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Travel Patterns, Socioeconomic Characteristics, and Commuter Transportation Preferences of Metropolitan Mamminasata Workers

Murshal Manaf*, Erwin Amri, Kamran Aksa

Urban and Regional Planning Study Program, Faculty of Engineering, Universitas Bosowa, 90231 Makassar, South Sulawesi, Indonesia

* Correspondence: Murshal Manaf (murshal.manaf@universitasbosowa.ac.id)

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Abstract: Indonesian metropolitan centers are rapidly expanding into suburbs, which has increased the demand for transportation and commuter flows. Socioeconomic disparity between the central city and the surrounding suburbs in the Mamminasata Metropolitan Area is anticipated to have an impact on commuter well-being, mode of transportation selection, and travel behavior. However, there is still a dearth of actual data demonstrating how commuters' views and socioeconomic factors interact to influence everyday travel patterns. This study uses covariance-based structural equation modeling (CB-SEM) on commuter data from 379 respondents in the Mamminasata Metropolitan Area to analyze the relationships between socioeconomic characteristics, commuter perceptions, daily mode choice, and travel patterns. The results indicate that commuter travel patterns (CTP) are significantly influenced by perceptions of comfort and safety (PCS) (β = 0.626; $p < 0.001$) and social and health activities of commuters (SHAC) (β = 0.222; p = 0.009). Daily mode choice of commuters (DMCC) is mainly influenced by commuter economic activities and livelihoods (EALC), SHAC, LHO, and PCS. DMCC shows a positive relationship with CTP (β = 0.320), but this relationship does not reach conventional statistical significance (p = 0.098). Meanwhile, the perception of transport service quality (PTSQ) is related to socioeconomic conditions but does not show a significant direct effect on DMCC or CTP, suggesting that structural factors outweigh psychological considerations in determining commuter behavior. The model explains a moderate to high proportion of variance across endogenous variables (R^2 = 0.45–0.60). This study demonstrates that commuter travel behavior in Mamminasata is primarily shaped by service quality perceptions and socioeconomic conditions rather than comfort and safety considerations alone. The findings emphasize the importance of improving public transport service quality and aligning transport policies with commuters' socioeconomic needs to enhance metropolitan resilience and promote sustainable mobility.

Keywords: Commuter mobility; Socioeconomics; Preferences; CB-SEM; Transport resilience; Metropolitan

1 Introduction

A metropolitan area is a rapidly developing urban area that extends into the surrounding suburbs. This development is unexpectedly transforming urban and suburban areas, impacting social, economic, spatial, and transportation aspects [1, 2]. The globally emerging urban decentralization is amplifying the effects of this urban and suburban transformation because local socioeconomic variations and governance capacity are highly determinant of development [3]. Thus, more intensive attention to this phenomenon is crucial for urban and regional planning studies and empirical case studies to adapt and respond to these transformations [4].

The above conditions are reflected in the Mamminasata metropolitan area, one of Indonesia's metropolitan areas [5]. After decentralization in 2001 and national development policies through Presidential Regulation Number 55 of 2011 concerning the Spatial Planning of the Makassar, Maros, Sungguminasa, and Takalar Urban Areas and regional regulations related to Regional Spatial Planning, the area has relatively grown and developed beyond administrative boundaries. The MM area includes the core city of Makassar and three surrounding autonomous district urban areas (Sungguminasa, Maros, and Takalar urban areas).

Following the expansion of Sultan Hasanuddin Airport and Nusantara Port in the 1990s, the spread of manufacturing industries in the late 2000s, and the development of large-scale housing and the new city of Pattalassang during the

same period, social service activities in education, government, and healthcare, as well as the physical expansion of regional space towards the periphery with the core city of Metropolitan Mamminasata, experienced rapid growth. This was supported by the expansion of industrial and transportation infrastructure and the commuting of people to the core city and vice versa. The development and growth of these socio-economic activities have led to an increase in population and commuters in this metropolitan area.

Currently, several studies on commuter travel in Indonesia have focused on socioeconomic characteristics, with a partial focus [6–8], travel experiences and psychology [9], and mode choice [10–14]. In a spatial context, other metropolitan studies primarily cover politics and governance [15–17], socioeconomic factors [18–20], urban economics [21–25], and transportation and geographical networks [26–29]. Despite the wide variation within metropolitan areas, understanding how socioeconomic inequality determines transportation mode choice, travel behavior, and physical changes in space, as well as the mental and physical health conditions of commuters, remains limited.

Our hypothesis is that socioeconomic disparities and income differences between the core city of Makassar and its surrounding suburban areas significantly influence commuter travel behavior, mode choice, and reliance on private vehicles. These disparities may also contribute to environmental changes and affect the physical health of commuters. The city center acts as a hub of financial services, trade, and government activities, attracting commuters across a wide income spectrum. Understanding how these socioeconomic disparities shape actual travel patterns and transportation mode choices is therefore critical for assessing commuter health outcomes and the resilience of metropolitan areas in Indonesia, particularly in the Mamminasata Metropolitan Area.

Based on this hypothesis, the study formulates the following research questions:

1. To what extent do socioeconomic inequalities exist among commuters in the Mamminasata Metropolitan Area?

2. How do these socioeconomic disparities influence travel patterns and behaviors that affect the physical and mental health of commuters?

Based on this hypothesis, the relationships among socioeconomic characteristics, transport service perceptions, daily mode choice, and CTP are conceptualized in an analytical framework (Figure 1).

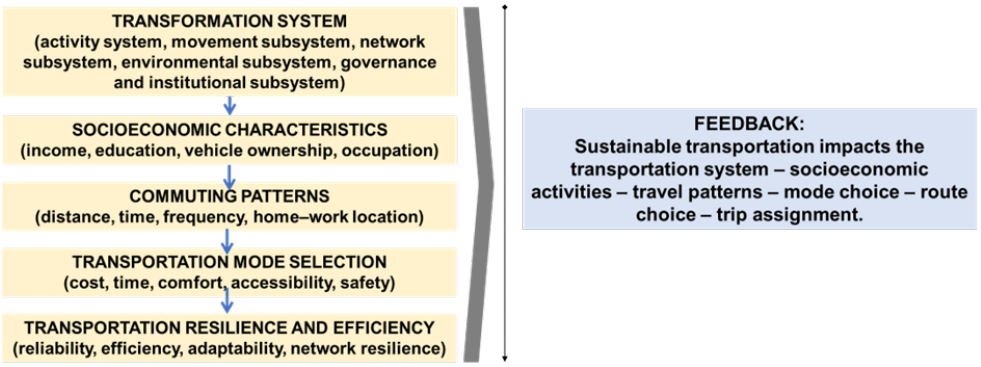

Figure 1. Conceptual framework for thinking

The framework illustrates how socioeconomic inequalities between the metropolitan core and surrounding suburban areas shape commuters' perceptions of comfort, safety, and transport service quality, which subsequently influence daily mode choice and travel patterns. These travel behaviors are expected to generate broader implications for physical and mental health outcomes, as well as for the resilience and sustainability of the Mamminasata metropolitan transportation system.

This study utilizes the 2024 Indonesian Statistics commuter dataset, which includes 379 respondents from Makassar and the surrounding suburban areas of Sungguminasa, Maros, and Takalar, collectively forming the Mamminasata metropolitan area. The preliminary expectation is that substantial socioeconomic gaps affect income levels, shaping mode choice preferences and resulting in increased physical health risks for commuters with long daily travel durations. The findings aim to provide actionable insights for local governments and city planners to expand and improve public transportation provision for suburban commuters.

This research is structured to provide a comprehensive understanding of commuter behavior and metropolitan dynamics in Mamminasata. The study begins with a literature synthesis that examines metropolitan inequalities, including socioeconomic conditions, commuter behavior and characteristics, travel patterns, land use accessibility, and the physical and mental health outcomes of commuters. Following this, the data and methodology section presents an analysis of travel networks, activity and land use systems, movement patterns, and environmental factors that influence commuter behavior.

The analysis section investigates the socioeconomic profiles of commuters, the interactions within the transportation system, travel behavior and mode choice, and the accessibility between the core city and surrounding suburban areas. Finally, the discussion and implications section assesses the consequences of commuter mobility on physical and mental health and explores the broader implications for the resilience and sustainability of metropolitan transportation systems.

Overall, the study focuses on three key aspects: first, the relationship between socioeconomic characteristics and daily travel patterns, including transportation mode choice; second, the impacts of commuter mobility on physical and mental health; and third, the policy and planning implications for enhancing the resilience and sustainability of metropolitan transportation systems.

2 Methodology

2.1 Research Design and Analytical Approach

This study adopts a quantitative approach using covariance-based structural equation modeling (CB-SEM) to examine the interrelationships among socioeconomic factors, service perceptions, and commuter travel behavior. CB-SEM is increasingly applied in quantitative research due to its ability to test theoretical models and analyze relationships among latent variables simultaneously [29, 30]. The latent constructs analyzed in this study include social and health activities of commuters (SHAC), economic activities and livelihoods of commuters (EALC), land and housing ownership (LHO), perception of comfort and safety (PCS), perception of transport service quality (PTSQ), daily mode choice of commuters (DMCC), and commuter travel patterns (CTP). Furthermore, model adequacy was assessed using standard goodness-of-fit indices, including Parsimonious Normed Fit Index (PNFI), Comparative Fit Index (CFI), Tucker–Lewis Index (TLI), and Standardized Root Mean Square Residual (SRMR), to ensure that the hypothesized model adequately represents observed commuter behavior.

2.2 Data Collection

This study utilised primary and secondary data. Primary data was obtained through a structured questionnaire survey administered to daily commuters travelling to Makassar City from surrounding areas, namely Makassar, Maros, Sungguminasa, and Takalar. The questionnaire covered information on travel characteristics (origin and destination, travel time, travel frequency, and mode of transport) as well as the socio-economic characteristics of respondents, such as age, gender, education level, occupation, and income. Secondary data was obtained from relevant agencies, including the Regional Development Planning Agency (Bappeda), the Transportation Agency, and the Central Statistics Agency (BPS), which included road network data, spatial zoning maps, demographic data, traffic volume, and regional transportation development plans.

The research population consisted of commuters who travelled daily to Makassar City. The sampling technique used was stratified random sampling to ensure the representativeness of the commuter group. Stratification was based on (1) origin of travel, (2) type of employment, and (3) primary mode of transport used. The sample size was calculated using the Slovin formula, with a 5% margin of error, resulting in 379 valid respondents. Data collection was conducted during morning and evening rush hours at major transportation hubs, including terminals, bus stops, and office areas.

2.3 Measurement of Variables and Questionnaire Items

This study measured all key variables as latent constructs represented by multiple observed indicators. The measurement design was developed to capture commuters' socioeconomic characteristics, perceptions of transport services, and daily travel behavior in the Mamminasata Metropolitan Area. Each construct was operationalized through questionnaire items formulated to reflect conditions commonly experienced by daily commuters in the study area.

A structured questionnaire was employed as the primary measurement instrument. All items were assessed using a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree), allowing respondents to express the intensity of their perceptions and experiences. Socioeconomic-related constructs, namely SHAC, EALC, and LHO, were measured using two indicators each, reflecting respondents' personal circumstances that potentially shape their mobility decisions.

Table 1 presents the definitions of variables and their corresponding measurement items. Perception-based constructs were measured in greater detail. PCS was represented by four indicators capturing comfort, accident risk, personal security, and vehicle conditions. PTSQ was measured using three indicators related to service availability, punctuality, and cost–service consistency. Behavioral outcome variables were also modeled as latent constructs. DMCC was measured using two indicators reflecting consistency and efficiency-based decisions, while CTP were measured using three indicators related to travel regularity, duration, and scheduling.

The complete list of variables, item codes, and questionnaire statements is presented in Table 1. Prior to testing the structural relationships, all measurement items were evaluated through confirmatory factor analysis (CFA) to assess

convergent validity, construct reliability, and discriminant validity. Only indicators that satisfied the recommended statistical thresholds were retained in the final structural equation model.

Table 1. The definitions of variables and their corresponding measurement items

Variable	Item Code	Questionnaire Statement
Social and health activities of commuters (SHAC)	SHAC1	Social and family activities influence my decision to undertake daily travel.
	SHAC2	My health condition affects the way and frequency of my daily travel.
Economic activities and livelihoods of commuters (EALC)	EALC1	The nature of my job requires a high level of daily mobility.
	EALC2	My income level influences the choice of transportation mode I use.
Land and housing ownership (LHO)	LHO1	My housing ownership status influences the distance and pattern of my daily travel.
	LHO2	The location of my residence influences my choice of transportation mode.
Perceptions of comfort and safety (PCS)	PCS1	The transportation mode I use provides comfort during my journey.
	PCS2	I feel safe from accident risks when using this transportation mode.
	PCS3	I feel safe from criminal incidents during my journey.
	PCS4	Vehicle conditions and supporting facilities enhance my sense of safety.
Perception of transport service quality (PTSQ)	PTSQ1	The availability of public transportation modes is adequate.
	PTSQ2	The punctuality of transport services meets my needs.
	PTSQ3	Transportation costs are consistent with the quality of service received.
Daily mode choice of commuters (DMCC)	DMCC1	I consistently use the same transportation mode on a daily basis.
	DMCC2	My mode choice is based on time and cost efficiency.
Commuter travel patterns (CTP)	CTP1	I travel back and forth every working day.
	CTP2	My daily travel duration is relatively consistent.
	CTP3	My travel pattern is influenced by work schedules and daily activities.

2.4 Data Analysis Method

The analysis was conducted to examine the characteristics of travel patterns and the socioeconomic conditions of commuting workers. The identification included departure times, travel duration and frequency, main destinations, modes of transportation used, and factors influencing mode choice. Descriptive statistical techniques were used to describe data trends through frequency distributions, percentages, means, and standard deviations. Socio-economic variables such as income, age, type of work, and gender were linked to mode preferences through cross-tabulation, for example, the relationship between income level and mode choice, or between gender and safety aspects. In addition, the travel time ratio—the comparison between the duration of public transportation and private vehicles—is calculated as an important indicator in influencing mode decisions, where a lower ratio increases the likelihood of using public transportation.

To analyze more complex relationships, this study applied CB-SEM using Jamovi 2.3 [30]. The analytical procedure consisted of two stages. First, the measurement model was tested to ensure data quality, including convergent validity, construct reliability, and discriminant validity. Reliability was assessed using Cronbach's alpha and composite reliability, while CFA was conducted to validate the Likert-scale items. Second, the structural model was evaluated by examining both direct and indirect paths, with bootstrapping applied to test mediation effects. Model fit was assessed using several indicators, including PNFI, CFI, TLI, and SRMR [31, 32]. Interpretation of

results was based on p-values ($\leq$0.05), with classification of full or partial mediation according to the significance of paths after including mediating variables. All variables were estimated according to the structural equation model specified in the research equation (Figure 2). The analysis focused entirely on the relationships among socioeconomic characteristics, service perceptions, and commuter behavior.

$$\text{SHAC} = \text{SHAC1} + \text{SHAC2}$$
$$\text{EALC} = \text{EALC1} + \text{EALC2}$$
$$\text{LHO} = \text{LHO1} + \text{LHO2}$$
$$\text{CTP} = \text{CTP1} + \text{CTP2} + \text{CTP3}$$
$$\text{DMCC} = \text{DMCC1} + \text{DMCC2}$$
$$\text{PTSQ} = \text{PTSQ1} + \text{PTSQ2} + \text{PTSQ3}$$
$$\text{PCS} = \text{PCS1} + \text{PCS2} + \text{PCS3} + \text{PCS4}$$
$$\text{PCS} = \text{LHO} + \text{EALC} + \text{SHAC}$$
$$\text{PTSQ} = \text{LHO} + \text{EALC} + \text{SHAC}$$
$$\text{DMCC} = \text{PCS} + \text{PTSQ} + \text{SHAC} + \text{EALC} + \text{LHO}$$
$$\text{CTP} = \text{DMCC} + \text{PTSQ} + \text{PCS} + \text{SHAC} + \text{EALC} + \text{LHO}$$

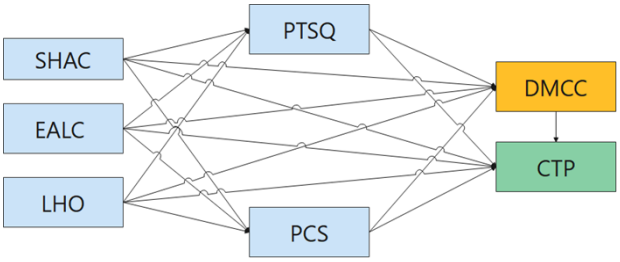

Figure 2. Conceptual model of perceptions of mode choice and commuter travel patterns

Note: SHAC = social and health activities of commuters, EALC = economic activities and livelihoods of commuters, LHO = land and housing ownership, PCS = perception of comfort and safety, PTSQ = perception of transport service quality, DMCC = daily mode choice of commuters, and CTP = commuter travel patterns.

3 Results

3.1 Socio-Economic Characteristics of Commuters

A survey of 379 commuters shows that private car ownership is relatively low. A total of 54% of respondents do not own a car, while 30% own one car, and only 16% own two or more cars. This indicates that private cars are not yet the dominant mode of transportation, possibly due to price, high operating costs, and the availability of other modes of transportation.

In contrast, almost all commuters own a motorcycle, with a fairly high distribution of ownership. A total of 57.18% of respondents own one unit, 31.72% own two units, and 22% own three or more units. This data confirms that motorcycles are the main mode of transportation for commuters, mainly due to their flexibility, relatively low operating costs, and ease of access in both urban and rural areas.

In terms of expenses, the daily cost of using a private car tends to be higher than that of a motorcycle. Approximately 24% of respondents who use cars spend between Rp 25,000 and Rp 50,000 per day, 18% spend between Rp 50,001 and Rp 100,000, and 8% spend more than Rp 100,000 per day. Only 10% spend less than Rp 25,000, while 40% do not use cars at all. In contrast, daily transportation costs for motorcycles are much more affordable. A total of 46% of respondents spend Rp 10,001–Rp 25,000 per day, 30% spend between Rp 25,001–Rp 50,000, and 24% spend less than Rp 10,000 per day. This reinforces the position of motorcycles as the most economical and practical mode of transportation for most commuters.

In addition, the aspect of transportation allowances from workplaces is also an important factor. The majority of commuters (82%) do not receive transportation allowances, while only 18% do. This condition shows that most workers bear the full cost of their own travel, so their choice of mode of transportation tends to be directed towards lower-cost alternatives, namely motorcycles.

To examine the interrelationships between socioeconomic characteristics, perception variables, daily mode choice, and CTP, this study employs a structural equation modeling (SEM) approach. The model is designed to

capture both direct and indirect effects among variables, allowing an integrated analysis of how socioeconomic inequalities shape commuter behavior through perception-based mechanisms.

The structural model incorporates socioeconomic constructs related to LHO, EALC, and SHAC. These variables are hypothesized to influence commuters' perceptions of transport service quality and PCS, which in turn affect DMCC and overall CTP. This modeling approach enables the identification of mediating pathways through which socioeconomic conditions translate into observable travel behavior outcomes. The conceptual relationships and estimated pathways among variables are illustrated in Figure 3.

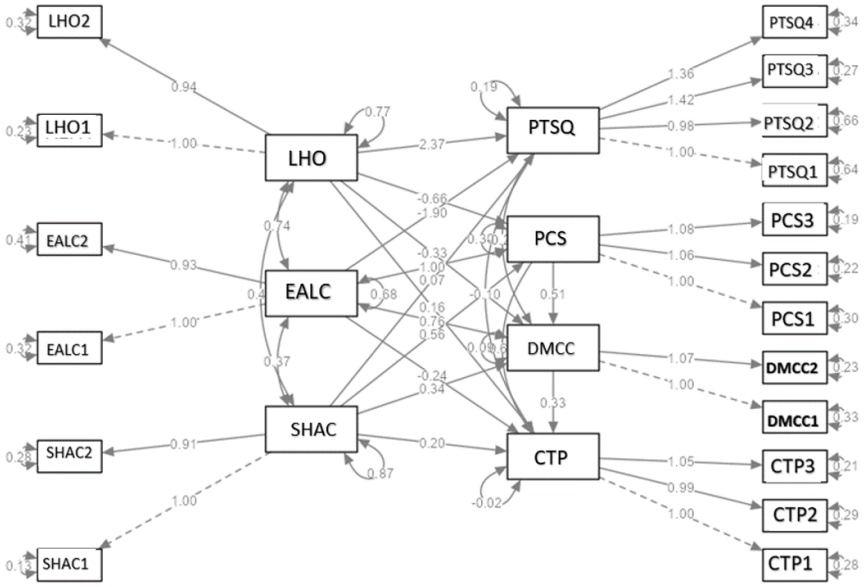

Figure 3. Model pathway: the influence of socioeconomic characteristics and perceptions on mode choice and commuter travel patterns

Note: SHAC = social and health activities of commuters, EALC = economic activities and livelihoods of commuters, LHO = land and housing ownership, PCS = perception of comfort and safety, PTSQ = perception of transport service quality, DMCC = daily mode choice of commuters, and CTP = commuter travel patterns.

Figure 3 presents the structural path model examining the relationships between socioeconomic characteristics, perception variables, daily mode choice, and CTP in the Mamminasata Metropolitan Area. The model integrates three groups of socioeconomic variables, LHO, EALC, and SHAC, with perception-based variables, namely PTSQ and PCS, as well as DMCC and CTP.

The results indicate that socioeconomic characteristics play a central role in shaping commuter behavior. Variables related to LHO and EALC show direct effects on PTSQ and PCS. This suggests that residential location, housing tenure, and income-related factors influence how commuters evaluate the quality, reliability, and safety of transportation services. Furthermore, perception variables act as important mediating factors between socioeconomic conditions and travel behavior. PTSQ and PCS significantly influence DMCC, which in turn affects CTP, including travel regularity and daily commuting duration. This indicates that commuters' decisions are not solely determined by socioeconomic constraints but are also shaped by their subjective evaluations of transport services. These relationships are summarized in Figure 3 and Table 2 and Table 3, which present the estimated results of direct effects.

In addition, SHAC exhibit both direct and indirect effects on CTP. This finding highlights the interconnection between daily social obligations, health conditions, and commuting behavior, particularly in metropolitan contexts where long-distance commuting is common. Overall, Figure 3 demonstrates that CTP in the Mamminasata Metropolitan Area is produced through a complex interaction of socioeconomic inequalities and perception-based factors. The structural model confirms that socioeconomic disparities influence travel behavior both directly and indirectly through perceptions of transport service quality, comfort, and safety, reinforcing the importance of integrated transport and land-use policies in improving commuter well-being and metropolitan resilience.

3.2 Trends in Commuter Activities and Commuter Housing

Survey results indicate significant shifts in commuters' social activities due to daily travel patterns. Longer commuting times and tight work schedules reduce interactions with family and community, while prolonged travel contributes to fatigue, stress, and health complaints. Only a small group maintains light exercise or recreation,

Table 2. Estimated results of direct effects

Code	Dependent	Predictor	Estimate (β)	SE	95% CI (Lower–Upper)	z	p
p19	PTSQ	LHO	3.462	1.114	0.188–4.557	2.129	0.033
p20	PTSQ	EALC	-2.618	1.127	-4.110–0.307	-1.687	0.092
p21	PTSQ	SHAC	0.101	0.137	-0.204–0.334	0.474	0.636
p22	PCS	LHO	-0.689	0.248	-1.144–-0.172	-2.655	0.008
p23	PCS	EALC	0.986	0.230	0.546–1.449	4.331	<0.001
p24	PCS	SHAC	0.631	0.066	0.435–0.695	8.515	<0.001
p25	DMCC	PTSQ	-0.163	0.234	-0.680–0.235	-0.952	0.341
p26	DMCC	PCS	0.520	0.091	0.331–0.687	5.606	<0.001
p27	DMCC	SHAC	0.386	0.066	0.209–0.467	5.118	<0.001
p28	DMCC	EALC	0.770	0.153	0.462–1.062	4.972	<0.001
p29	DMCC	LHO	-0.352	0.150	-0.623–-0.034	-2.189	0.029
p30	CTP	DMCC	0.320	0.201	-0.061–0.725	1.654	0.098
p31	CTP	PCS	0.626	0.096	0.449–0.824	6.645	<0.001
p32	CTP	PTSQ	-0.068	0.162	-0.414–0.221	-0.594	0.552
p33	CTP	SHAC	0.222	0.077	0.051–0.353	2.618	0.009
p34	CTP	EALC	-0.232	0.125	-0.483–0.006	-1.915	0.056
p35	CTP	LHO	0.163	0.105	-0.047–0.362	1.508	0.132

Note: Significance < 0.05; SHAC = social and health activities of commuters, EALC = economic activities and livelihoods of commuters, LHO = land and housing ownership, PCS = perception of comfort and safety, PTSQ = perception of transport service quality, DMCC = daily mode choice of commuters, and CTP = commuter travel patterns.

Table 3. Estimated indirect effects

Code	Mediation Pathway	Estimate (β)	SE	95% CI (Lower–Upper)	z	p
IE1	LHO → PCS → DMCC → CTP	-0.181	0.240	-0.646–0.296	-0.729	0.466
IE2	LHO → PCS → CTP	-0.236	0.418	-1.049–0.591	-0.546	0.585
IE3	LHO → PTSQ → DMCC → CTP	-0.115	0.074	-0.257–0.035	-1.496	0.135
IE4	LHO → PTSQ → CTP	-0.432	0.175	-0.762–-0.076	-2.393	0.017
IE5	LHO → DMCC → CTP	-0.112	0.084	-0.274–0.056	-1.292	0.196
IE6	EALC → PCS → DMCC → CTP	0.137	0.206	-0.263–0.544	0.682	0.495
IE7	EALC → PCS → CTP	0.178	0.346	-0.494–0.861	0.530	0.596
IE8	EALC → PTSQ → DMCC → CTP	0.164	0.101	-0.029–0.366	1.668	0.095
IE9	EALC → PTSQ → CTP	0.617	0.184	0.274–0.995	3.449	<0.001
IE10	EALC → DMCC → CTP	0.246	0.162	-0.065–0.571	1.560	0.119
IE11	SHAC → PCS → DMCC → CTP	-0.005	0.010	-0.024–0.014	-0.489	0.625
IE12	SHAC → PCS → CTP	-0.007	0.016	-0.038–0.026	-0.386	0.700
IE13	SHAC → PTSQ → DMCC → CTP	0.105	0.053	-0.009–0.200	1.789	0.074
IE14	SHAC → PTSQ → CTP	0.395	0.065	0.232–0.487	5.516	<0.001
IE15	SHAC → DMCC → CTP	0.123	0.067	-0.020–0.244	1.666	0.096
IE16	PCS → DMCC → CTP	-0.052	0.078	-0.226–0.079	-0.949	0.343
IE17	PTSQ → DMCC → CTP	0.166	0.094	-0.016–0.354	1.791	0.073

Note: Significance < 0.05; SHAC = social and health activities of commuters, EALC = economic activities and livelihoods of commuters, LHO = land and housing ownership, PCS = perception of comfort and safety, PTSQ = perception of transport service quality, DMCC = daily mode choice of commuters, and CTP = commuter travel patterns.

highlighting an overall decline in social engagement and increased health risks, particularly for those traveling more than 20 km daily.

From an economic perspective, commuters show adaptation through income diversification, with many engaging in side businesses, especially online. Rising transport costs drive this trend, although high expenditure (over 15% of monthly income) limits opportunities for additional work. Some respondents have also shifted to jobs closer to home, reflecting household strategies to balance income needs with time efficiency.

Housing patterns also reveal changes, with middle- and low-income commuters moving to peripheral areas where land and housing are more affordable, despite longer travel distances. Higher-income groups tend to secure private housing in strategic locations with better transport access. The trend illustrates compromises between affordability, location, and accessibility, while continued investment in property improvements indicates long-term asset prioritization despite commuting burdens.

Structural model analysis was conducted using the CB-SEM estimation, which is appropriate for ordinal scale data.

1. Model Fit. Testing the goodness of fit of the CB-SEM model with DWLS estimation produced excellent values for almost all indices. The CFI = 0.990, TLI/NNFI = 0.987, NFI = 0.988, RFI = 0.984, and IFI = 0.990 values all exceed the recommended minimum threshold of $\geq$0.90. The PNFI value of 0.742 also exceeds the minimum threshold of $\geq$0.60, indicating adequate model fit from a parsimony perspective. Overall, this combination of excellent indices indicates that the model is suitable for further analysis.

2. In CB-SEM, the R^2 (Squared Multiple Correlation) value indicates the proportion of variance of an endogenous variable that can be explained by its predictor variables in the model. The interpretation is similar to that in multiple regression, except that R^2 here is calculated based on the overall relationship in the structural model.

The results of the analysis with SEM-CB show the R^2 value, which represents how much of the variation between endogenous variables can be explained by the variables in the model. In CTP, R^2 describes the percentage of variation in travel patterns influenced by LHO, EALC, and SHAC. For example, if R^2 = 0.52, it means that 52% of the CTP variation can be explained by these three factors, while the remaining 48% is influenced by other factors outside the model. In PCS, R^2 shows the proportion of variance explained by LHO, EALC, and SHAC, where a high value indicates a significant contribution of socioeconomic and activity-related factors to perceptions of comfort and safety. Furthermore, in the DMCC, the R^2 value reflects the extent to which PCS, PTSQ, LHO, EALC, and SHAC influence mode choice decisions; the higher the value, the greater the influence of the combination of perceptual and socioeconomic factors on commuter choice. Finally, in CTP, R^2 shows the model's ability to explain travel patterns based on PCS, PTSQ, DMCC, LHO, EALC, and SHAC. A moderate to high R^2 value indicates that the model has good predictive ability regarding variations in CTP.

3. Table 2 presents the estimated results of direct effects among the latent constructs. In the measurement model, all latent construct indicators have factor loadings above 0.50 and are significant at $p < 0.001$, so they can be considered valid in representing their respective constructs. The SHAC variable is measured by two indicators (0.934 and 0.846), EALC by two indicators (0.826 and 0.767), LHO by two indicators (0.876 and 0.825), PCS by three indicators (0.836–0.902), and PTSQ by four indicators (0.587–0.855).

4. Both significant and non-significant paths are considered to provide a balanced interpretation:

• Both statistically significant and non-significant relationships are considered to provide a balanced interpretation of the structural model. The results show that LHO has a positive and significant effect on PCS, indicating that better residential conditions and housing security contribute to higher levels of perceived comfort and safety among commuters. In contrast, the effect of EALC on PCS is negative but not statistically significant, suggesting that economic factors alone do not directly shape comfort and safety perceptions in daily commuting.

• Regarding PTSQ, the analysis reveals a negative and statistically significant relationship with LHO. This unexpected inverse association suggests that commuters living in more secure or better housing environments tend to have higher expectations of transport services, which may result in more critical evaluations of service quality. Conversely, both EALC and SHAC exhibit positive and significant effects on PTSQ, indicating that higher socioeconomic engagement and activity intensity are associated with more favorable perceptions of transport service quality.

• Table 3 presents the estimated indirect effects among the latent constructs. Beyond direct effects, the model highlights the role of indirect pathways in influencing CTP. The indirect effect of LHO on CTP through PTSQ is statistically significant, demonstrating the mediating role of transport service quality perception in linking residential conditions to observed travel behavior. However, other indirect pathways, such as LHO $\rightarrow$ PCS $\rightarrow$ DMCC $\rightarrow$ CTP, are not statistically significant, indicating that perceptions of comfort and safety do not consistently mediate the relationship between land and housing conditions and overall CTP.

• Overall, these findings suggest that not all socioeconomic and perceptual pathways equally influence commuter mobility. Instead, specific mechanisms, particularly those related to service quality perception, play a more decisive role in shaping daily mode choice and CTP in the Mamminasata Metropolitan Area.

5. Health-Related considerations, although commuting comfort and safety may influence health outcomes, no direct health variables were modeled in this study. Future research could incorporate health-related measures, such as stress, fatigue, or physical activity, to better assess the impact of commuting on health.

4 Discussion

The CB-SEM analysis shows that PTSQ is the most consistent and significant variable influencing commuter travel behavior, both in DMCC and PTSQ. In the Mamminasata context, this reflects the practical importance of punctuality, route availability, and service reliability in shaping everyday commuting decisions, particularly in suburban areas with limited modal alternatives. These findings align with Manaf [1, 2], who emphasized that service quality is a dominant factor in commuter mode selection in Indonesian metropolitan areas. However, compared to Manaf's study, which primarily analyzed urban centers, this study provides additional insight into suburban contexts,

where the interaction between service quality and socio-economic activities plays a stronger role in shaping travel patterns. This highlights a methodological contrast: while Manaf focused on urban ridership surveys, our study integrates socio-economic and accessibility factors in a CB-SEM framework, allowing a more holistic understanding of travel behavior. Theoretically, this finding strengthens the argument that perceived service quality functions as a key mediating mechanism linking structural conditions and individual travel behavior.

The route to PCS is also significantly influenced by EALC and SHAC. This suggests that commuters with higher activity intensity are more sensitive to service performance because their daily schedules depend on time efficiency and network connectivity. This supports Aritenang's argument [3], which highlights that socio-economic variations among commuters directly contribute to differences in mode preferences and transportation accessibility. Commuters with high economic activity intensity tend to give positive assessments of public modes because they depend on transportation efficiency to support productivity, while social mobility and health needs encourage users to appreciate modes that facilitate connectivity between activities. Practically, this indicates that improving service quality for activity-dense commuter groups can generate broader behavioral shifts toward public transport use.

Conversely, LHO has a negative effect on PCS and DMCC, indicating a tendency for housing/land owners to choose private modes of transportation. In suburban Mamminasata, homeownership is often associated with lower-density residential locations and weaker public transport coverage, reinforcing private vehicle dependence. This pattern reinforces the studies by Amri et al. [33] and Manaf et al [6], which found that suburban areas are dominated by communities with a high level of dependence on private vehicles. This phenomenon is also consistent with global literature on urban decentralization, which causes transportation access inequality due to local socio-economic variations and governance capacity [3]. This finding contributes empirically by confirming that tenure status operates as a structural constraint rather than merely a socioeconomic attribute.

Interestingly, PCS does not exhibit a significant direct effect on DMCC or CTP, despite its positive association with LHO. This indicates that comfort and safety considerations do not immediately translate into behavioral change when commuters face limited alternatives and rigid daily schedules. This finding contrasts with studies by Herdayati and Eryando [7] and Rosida et al. [14], which emphasize the central role of psychological factors—such as comfort, safety, and travel stress—in shaping commuter experiences. In the Mamminasata Metropolitan Area, however, commuting decisions appear to be more strongly constrained by structural and pragmatic considerations, including limited transport alternatives, service reliability, and economic necessity. Under such conditions, commuters tend to prioritize modes that ensure time efficiency and cost control, even when comfort and safety are perceived as suboptimal.

This result indicates that PCS functions more as a background evaluative factor rather than a direct behavioral trigger. Psychological perceptions become secondary when daily mobility is shaped by routinized patterns and infrastructural constraints typical of suburban commuting. Comfort and safety perceptions do not immediately alter established commuting routines, particularly in suburban settings where daily travel patterns are already routinized and difficult to change. Instead, PCS may influence travel behavior indirectly by shaping broader expectations toward transport services, which are more directly captured through PTSQ. Thus, the non-significant direct paths from PCS to DMCC and CTP reflect not the irrelevance of psychological factors, but their subordinate role within a mobility system dominated by structural constraints and economic imperatives. This refines existing behavioral models by positioning psychological variables as conditional rather than primary determinants.

Other findings indicate that PCS has a significant effect on CTP, along with SHAC. This suggests that service quality perceptions and daily social-health mobility jointly shape the regularity and predictability of commuting behavior. This means that positive perceptions of public services can shape more regular, punctual, and efficient travel patterns, in line with the argument by Manaf et al. [6] that the interaction between individual mobility and changes in suburban lifestyles shapes new travel behaviors in metropolitan areas. In other words, perceptions of public services not only influence mode choice but also the consistency and regularity of travel. This finding extends prior studies by demonstrating that service perceptions affect not only modal selection but also temporal travel organization.

Overall, the dominance of private vehicles in Mamminasata's commuting patterns indicates a perceived weakness in the quality of public services, despite the significant potential that exists if this quality were to be improved. This dominance reflects an adaptive response to service limitations rather than a simple preference for private mobility. This is consistent with the study by Kusmawan and Susilowati [9], which found that the quality of life of commuters is closely related to the reliability of public transportation. High dependence on private vehicles also has an impact on the environmental, physical health, and mental vulnerability aspects of commuters, as demonstrated by Herdayati and Eryando [7] and Kusmawan et al. [8].

Thus, the results of this study enrich the literature on socio-economic linkages, travel patterns, and public transportation quality in Indonesian metropolitan areas. By explicitly integrating socioeconomic activities, perceptions, and behavioral outcomes within a single CB-SEM framework, this study provides empirical evidence from a suburban metropolitan context that remains underrepresented in existing research. These findings support the theory that

socio-economic inequality and poor public service quality contribute to private vehicle dependency [3, 4], while emphasizing the need for policies to improve service quality and integrate public transportation in Mamminasata to strengthen metropolitan resilience [5].

Key findings from this study show that although commuters in Mamminasata tend to predominantly use private vehicles, the quality of public transportation services and support for economic and social needs remain the main determinants of travel behavior. This confirms that behavioral change is more likely to occur through improvements in system performance than through individual-level persuasion alone. Commuters who rate the punctuality, accessibility, and efficiency of public transportation positively tend to choose this mode of transportation and form more regular travel patterns. However, homeowners who use private vehicles more often have fewer positive perceptions of public service quality, indicating unmet service expectations. This suggests that the dominance of private vehicles is influenced by the perceived low quality of public transportation services. Therefore, policies that focus on improving the operational quality and accessibility of public transportation are essential to encourage behavioral change toward public transportation use and reduce dependence on private vehicles.

5 Conclusions

This study shows that commuter travel behavior in the Mamminasata Metropolitan Area is primarily shaped by the interaction between socioeconomic characteristics and commuters' perceptions of transportation services. The CB-SEM analysis identified perceived transportation service quality as the most influential factor determining the consistency of daily mode choice and CTP, exceeding the direct influence of PCS. Economic activity, livelihood, and social and health activities indirectly influence travel behavior by strengthening positive evaluations of transportation quality. Meanwhile, LHO strengthens its reliance on private vehicles and is associated with more critical service perceptions. Theoretically, this study contributes to understanding the mediating role of perceived service quality in linking socioeconomic inequality to travel behavior.

Several limitations should be acknowledged. First, this study relies on self-reported survey data, which may involve recall bias and subjective assessments of travel behavior. Second, this analysis is limited to a single metropolitan area, thus limiting the applicability of the findings to regions with different spatial structures, transportation systems, or governance arrangements. Third, although social activities and health are included as explanatory variables, direct health outcomes such as stress, fatigue, or physical activity levels are not explicitly modeled. Future research should incorporate objective mobility data, such as GPS-based travel logs, expand comparative analysis across metropolitan areas, and integrate measurable health indicators into the modeling framework. This direction would strengthen causal inference and provide deeper insights into the long-term implications of travel patterns for commuter well-being and metropolitan resilience.

Author Contributions

Conceptualization, M.M., E.A., and K.A.; methodology, M.M.; software, E.A.; validation, M.M. and E.A.; formal analysis, M.M. and E.A.; investigation, M.M., E.A., and K.A.; resources, M.M.; data curation, E.A. and K.A.; writing—original draft preparation, M.M. and E.A.; writing—review and editing, M.M. and E.A.; visualization, E.A.; supervision, M.M.; project administration, M.M. and K.A.; funding acquisition, M.M. All authors have read and agreed to the published version of the manuscript.

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Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Nomenclature

SHAC	Social and Health Activities of Commuters
EALC	Economic Activities and Livelihoods of Commuters
LHO	Land and Housing Ownership
PCS	Perception of Comfort and Safety
PTSQ	Perception of Transport Service Quality
DMCC	Daily Mode Choice of Commuters
CTP	Commuter Travel Patterns