. Following the estimation procedures for each respondent facing two alternative conditions, a total of 196 respondents were represented by 392 observations. This is also a similar way to project the estimation results based on the mode choice preference and the age and employment status of the model.

2) Mode Choice Preference Model Between BRT and Car Based on Age for Corridor I and Corridor II

Table VI presents the model of preference for choosing a transportation mode between BRT and cars for respondents aged above 28 years in Corridor I. The travel cost has a negative coefficient with statistical significance (P=0.000),

indicating that financial expenditure is a determinant factor in the travel mode choice. In addition, travel time showed a significant influence ($P=0.012$), indicating that temporal efficiency is a prioritized factor for this age group. Regarding respondents' characteristics, the educational background is statistically significant ($P=0.025$) with a negative coefficient of -0.097463 . The model is based on 402 observations from 201 individual respondents (each facing 2 alternatives), with a Prob > χ^2 value of 0.006.

TABLE V. ESTIMATION RESULTS OF THE MODE CHOICE PREFERENCE MODEL FOR BACKGROUND EDUCATIONAL ON HIGHER EDUCATION OF CORRIDOR II

Set selection	Type of educational degree level	
Variable	Coef.	P> Z
Independent		
Travel cost (X_1)	-0.0000851	0.000
Travel time (X_2)	-0.0432372	0.013
Base category	BRT	
Category	Car	
Variable	Coef.	P> Z
Independent		
Age	-0.0379593	0.192
Number of vehicles (Cars)	-0.4844309	0.121
Income dummy	0.0000251	0.829
Expenditure dummy	-0.002232	0.029*
Trip purpose	-0.0022837	0.573
Trip frequency	0.4438784	0.353
cons	2.839258	0.015
Prob > χ^2	0.0000	
Number of observations	392	

Note: * Significance level more than 95%.

TABLE VI. ESTIMATION RESULTS OF MODE CHOICE PREFERENCE BASED ON AGE ABOVE 28 YEARS CORRIDOR I

Set selection	Age above 28 years	
Variable	Coef.	P> Z
Independent		
Travel cost (X_1)	-0.0002594	0.000
Travel time (X_2)	0.1918132	0.012
Base category	BRT	
Category	Car	
Variable	Coef.	P> Z
Independent		
Educational background	-0.9746365	0.025*
Number of vehicles (Cars)	-0.3128551	0.398
Income dummy	0.0000386	0.843
Expenditure dummy	0.0003112	0.765
Trip purpose	-0.736963	0.098
Trip frequency	-0.2017146	0.665
cons	3.759444	0.006
Prob > χ^2	0.0000	
Number of observations	402	

Note: * Significance level more than 95%.

Based on the results shown in Table VII, the model of preference for choosing a transportation mode between BRT and car based on the age group shows that the travel cost has a negative coefficient with statistical significance of $P=0.000$. Moreover, travel time has a statistically significant influence ($P = 0.015$). In addition, the expenditure is also statistically significant ($P=0.02$) with a negative coefficient of -0.0022076 . The model is based on 446 observations from 223 individual respondents with a Prob > χ^2 value of 0.0012.

TABLE VII. DATA ESTIMATION RESULTS OF THE MODE PREFERENCE MODEL BASED ON AGE ABOVE 28 YEARS CORRIDOR II

Set selection	Age above 28 years	
Variable	Coef.	P> Z
Independent		
Travel cost (X_1)	-0.0000688	0.000
Travel time (X_2)	-0.0390911	0.015
Base category	BRT	
Category	Car	
Variable	Coef.	P> Z
Independent		
Educational background	0.1761856	0.638
Number of vehicles (Cars)	-0.3610733	0.186
Income dummy	-0.0000189	0.843
Expenditure dummy	-0.0022076	0.02*
Trip purpose	0.2083313	0.523
Trip frequency	0.1733333	0.687
cons	1.869426	0.009
Prob > χ^2	0.0000	
Number of observations	446	

Note: * Significance level more than 95%.

3) Mode Choice Preference Model Between BRT and Car Based on Employment of Entrepreneur and Private Employee Corridors I and II

Table VIII presents the model of preference for choosing a transportation mode between BRT and cars for respondents working in the private sector and self-employment within Corridor I. The travel cost variable produced a negative coefficient of -0.0002838 with statistical significance ($P=0.000$), confirming that financial expenditure is a determinant factor in mode choice. Additionally, travel time shows a statistically significant influence (0.2051711 , $P=0.009$), suggesting that temporal efficiency is a prioritized factor for this employment group. Regarding respondents' characteristics, both educational background and trip purpose are statistically significant, with negative coefficients of -0.9379066 and -0.9914073 , respectively. The total employment for entrepreneurial and private is 398 observations from 199 individual respondents with a Prob > χ^2 value of 0.0000.

Table IX presents the model of preference for choosing a transportation mode between BRT and cars for respondents working in the private sector and self-employment within Corridor II. The travel cost variable produced a negative coefficient of -0.0000768 with statistical significance ($P=0.000$), confirming that financial expenditure is a determinant factor in mode choice. Additionally, travel time shows a statistically significant influence (-0.0348168 , $P=0.050$), suggesting that temporal efficiency is a prioritized factor for this employment group. Regarding respondents' characteristics, the number of vehicles, expenditure dummy, and trip frequency are statistically significant ($P=0.05$), with coefficients of -0.4623804 , -0.002159 , and 0.8915295 , respectively. The ASC of 2.506985 reflects a baseline preference for private car usage not captured by cost and time, with marginal significance ($P=0.051$). The total observations for self-employment and private sector jobs were 370 observations from 185 individual respondents, with a Prob > χ^2 value of 0.0002.

TABLE VIII. ESTIMATION OF MODE CHOICE PREFERENCE BASED ON ENTREPRENEURIAL AND PRIVATE EMPLOYEES CORRIDOR I

Set selection	Self-employment and private sector jobs	
Variable	Coef.	P> Z
Independent		
Travel cost (X ₁)	-0.0002838	0.000
Travel time (X ₂)	0.2051711	0.009
Base category	BRT	
Category	Car	
Variable	Coef.	P> Z
Independent		
Age	0.0069325	0.834
Educational background	-0.9379066	0.038*
Number of vehicles (Cars)	-0.4033075	0.302
Income dummy	-0.0000187	0.914
Expenditure dummy	-0.0005096	0.609
Trip purpose	-0.9914073	0.04*
Trip frequency	0.2532366	0.624
cons	4.832489	0.009
Prob > chi ²	0.0000	
Number of observations	398	

Note: * Significance level more than 95%.

TABLE IX. ESTIMATION OF MODE CHOICE PREFERENCE BASED ON ENTREPRENEURIAL AND PRIVATE EMPLOYEES, CORRIDOR II

Set selection	Self-employment and private sector jobs	
Variable	Coef.	P> Z
Independent		
Travel cost (X ₁)	-0.0000768	0.000
Travel time (X ₂)	-0.0348168	0.05
Base category	BRT	
Category	Car	
Variable	Coef.	P> Z
Independent		
Age	-0.0176619	0.544
Educational background	0.0955612	0.795
Number of vehicles (Cars)	-0.4623804	0.050*
Income dummy	0.0000387	0.739
Expenditure dummy	-0.002159	0.033*
Trip purpose	0.2850474	0.447
Trip frequency	0.8915295	0.05*
cons	2.506985	0.051
Prob > chi ²	0.0002	
Number of observations	370	

Note: * Significance level more than 95%.

The estimated results of the mode choice model based on stated preferences indicate that travel time and travel cost are statistically significant variables. However, the impact of these variables differs across Corridor I and Corridor II users. Specifically, the model reveals that a greater number of variables have a significant effect on users of Corridor I compared to those of Corridor II. For Corridor I, the influential factors are primarily related to sociodemographic characteristics, whereas for Corridor II, the significant effects are more closely associated with travel-related attributes.

D. Estimation of Mode Choice Probability BRT and Car

The probability of choosing a specific transportation mode in this study is derived from the utility function of the model. Each alternative's utility (V) is calculated based on the estimated parameters for travel attributes and respondent

characteristics, assuming that individuals select the option that maximizes their perceived utility.

Figure 6 indicates that most respondents in this group prefer BRT (55.59%) to car (44.41%). This tendency may be attributed to factors such as cost efficiency, ease of access, and a general preference for environmentally friendly modes of public transportation. These findings are consistent with the observations of [23], which reported that across four respondent travel characteristics, individuals tend to choose BRT due to lower travel costs and shorter travel time.

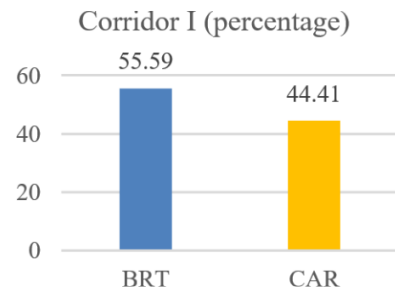


Fig. 6. Transportation mode choice probability between BRT and car (Corridor I).

Figure 7 shows that most respondents preferred to use BRT rather than cars. This indicates that BRT an efficient, affordable, or accessible mode of transportation by most people using Corridor II. The advantages of BRT usually lie in a transportation system that is fast, organized, and often more cost-effective than private cars. Moreover, a previous study on public transportation preference in Asian cities found that BRT is preferred, with dominant factors being cost, travel time, and convenience [24].

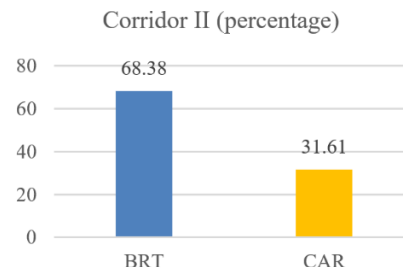


Fig. 7. Transportation mode choice probability between BRT and car (Corridor II).

Despite BRT's dominance as the preferred mode of transport (68.38%), the respondents still opted for private cars (31.61%). This indicates that for a notable portion of the population, the convenience, privacy, and flexibility associated with private vehicle use continue to outweigh the benefits of more efficient mass transportation options. Such preferences highlight the appeal of private mobility, even in contexts where public transport systems are available and well-functioning.

E. Sensitivity of Preference Model

The sensitivity of the model was calculated based on the utility value of the mode, in this case, the cost and travel time

attributes. The sensitivity to switching to BRT mode can be calculated through changes in the utility values of the cost attribute data and BRT travel time attributes.

1) Sensitivity to Changes in Travel Costs for Educational Background

Figure 8 demonstrates that at a travel cost of 5,000 IDR, the probability of switching to the BRT mode exceeds 68.78%. This suggests that when travel costs are relatively low, most users tend to prefer BRT, likely due to its affordability, practicality, and convenience. In contrast, when the travel cost rises above 30,000 IDR, the probability of switching to BRT decreases significantly to approximately 8.40%, indicating a stronger inclination toward private car use or alternative transport modes at higher fare levels. This underscores the sensitivity of users to fare changes and highlights the crucial role of pricing in shaping mode choice behavior.

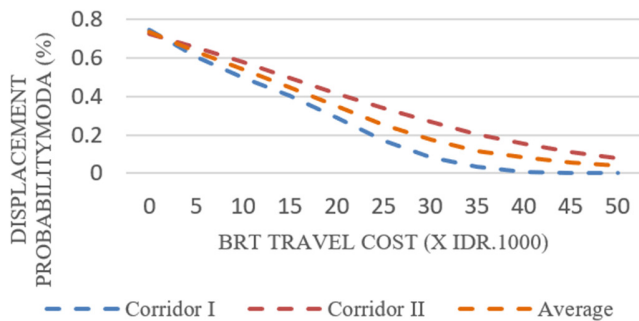


Fig. 8. Mode shift sensitivity graph based on travel cost attribute.

BRT is an optimal transport solution due to its capacity to accommodate high passenger volumes at relatively low operational costs compared to other mass transit systems [25]. Furthermore, the results from Corridor II reveal a similar pattern: at a travel cost below 5,000 IDR, the probability of switching to BRT exceeds 65.60%, suggesting that a greater proportion of users prefer BRT over other modes. However, when the travel cost exceeds 30,000 IDR, the probability of shifting from car to BRT drops to approximately 26.60%, reaffirming the inverse relationship between fare levels and the likelihood of a mode shift from private to public transport.

These findings have important policy implications, particularly in the context of promoting public transport usage and reducing reliance on private modes. The high sensitivity to fare levels suggests that maintaining low and affordable travel costs can significantly enhance the attractiveness of BRT services. In this regard, fare subsidies or integrated ticketing schemes can serve as effective tools to encourage mode shifts toward public transportation. Moreover, targeted pricing strategies may be particularly relevant for corridors with lower mode shift probabilities at higher cost levels, such as Corridor II, to maximize ridership and support sustainable urban mobility.

2) Sensitivity to Changes in Travel Time for Educational Background

As shown in Figure 9, the users of Corridors I and II with travel times of 20 min or less have a probability of switching to the BRT mode of more than 90.55%. For a travel time of more than 40 min, the probability decreases to about 62.11%. This shows that when trips are shorter, especially in that time range, people are more likely to switch to BRT mode due to convenience reasons, as travel time is one of the factors that strongly influence the decision of which mode to choose [26].

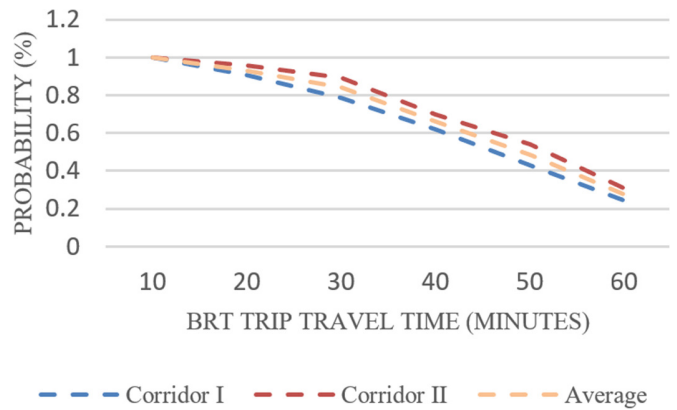


Fig. 9. Mode shift sensitivity graph based on travel time.

3) Sensitivity to Changes in Travel Costs for Age

Figure 10 illustrates that for people aged over 28 years and a travel cost of 5,000 IDR, the probability of switching to the BRT mode reaches 61.36%. This finding suggests that low travel costs significantly influence individuals' decisions to shift to BRT, particularly when economic considerations are prioritized. Fare affordability is a key determinant of mode choice behavior. However, when travel costs exceed 30,000 IDR, the probability of switching to BRT declines sharply to 8.60%. This indicates that at higher fare levels, users are more inclined to choose alternative modes of transport, possibly due to a perceived imbalance between cost and service benefits. These results are consistent with the findings of [27], where it was emphasized that travel cost is a crucial determinant of mode choice, with lower fares leading to increased demand for public transportation options [27].

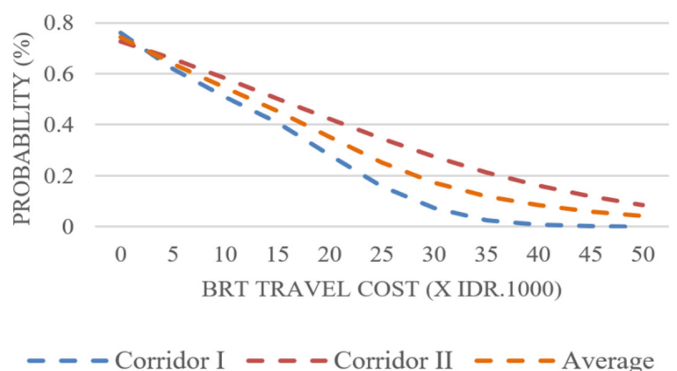


Fig. 10. Mode shift sensitivity graph based on travel cost.

4) Sensitivity to Changes in Travel Time for Age

Figure 11 shows that for Corridor I the probability of switching to BRT is more than 92.35%, indicating that if the travel time by other modes (such as private cars or other public transportation) is less than 20 min, almost all users will switch to BRT. This indicates that within a relatively short travel period, BRT is very competitive in terms of time and convenience. BRT may also offer ease of access and more efficient pricing for short trips.

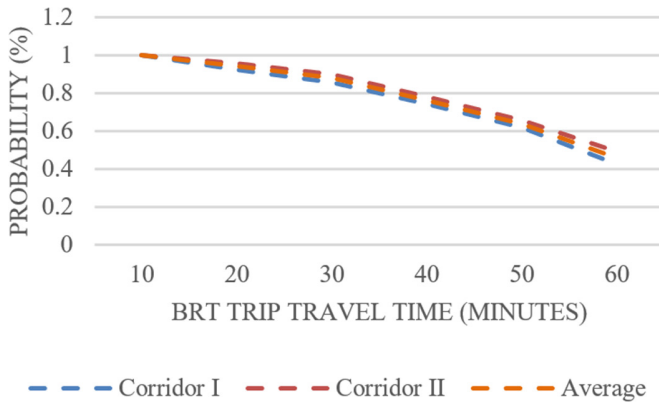


Fig. 11. Mode shift sensitivity graph based on travel time attribute.

5) Sensitivity to Changes in Travel Costs for Job Types

Figure 12 demonstrates that an affordable price is the main factor in attracting users from the car mode to BRT. This indicates that in the occupational groups of entrepreneurs and private employees, the decision to use BRT is very sensitive to low travel costs. Low prices increase the attractiveness of BRT as a more economical mode of transportation compared to cars. Authors in [28] showed that low cost and affordability are the main factors in users' decisions to switch to mass transportation modes such as BRT.

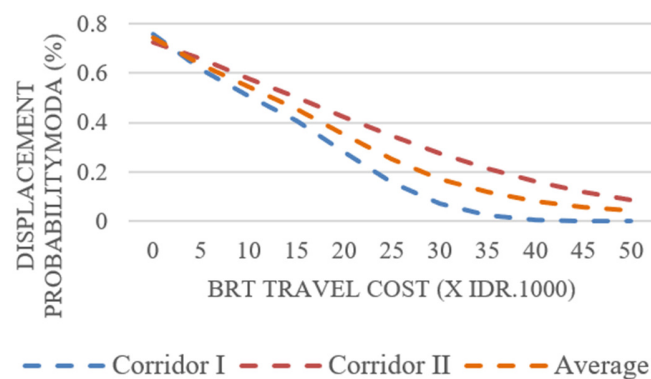


Fig. 12. Mode shift sensitivity graph based on travel cost attribute.

6) Sensitivity to Changes in Travel Time for Job Types

Figure 13 indicates the BRT operations, while the average occupations of entrepreneurs and private employees tend to choose BRT when their travel time is 20 min or less. The probability of switching to BRT under this condition exceeds

89.30%, indicating a strong preference for BRT as a transportation option when the travel time is sufficiently short. This may indicate that ease of access and travel time efficiency are important factors that influence the decision to switch transportation modes. When the travel time exceeds 40 min, the probability of switching from car to BRT decreases to 68.14% or less. Longer travel times can reduce the attractiveness of BRT for private car users. According to [29, 30], switching from private cars to public transportation modes such as BRT is strongly influenced by the level of comfort, cost, and efficiency of travel time.

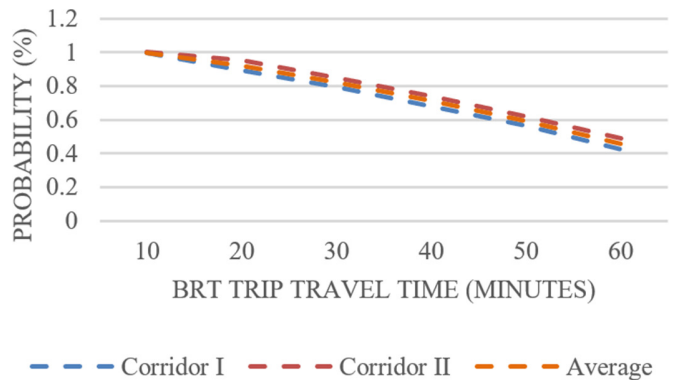


Fig. 13. Mode shift sensitivity graph based on travel time.

F. Validation of the Transportation Mode Choice Model Between BRT and Car

The BRT and car estimation results using the model parameter values were validated using 50% of a randomly selected survey of respondents. The validation results of the transportation mode choice model are listed in Table X.

TABLE X. VALIDATION RESULTS OF GENERAL TRANSPORTATION MODE CHOICE BETWEEN BRT AND CAR

Mode choice type	Mode choice probability (%)		Validation level (%)
	Model	Observation	
Corridor I			
BRT	56	56.8	99.8
Car	44	43.2	99.2
Corridor II			
BRT	68.4	68	99.4
Car	31.6	32	99.6
Total validation level			99.54

The validation results presented in Table VIII indicate that the estimated model parameters exhibit a high level of validity with an accuracy rate of 99.54%. This strong validity is evidenced by the minimal discrepancy between the predicted probabilities of the mode choice and the actual observations obtained from the field. The close alignment between the model outputs and empirical data confirms the robustness of the model in capturing the decision-making behavior of respondents [7, 31].

IV. CONCLUSIONS

The analysis of Bus Rapid Transit (BRT) user characteristics on Corridor I indicates that the majority of

travelers are aged 31–40 years, travel approximately three times per month, and typically the travel purpose is family visits. These users are generally accompanied by family members, with an average household size of five individuals. Most respondents are engaged in entrepreneurial occupations, possess a Bachelor's or diploma degree, and earn a monthly income ranging from 3,000,001 - 5,000,000 Indonesian Rupiah (IDR).

The analysis for Corridor I, using a conditional logit framework, suggests that travel attributes-specifically, travel cost and time-tend to have a significant influence on mode choice. This pattern appears relatively consistent across several examined user segments, including age groups and occupations. Similarly, in Corridor II, cost and time emerge as primary determinants within the model's assumptions, particularly among different age groups.

The sensitivity analysis results indicate a potential correlation, where increases in BRT travel cost and time are associated with an increased likelihood of users shifting toward private car usage. Conversely, lower costs and shorter durations are estimated to relate to higher BRT retention. These trends point to the importance of considering competitive fare structures and service reliability when planning to maintain public transport patronage.

Furthermore, the estimation results revealed differences in the mode choice probabilities between the two corridors. For Corridor I, the model predicts a modal preference of 63.38% for BRT and 36.62% for private cars, whereas for Corridor II, the preference is estimated at 88.96% for BRT and 11.04% for cars. These figures suggest that under the study's stated conditions, BRT services are perceived as a favorable alternative, particularly when service levels are optimized.

The analysis also estimates a potential modal shift, indicating that approximately 14.19% of car users in the sample might consider switching to BRT, primarily driven by improvements in travel time and cost-effectiveness. This implies that the BRT system could potentially reduce dependence on private modes in the Mamminasata Metropolitan Area (MMA), provided that service improvements are realized.

These findings offer insights into urban transport policy, highlighting the potential benefits of integrated strategies that promote fare affordability and operational efficiency. Enhancing service reliability and improving access/egress connectivity may help consolidate BRT as a viable mode of urban mobility. For operators, the results suggest that focusing on travel time efficiency and strategic fare management can support user retention.

For local governments, this study proposes that prioritizing policies for middle-income, working-age populations, who show a higher probability of shifting modes in this model, could be beneficial. Integrating BRT development with broader land-use policies and equitable access measures is proposed to foster a more inclusive urban mobility environment in the MMA.

It is important to acknowledge certain limitations of this research. First, the findings are based on Stated Preference (SP) data, which reflect intended behavior under hypothetical scenarios rather than observed real-world choices thus, an "intention-behavior gap" may exist. Second, the mode choice model assumes a specific set of variables and alternatives that may not capture all latent psychological or environmental factors influencing commuter decisions. Finally, the sample size and geographic scope, while representative of the selected corridors, may limit the generalizability of the results to the entire metropolitan population. Future studies incorporating Revealed Preference (RP) data and broader longitudinal observations are proposed to further validate these trends.

DECLARATION OF COMPETING INTERESTS

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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DATA AVAILABILITY

The data supporting the findings of this study are not publicly available due to confidentiality agreements but are available from the corresponding author upon reasonable request and with permission from the relevant authority.

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