EXPLORING CONTRIBUTING FACTORS TO HOUSEHOLD VEHICLE OWNERSHIP IN DEVELOPING COUNTRIES: A CASE OF BANDA ACEH, INDONESIA

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Resume

Household car ownership has become a crucial issue in Indonesia due to rapid urbanization and economic growth, which have led to increased demand for personal vehicles. This surge in vehicles contributes to traffic congestion, pollution, and strains on urban infrastructure. This study aimed to investigate private vehicle ownership in relation to household characteristics and mobility attributes in developing country settings. The methodology used is the multinomial logit model (MNL) to analyze ownership patterns. The empirical results showed the significant impact of the income variable on vehicle ownership. Ownership of multiple private vehicles was more prevalent among individuals with a driver's license, males, and those who traveled longer distances. These outcomes could be invaluable for policymakers focused on reducing auto dependency and enhancing the efficiency of urban transportation systems.

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1 Introduction

Traffic congestion in Banda Aceh has become increasingly severe due to a thriving economy, population growth, and urbanization. This surge in private vehicle usage threatens the transportation system of the city. To maintain a smooth transportation system, it is crucial to reduce reliance on private vehicle and promote public transportation. However, the effectiveness of both existing and proposed public transportation remains uncertain. Banda Aceh, the capital of Aceh Province, is a burgeoning city and a hub for government administration, education, private offices, tourism, and numerous shopping centers. It attracts not only residents but also people from neighboring areas of Aceh Besar. In 2020, the city's population reached 259,913, with a density of 42 individuals per hectare, covering an area of 61.36 square kilometers and experiencing an annual population growth rate of approximately 2%. This growing population density has led to an increase in daily travel, resulting in new residential areas, shopping centers, and food hubs. Consequently, high levels of daily activities disrupt traffic flow and decrease road service quality.

The increasing reliance on private vehicle can primarily be attributed to the lack of improvement in the quality of public transportation services [1-2]. As a result, individuals with higher and middle incomes tend to opt for private vehicle [3]. This trend posed significant challenges for the transportation system, leading to congestion and environmental problems [4-5]. The consequences include the loss of time, difficulties in traffic flow, and an increased risk of traffic accidents. Therefore, a comprehensive understanding of the factors influencing private vehicle ownership is crucial for effective planning and management of urban transportation systems.

The current study aimed to exploring the factors affecting private car ownership intensity. In this study the term of exploring refers to a comprehensive

investigation into the factors influencing vehicle ownership in households. This includes studying demographic, economic, and policy-related influences, and understanding how they shape vehicle ownership trends in a developing urban setting like Banda Aceh.. To achieve this, multinomial logit regression (MNL) was used as the analytical method. MNL regression model was developed to predict private vehicle ownership based on the number of vehicles owned. Following the estimation and validation of model under specific criteria, sensitivity analysis and policy scenario assessments were conducted. The study considered socioeconomic characteristics and built environment attributes as unique factors hypothesized to influence household vehicle ownership. Identifying the determinants of private vehicle ownership is crucial for developing consistent land-use and transportation policies that promote sustainable urban transportation systems. Therefore, by reducing household vehicle dependency, it is expected that auto traffic will decrease, flow will improve, and cleaner transportation will be facilitated.

The remaining sections of this paper are organized as follows: Section 2 presents a concise overview of the determinants of household vehicle ownership and the previously studied algorithms. Section 3 shows model's structure, data sources, and the mathematical foundation. The subsequent section addresses model's estimation, application outcomes, and policy implications. The concluding section provides closing thoughts and suggestions for future study.

2 Literature review

Studies on vehicle ownership often rely on aggregate and disaggregate models, or focused on motorcycles [6-9]. Aggregate model may be subject to aggregation bias and multicollinearity between explanatory variables [10]. In contrast, disaggregate modeling addresses these limitations by capturing individual choice behavior and explanatory variables at the individual level, leading to more reliable estimates. As a result, it has gained significant attention in recent studies on vehicle ownership. The dependent variable, the number of vehicles in household, is typically analyzed using ordered or unordered response choice models [11-12]. With household's decision to own vehicle, an individual's usage is measured in miles (or kilometers) per year, and the relationship between vehicle type and this variable can be examined simultaneously [13].

In-depth investigation has been conducted on the selection and usage of vehicle in developed countries, considering factors such as household characteristics and the number of vehicles owned [14-15]. However, studies in developing countries such as Indonesia, where the transportation system is significantly different, are less common. In many Asian countries, the focus tends to be on a single aspect of vehicle ownership [16] and [17-19], which limits the scope for policy-making. In recent years, studies of household vehicle ownership with panel data have increasingly adopted ordered-response model that account for state dependence and heterogeneity [20-22]. Panel data analysis of vehicle usage typically uses random and fixed effects specifications, allowing for unobserved heterogeneity [20, 23].

Studies on private car ownership and usage are relatively limited. For instance, [24] applied ordered probit and tobit/probit regression models with sample selection to investigate motorcycle usage in the metropolitan area of Jabotabek, Indonesia, identifying key explanatory variables such as residential location, land use, transportation system performance, and socioeconomic/demographic characteristics. A two-level Nested Logit (NL) model is widely used to examine household's decision to own motorcycles at the upper level and the choice of engine sizes at the lower level. Furthermore, a three-level NL model was proposed to analyze household joint choices regarding the number of cars, the number of motorcycles, and the mode of transportation for work [25]. An integrated model was also proposed to analyze choice behaviors associated with ownership, type, and usage of cars and motorcycles in Taiwan. Two related studies were recently conducted, namely [26], investigating the factors influencing private car ownership and vehicle usage measured in kilometers [27] and [28], examining the factors affecting motorcycle ownership and vehicle usage measured in kilometers. However, these studies are limited to developed countries and have not been conducted in Banda Aceh City, Indonesia. The current study aimed to investigate the factors influencing private car ownership and analyze their effects on private car ownership in Banda Aceh City. It was particularly beneficial for countries with poor public transportation systems and high automobile dependence, such as Indonesia.

3 Methodological framework

3.1 Car ownership model

Car possession model assessed the number of cars owned by households each year. Households may choose to alter or retain the number of cars in the following year. Traditional methods for this type of dependent variable usually use discrete choice, ordered logit or probit, and count data models [29]. However, the unordered discrete choice model is preferred because it provides a theoretical framework based on random utility theory commonly used to explain behavior propensity. In the framework of discrete choice analysis, a decision-maker (i.e., a household) was assumed to select the alternative (i.e., the number of cars owned) with the highest utility under the principle of utility maximization. Furthermore, the appeal (in terms of utility) of each alternative can be represented by the sum of the systematic (observable)

and random (unobservable) error components. The total utility of alternative i for household n in year t is specified as:

$$U_{itn} = V_{itm} + \varepsilon_{itn}, \quad (1)$$

where $\boldsymbol{V_{itn}}$ is the observed component of utility; $\boldsymbol{S_{tn}}$ (household's characteristics) and Ltn (location characteristics and transportation system performance) are vectors of alternative specific variables that do not vary over alternatives; C_{itn} is a vector of generic variables including fixed and variable costs of the owned cars; these vary by alternatives and allow the same marginal effect on each alternative's utility; α_i (alternative specific constant), $\beta, \gamma, \delta,$ and λ and are the unknown parameters to be estimated; ε_{itn} is the random error term.

In Equation (1), lagged dummy variables are used to account for state dependence. For each alternative, when the number of cars owned by household n in year t is equal to the number of cars owned by household *n* in the previous year (t - 1), *then* D_{itn} = 1, and 0 otherwise. A statistically significant value of the state dependence parameter shows that car ownership in the current year is influenced by car ownership in the previous year. A discrete choice model can be formulated under specific distributional assumptions regarding the error term. MNL model is commonly used due to its straightforward probability formulation and efficient computational process. The probability expression for model is as follows:

$$P_{itn} = \frac{\exp(V_{itn})}{\sum \exp(V_{jtn})}. \quad (2)$$

The logsum parameter should be within the range of 0 to 1 to ensure consistency with utility maximization. MNL specification is more suitable when NL fails to surpass model. Likelihood ratio test can be used to evaluate MNL and different NL models, in order to ascertain whether the independence of irrelevant alternatives (IIA) assumption is valid [30].

The current study used MNL, a commonly used statistical method for analyzing discrete choices between multiple alternatives. The dependent variable in this model comprised three distinct categories representing varying levels of private car ownership, namely no private car ownership, one private car, and two private cars. MNL analysis facilitated investigating the influence of different factors on individuals' choices among these discrete categories of car ownership. By examining the coefficients associated with the various independent variables, the relative significance and effect of each factor on the probability of belonging to one of the specified categories of private car ownership can be determined. This method provided a robust foundation for exploring the intricate dynamics underlying individuals' decisions regarding car ownership. MNL delineates the relationships between the predictor variables and the probability of belonging to specific ownership categories, offering valuable insights into the factors influencing transportation choices and car ownership patterns.

3.2 Study area and data distributions

This study was conducted in Banda Aceh, the capital of Aceh Province, located in the westernmost part of Indonesia, as shown in Figure 1. It focused on households within the city, comprising nine districts, namely Baiturrahman, Banda Raya, Jaya Baru, Kuta Alam, Kuta Raja, Lueng Bata, Meuraxa, Syiah Kuala, and Ulee Kareng. Furthermore, residents living near Banda Aceh and Aceh Besar municipal areas were included as target respondents.

Revealed Preference (RP) survey method was used to obtain information about the socioeconomic characteristics, travel patterns, and mobility attributes of the targeted households. Furthermore, a paper-pencil direct interview was distributed to 400 respondents in 2020, resulting in 349 valid samples being analyzed. A summary of RP survey results is presented in Table 1.

Table 2 presents descriptive statistics in the form of frequency and percentage (%) of the total number of private car owners based on the aforementioned variables. A total of 349 participants took part in the study. Descriptive statistics was presented based on the collected data, including frequency, percentage, and cumulative percentage. The Table 2 provides a comprehensive overview of the socioeconomic and environmental characteristics of the study sample, presenting descriptive statistics on the frequency distribution and percentage of the various variables under study. Regarding socioeconomic characteristics, 193 respondents (55.30%) were male, while 156 (44.70%)

Table 1 *Summary of RP survey*

Description	Detail
The year of survey	2020
Target location	Banda Aceh city (nine districts and a surrounding area of Aceh Besar municipal)
Distribution sampling method	direct interviews and collected by the enumerators
Number of Sample	400 collected
	349 valid/used for analysis
Distributions	Weekdays (80%) & Weekends (20%)

were female. In terms of age distribution, the majority fell within the 20-29 age group (76.22%). The highest level of education attained by the respondents was also reported, with the majority holding a bachelor's degree (53.87%). Furthermore, the Table 2 covers the distribution of occupation types and monthly income levels within specific categories. Being a student was the most prevalent occupation type (58.74%), and 98 respondents (28.08%) had a monthly income between 3-4.9 million IDR.

Table 3 provides information about mobility attributes and environmental characteristics of the respondents. Specifically, it details the travel time to the nearest bus stop, which refers to the duration of the respondents' journeys. The frequency of respondents in each travel time category was also presented, with 77 (22.06%) spending 2-4 minutes to reach the nearest bus stop. Also included was the travel purpose and origin-destination travel distance (in kilometers). The majority had a travel purpose related to school/college (52.72%), and 94 (26.93%) had travel distances of 4-6.9 kilometers.

Concerning the residential and destinations of trips, 112 respondents (32.09%) were from the Syiah Kuala district, and 162 (46.42%) traveled to the same district. Furthermore, the Table 3 presents characteristics of driving license ownership. The majority of the respondents had a type A driving license (60.46%). An overview of the number of private cars owned by the respondents was also provided. The majority did not own a private car (47.85%), while 142 (40.69%) owned one private car.

4 Empirical result and discussion

4.1 Private vehicle ownership model

A discrete choice multinomial logistic regression analysis was conducted to determine the factors influencing ownership of one or two private cars compared to not owning car. The dataset contained information from 349 respondents. The results of multinomial logistic regression estimation and the goodness of fit for the two models tested are presented in Table 4. In the first model, the initial log-likelihood value (LL_0) was -337.43, and after five iterations, convergence was reached at a log-likelihood value ($LL_{convergent}$) of -280.41. This model showed a significant influence of the variables, with an LR chi-square of 114.04 and a probability of less than 0.001. Furthermore, the pseudo R-squared value of 0.169 showed that model could explain approximately 16.90% of the variation in data.

The first model (car ownership in household) comprised several independent variables. The "Amount of income" variable, ranging from 5-6.9 million IDR (1 USD = 15.822 IDR), had a coefficient of 0.960 and

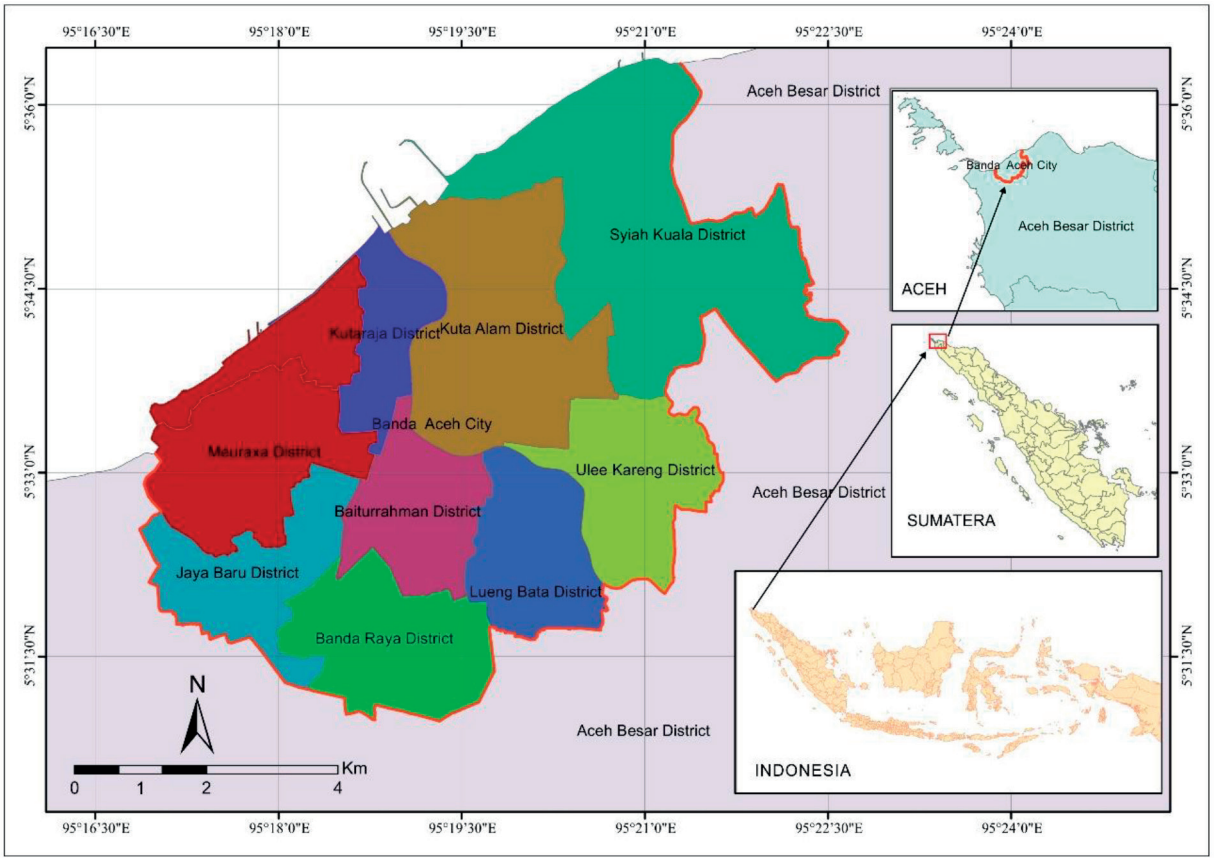

Figure 1 *Banda Aceh city (the area of study within the red area)*

Table 2 *Distribution of socioeconomic variables*

Variable	Freq.	Percent.	Cum.
Socioeconomic characteristics;			
Gender			
Male	193	55.30	55.30
female	156	44.70	100.00
Total	349	100.00	
Age group category			
17 -19 years	46	13.18	13.18
20 - 29 years	266	76.22	89.4
30 - 39 years	27	7.74	97.13
40 - 49 years	8	2.29	99.43
50 - 59 years	2	0.57	100
Total	349	100	
Educational level of household			
Primary education or equivalent	118	33.81	33.81
Diploma	23	6.59	40.4
graduate	188	53.87	94.27
postgraduate	20	5.73	100
Total	349	100	
Type of persons employed			
Government employees	38	10.89	10.89
Employee	34	9.74	20.63
Businessman or Self-employed	15	4.30	25.21
Housewife	56	15.19	100
College or school student	205	58.74	84.81
Total	349	100	
Monthly income in Indonesia Rupiah (IDR), 1 USD equal to 15,743 IDR			
< 1 million IDR	49	14.04	14.04
1 - 2.9 million IDR	68	19.48	33.52
3 - 4.9 million IDR	98	28.08	61.6
5 - 6.9 million IDR	66	18.91	80.52
7 - 9.9 million IDR	35	10.03	90.54
≥ 10 million IDR	33	9.46	100
Total	349	100	

a significance level of 0.040. Therefore, an increase in this category raised the probability of the event by 2.61 times. The "Ownership of Car License, SIM A; yes" variable had a coefficient of 2.356 and a significance level of 0.001, showing that owning a type A car license had a significant positive impact on the probability of the event. Meanwhile, the "Gender; male" variable had a coefficient of -0.529 and a significance level of 0.087, showing a weak negative influence on the event's probability. The "Origin - Destination travel distance (Km); 10-12.9 Km" variable had a coefficient of 0.896 and a significance level of 0.020, showing that an increase in travel distance in this category could increase the probability of the event by 0.896 times. The constant variable had a coefficient of -0.954 and a significance level of 0.001, showing the basic value of the event's probability of owning car in household.

The second model, comprising owning two cars in household, also converged after five iterations to achieve a log likelihood ($LL_{convergent}$) of -280.41. The LR chi-square value of 114.04 and a probability of less than 0.001 showed that the variables in this model had a significant influence. The Pseudo R-squared value of 0.169 showed that model could explain approximately 16.90% of the variation in data. The second model had the same independent variables as the first. The "Amount of income; 5-6.9 million Rupiah (dummy variable)" had a coefficient of 1.608 with a significance of 0.006. Therefore, an increase in this category could raise the probability of an event by approximately 4.993 times. The "Ownership of Car License, SIM A; yes" variable had a coefficient of 3.453 with a significance of 0.001,

Table 3 *Distributions of mobility attributes (1/2)*

Variable	Freq.	Percent.	Cum.
Built Environment characteristics			
Travel Time to Bus Stop			
< 2 minute	37	10.6	10.6
2-4 minute	77	22.06	32.66
5-6 minute	75	21.49	54.15
7-8 minute	55	15.76	69.91
9-10 minute	53	15.19	85.1
>10 minute	52	14.9	100
Total	349	100	
Type of Travel destination			
Work trip	67	19.2	19.2
Trip to school or campus	184	52.72	71.92
Shopping trip	41	11.75	83.67
travel for social activities	14	4.01	87.68
travel for recreational activities	23	6.59	94.27
Work trip	20	5.73	100
Total	349	100	
Travel distance			
<4 km	108	30.95	30.95
4-6.9 km	94	26.93	57.88
7-9.9 km	64	18.34	76.22
10-12.9 km	39	11.17	87.39
> 13	44	12.61	100
Total	349	100	
Location of residence (District)			
Baiturrahman	17	4.87	4.87
Banda Raya	12	3.44	8.31
Jaya Baru	6	1.72	10.03
Kuta Alam	38	10.89	20.92
Kuta Raja	3	0.86	21.78
Lueng Bata	29	8.31	30.09
Meuraxa	7	2.01	32.09
Syiah Kuala	112	32.09	64.18
Ulee Kareng	31	8.88	73.07
Aceh Besar	94	26.93	100
Total	349	100	
Travel destination location (District)			
Baiturrahman	51	14.61	14.61
Banda Raya	6	1.72	16.33
Jaya Baru	4	1.15	17.48
Kuta Alam	43	12.32	29.8
Kuta Raja	3	0.86	30.66
Lueng Bata	11	3.15	33.81
Meuraxa	4	1.15	34.96
Syiah Kuala	162	46.42	81.38
Ulee Kareng	14	4.01	85.39
Aceh Besar	51	14.61	100
Total	349	100	

Table 3 *Distributions of mobility attributes (2/2)*

Variable	Freq.	Percent.	Cum.
Mandatory trip duration (Minutes)			
< 10 minute	92	26.36	26.36
10 - 19 minute	142	40.69	67.05
20 - 29 minute	59	16.91	83.95
30 - 39 minute	31	8.88	92.84
40 - 49 minute	6	1.72	94.56
> 50 minute	19	5.44	100
Total	349	100	
Owning of driving license			
Owning a driving license, SIM A (motorcycle driving license)			
yes	211	60.46	60.46
not	138	39.54	100
Owning a driving license SIM C (private car driving license)			
yes	53	15.19	15.19
not	296	84.81	100
Total	349	100	
Car Ownership			
Number of owning a private car			
Zero vehicle; 0	167	47.85	47.85
One vehicle; 1	142	40.69	88.54
Two vehicles; 2	40	11.46	100
Total	349	100	

Table 4 *Empirical results of private vehicle ownership using MNL*

Variables	Coeff.	S.E	t-value
Model 1: Number of private vehicle ownership (private car=1)			
Monthly income (IDR);			
5 - 6.9 million (dummy variable)	0.960	0.469	2.05**
Owning a driving license (SIM A);			
Yes	2.356	0.329	7.17***
Gender;			
Male	-0.529	0.309	-1.71*
Travel distance Origin -Destination (Km);			
10-12.9 Km (dummy variable)	0.896	0.386	2.32**
Constant	-0.954	0.195	-4.90***
Model 2: Number of private vehicle ownership (private car =2)			
Monthly income (IDR);			
5 - 6.9 million (dummy variable)	1.608	0.587	2.74***
Owning a driving license (SIM A);			
yes	3.453	0.489	7.06***
Gender;			
Male	-2.157	0.492	-4.38***
Travel distance Origin -Destination (Km);			
10-12.9 Km (dummy variable)	0.922	0.572	1.61
Constant	-2.362	0.335	-7.06***
Summary of Statistics			
Pseudo r-squared	0.169		
Chi-square	114.05		
Akaike crit. (AIC)	580.82		
LL-Null	-337.43		

showing a significant positive influence on the chance of an event. The "Gender; male" variable had a coefficient of -2.157 with a significance of 0.001, showing a strong negative influence on the probability of occurrence. The "Origin - Destination travel distance (Km); 10-12.9 Km" variable had a coefficient of 0.922 with a significance of 0.107, showing a weak positive influence on the probability of an event. In addition, the constant had a coefficient of -2.362 with a significance of 0.001, showing the basic value of the probability of occurrence.

This analysis provided comprehensive insights into the impact of each factor on the probability of owning a private car in the multinomial regression model evaluated. Understanding these relationships could offer valuable guidance for creating sustainable and efficient transportation policies in Banda Aceh. To achieve this, transportation planning efforts can focus on developing mobility solutions that correspond with people's needs and preferences while considering the environmental and social consequences of owning a private vehicle.

The odds ratio value from the estimation of private vehicle ownership model could be interpreted using two models. One model comprised numerous independent variables. The "Amount of income; 5-6.9 million Rupiah (dummy variable)" had a coefficient of 0.960 with a significance level of 0.040, showing that an increase in this category could raise the probability of an event by 2.613 times (exp*0.960). The "Ownership of Car License, SIM A; yes" variable had an odds ratio of 10.55 with a significance of 0.001, showing that owning a type A car license significantly raised the chance of occurrence by 10.55 times. The "Gender; male" variable had an odds ratio value of -0.529 with a significance of 0.087, showing a modest negative impact on the probability of occurrence. Lastly, the "Origin - Destination travel distance (Km); 10-12.9 Km" variable had an odds ratio of 2.45 with a significance of 0.020, showing that an increase in travel distance in this category could raise the odds of an event by 2.45 times.

The second model had the same independent variables as the first model. The "Amount of income; 5-6.9 million Rupiah (dummy variable)" had an odds ratio of 4.99 with a significance of 0.006, showing that an increase in this category could result in an approximately 4.99 times greater chance of the event occurring. The "Ownership of Car License, SIM A; yes" variable had an odds ratio of 31,594 with a significance of 0.001, showing a significant positive influence on the event's chance of occurring, with an influence of 31,594 times. Furthermore, the "Gender; male" variable had an odds ratio of 0.12, with a significance of 0.001, showing a strong negative influence on the event's chance of occurring, reducing it by 0.12 times. Lastly, the "Origin - Destination travel distance (Km); 10-12.9 Km" variable had an odds ratio of 2.52 with a significance of 0.107, showing a weak positive influence on the event's chance of occurring.

Further insights regarding the interpretation of model could be obtained through marginal effect analysis. The estimation results provided a comprehensive understanding of the impact of each variable on the probability of private-car ownership in the multinational regression model evaluated. The utility function model equation for private car ownership, as derived from the parameter estimation results, is as follows: a) The utility function model for private car ownership for category 1, as presented in the parameter estimation results table, is:

$$U_{i,1} = -0.954 + (0.960*X_2) + (2.356*X_9) + \\ + (-0.529*X_1) + (0.896*X_6) \quad (3)$$

and (b) The utility function model for private car ownership for category 2, based on the parameter estimation results table, is

$$U_{i,2} = -2.362 + (1.608*X_2) + (3.453*X_9) + \\ + (-2.157*X_1) + (0.922*X_6). \quad (4)$$

In this context, the dependent variable is the "number of private car ownership," while the independent variables consist of four predictor variables, namely total income (variable X_2), ownership of SIM A (variable X_9), gender (variable X_1), and distance from origin to destination (variable X_6).

4.2 Model sensitivity

The sensitivity of model was assessed by calculating marginal effects, which measured the change in the outcome or response variable resulting from a small adjustment in a specific predictor variable while keeping other predictor variables constant. Marginal effects showed how a change in one independent variable influenced the dependent variable, solely considering the impact of that variable and disregarding the impact of others. In policy analysis and decision-making, marginal effects clarified how modifications in particular factors could lead to desired outcomes. The outcomes of the marginal effect analysis are presented in Table 4.

Table 5 presents the outcomes of the marginal effect estimation, offering insights into the variables influencing the probability of an individual owning a private car in the estimated model. These estimations showed the alterations in the probability of vehicle ownership when the predictor variables change. Furthermore, the relevant predictor variables were age group, education level, income level, travel duration from home to the nearest stop, travel destination, and distance between the origin and destination points. The average marginal effect estimate (dy/dx) for each variable measured the change in the probability of owning one private car when the variable changes.

Table 5 *Marginal Effect Calculation*

Variable	0 vehicle ownership	1 vehicle ownership	2 vehicle ownership
Income level; 5-6.9 m Rupiah (dummy variable)	-0.202	0.092	0.110
Vehicle License Ownership,SIM A; yes	-0.521	0.307	0.213
Gender; male	0.137	0.019	-0.157
Travel distance Origin-destination (Km); 10-12.9 Km (dummy variable)	-0.167	0.136	0.031

Note: dy/dx for factor levels is the discrete change from the base level.

Table 6 *Sensitivity analysis using monthly household income as driver*

Policy Scenario	Base Model (Calibrated Model)	Income Increase (+5%)	Income Increase (+10%)	Income Increase (+15%)
0 Private Car Ownership	0.4790	0.4780	0.4770	0.4760
1 Private Car Ownership	0.4070	0.4073	0.4079	0.4080
2 Private Car Ownership	0.1150	0.1154	0.1161	0.1161

The outcomes of the marginal effect estimation showed that an income level of 5-6.9 million IDR per month significantly increased the probability of owning a private car. The marginal effect estimate of 0.0916 (9.16%) showed the probability of owning a private car increased when the respondent fell within this income group. On the other hand, the "Ownership of Driving License, SIM A;" variable had a significant effect on the probability of owning a private car. Also, the average marginal effect estimate of 0.307 (30.7%) showed that changes in the SIM A ownership level significantly affected the probability of vehicle ownership. Regarding gender, males had a significant influence in reducing the probability of owning a private car. The average marginal effect estimate of 0.019 showed that males were associated with a decrease in the probability of vehicle ownership, with a 95% confidence interval ranging between -0.256 and -0.028. Furthermore, Travel Distance Origin - Destination (Km); 10-12.9 Km had a considerable impact in increasing the probability of owning a private car. The average marginal effect estimate of 0.136 showed that longer travel durations were correlated with an increase in the probability of vehicle ownership, with a 95% confidence interval ranging between 0.049 and 0.277.

The analysis of the marginal effect for the category of owning two private cars showed that individuals with an income level of 5-6.9 million IDR per month had a positive impact on the probability of owning two private cars, though not statistically significant. The marginal effect estimate of 0.110 showed that a change in this income group had a small influence on the probability of owning two private cars, with a 95% confidence interval. Owning a Driving License, SIM A, and a higher educational level had a significant positive influence on the probability of owning two private cars. The marginal effect estimate of 0.213 showed that a change in educational level had a significant impact on vehicle ownership, with a 95% confidence interval. However, being a male had a significant negative influence on the probability of owning two private cars. The marginal effect estimate of -0.156 showed that males were negatively correlated with the probability of vehicle ownership. Travel distance origin to destination (km); 10-12.9 km did not have a significant impact on the probability of owning two private cars, specifically 0.0312 (3.12%).

The analysis of marginal effect estimates provided a deeper comprehension of how individual predictor variables impacted the probability of owning one or more private cars. These results provided meaningful guidance for creating better and more sustainable transportation policies in urban areas. The results of the marginal effect estimates, obtained using delta method, provided insight into how discrete adjustments in specific variables affected the probability of car ownership within the context of the estimated model. These marginal effects showed the changes in the probability of vehicle ownership, considering standard errors and p-values.

4.3 Model applications for policy formulation

This study aimed to implement private vehicle ownership model in various scenarios focusing on household income levels ranging from 5-7 million Indonesian Rupiah per month. It also assessed the effect of the income levels on the number of vehicles owned. Specifically, various income level changes (5%, 10%, and 15% increases) were examined, as presented in Table 5.

Table 7 *Validation predicted model*

Observed	Classification			
	Predicted			
	0	1	2	Percent Correct
Zero vehicle ownership (32)	22	10	0	68.75%
1 vehicle ownership (27)	8	18	1	66.66%
2 vehicle ownership (8)	2	6	0	0.00%
Overall Percentage	47.76%	50.74%	1.49%	59.7%

Note: Number of data testing: 67

Tables 5 and 6 present the effects of policy scenarios on household income levels and private car ownership, respectively. Table 6 compares actual conditions with different income change scenarios, while Table 5 explores how private car ownership might change due to income variations. In the base scenario (calibrated model), private car ownership percentages were 47.85%, 40.68%, and 11.46% for each ownership category. With a 5% income increase scenario, private car ownership rose to 40.70% and 11.50% for one and two private cars, respectively. A 10% income increase further raised private car ownership to 40.73% and 11.54% for one and two private cars, respectively. Lastly, in the most extreme scenario, a 15% income increase resulted in private car ownership percentages of 40.79% and 11.61% for one and two private cars, respectively. Sensitivity analysis in Table 5 provides crucial insights for policymakers and practitioners in transportation and public policy to understand the impact of various income change scenarios on private car ownership.

4.4 Model validation

The utility of the model requires rigorous verification to validate its accuracy. Table 7 illustrates the model's predictive capability, where 20% of the data was allocated to the testing subset and applied to the calibrated parameters. The model demonstrates an overall accuracy of 59.70%, suggesting a commendable level of generalizability. The decision to allocate 80% of the data for model calibration was instrumental in achieving an accuracy rate of 65.0%.

In terms of vehicle ownership prediction, the model exhibits reliable performance across different ownership categories. The highest accuracy was observed in the prediction of single-vehicle ownership, with a correct prediction rate of 66.66%. However, the model's highest mispredictions occurred in the zero-vehicle ownership and two-vehicle ownership categories. Despite these mispredictions, the model's performance concerning underfitting and overfitting remains within acceptable limits, with deviations from the testing data predictions staying below 10%. This indicates that the model's predictive reliability is within permissible bounds, ensuring its validity for further application.

5 Conclusions

In conclusion, this study explored discrete choices pertaining to the number of cars based on a survey of car ownership in Banda Aceh. To account for potential independence among alternatives and individual heterogeneity, MNL model was used. The study also assessed the impact of various management strategies on reducing the number of cars.

The initial results showed that a variable income range between 5 and 6.9 million IDR had a significant positive impact on the probability of car ownership. Owning car license (SIM A) significantly improved this probability. On the other hand, male gender had a negligible negative influence, while longer travel distances had a positive effect. In the second model, focusing on owning two cars, a variable income range of 5-6.9 million IDR and having car license (SIM A) significantly increased the probability of car ownership. Being male tended to significantly decrease this probability, and longer travel distances had a weak positive influence.

Sensitivity analysis showed that individual earning between 5-6.9 Million IDR per month had significant probability of owning a private car, contributing up to 9.2%. Owning a driving license also had a significant contribution of approximately 30.7% to car ownership. Conversely, being male had a negative impact on the probability of owning a private car by 1.9%. Longer travel distances tended to increase car ownership within households by 13.6%. Sensitivity analysis showed a similar trend for owning multiple cars within households, with owning a driving license and traveling longer distances contributing to 21.3% and 3.11% of car ownership, respectively.

The outcomes of model application showed that the probabilities of owning no, one, and two cars in household were 47.85%, 40.68%, and 11.46%, respectively. As household income increased by 5-7 million IDR, the proportions slightly moved to 40.70% and 11.48% for the one and two private car ownership categories, respectively. These proportions rose to 40.73% and 11.54%, respectively with a 10% income increase. In the most significant scenario, with a 15% income increase, the proportions further rose to 40.79% and 11.61% for the one and two private car ownership categories,

respectively. These results showed the significant impact of the income variable on vehicle ownership, particularly in developing countries like Indonesia.

Vehicle ownership in Indonesia was significantly influenced by income and driving license ownership. The empirical results showed a positive and significant relationship between these variables, offering valuable insights for policymakers, particularly in reducing private mode dependence and improving the public transportation system. This study had certain limitations, including the focus on a typical medium-sized city in a developing country. Therefore, the results might not be applicable to other cities with distinct characteristics, affecting its usefulness for policymaking.

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Conflicts of interest

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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