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Developing Mode Choice Models for Work and Education Trips in Budhanilkantha Municipality, Nepal

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Abstract

Rapid urbanization and increasing travel demand have created significant transportation challenges in Budhanilkantha municipality including traffic congestion and an inefficient public transportation system. This study aimed to develop and analyze transport mode choice models for work and education based trips using the Multinomial Logit (MNL) modeling approach to identify the influence of socio-economic variables and trip characteristics on commuter's mode choice. A Revealed Preference (RP) survey was conducted to collect 1,043 responses through a multistage stratified sampling technique. The results showed that two-wheelers were the dominant mode for work-based trips while buses were the most preferred mode for education-based trips. For work-based trips, gender, monthly income, travel time, trip distance and travel cost were found to be significant in influencing mode choice, whereas for education-based trips, gender, age, travel time and trip distance were the significant determinants. The developed work and education based trip models achieved overall prediction accuracies of 93.2% and 69.2% respectively, and provide evidence-based support for urban transport planning within the municipality.

Keywords: *Mode Choice Model, Multinomial Logit Model, Work-Based Trips, Education-Based Trips.*

1. Introduction

The urban areas currently hold more than half of the world's population (UN-Habitat, 2022). Excessive and unplanned growth around urban centers of the developing nations have created an immense pressure on its existing transportation network (Mwale et al., 2022). As per the MTMP (2020) of Budhanilkantha municipality, the municipality is rapidly urbanizing, leading to the expansion of mobility needs and travel growth. Meanwhile, the non-uniform population distribution across all the wards has developed varied travel patterns, providing significant challenges for transportation planning.

The master plan further highlights the existence of several transportation issues such as increasing traffic pressure and inefficient public transportation facilities. This has resulted in traffic congestion and a reduction in the overall efficiency of the transportation system. A comprehensive understanding of the mode choice decisions is essential to analyze the factors that influence the choice of transport modes in order to obtain valuable insights for effective urban transportation planning (Chen et al., 2022).

Logit modeling approach based on the principle of random utility maximization is widely used for the evaluation of the mode choice behavior (Haghani et al., 2021). Al-Salih and Esztergár-Kiss (2021) stated that the linear utility function of mode choice is adopted to estimate the utility values, which depend on travel cost, travel time, trip distance along with the parameters linked to the available alternatives. The general form of the utility equation is given below:

$$U_i = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_4 + \ldots\ldots\ldots\ldots + \beta_n X_n \quad \text{........ Equation (1)}$$

Where,

$U_i =$ Total utility of the alternative, also known as representative utility;

$\alpha =$ Calibrated mode-specific constant;

$\beta_1, \beta_2, \beta_3, \ldots\ \beta_n =$ Parameters that measure the importance of each attribute;

$X_1, X_2, X_3, \ldots\ X_n =$ Observable attributes representing travel and socio-economic characteristics of the alternatives.

Out of several discrete choice model types, the Multinomial Logit Model (MNL) is changed to Multinomial Logit (MNL) model is adopted when there is a presence of more than two travel mode options. It is mostly preferred due to its simplicity and flexibility in integrating and eliminating travel options. The MNL model identifies the proportions of selecting each travel option on the basis of the systematic portions of its utility. Each model represents a relationship through a set of mathematical parameters (Ranjan & Sinha, 2024). The general equation for determining the probability of the mode choice for option 'k' out of 'n' number of travel options using MNL is given by:

$$P(k) = \frac{e^{U_k}}{\sum_k^n e^{U_k}} \quad \text{.............................. Equation (2)}$$

Where,

$P(k) =$ Probability that mode option 'k' would be chosen;

$e =$ Base of natural logarithms.

Several studies have identified socio-economic variables and trip characteristics as the major determinants of travel behavior and mode choice. He et al. (2022) highlighted trip distance, travel cost, age and monthly income whereas Tampanatu (2022) analyzed socio-economic variables such as age, monthly income, vehicle ownership and family size as the influential factors for the choice of transport modes. Similarly, Ali and Esztergár-Kiss (2026) revealed license ownership as a crucial predictor of motorized mode choice along with age, gender, family size and monthly income.

The mode choice analysis in the Nepalese context has been primarily concentrated on work-based trips while education-based trips are often neglected and remain limited. Chataut and Shrestha (2021) explained that education-based trips comprise a majority of travel demand, requiring adequate study for policy formulation. Therefore, the objective of the study is to develop and analyze transport mode choice models for both work and education based trips in Budhanilkantha Municipality.

2. Materials and Methods

The study adopted a quantitative research approach using both primary and secondary data. In order to collect primary data, the Revealed Preference (RP) survey was conducted using a questionnaire consisting of two sections. Section I represented the questions related to socio-economic characteristics whereas Section II represented trip characteristics. For the secondary data, the MTMP (2020), NSO (2021) and other relevant literatures were adopted.

2.1 Sample Size and Sampling Technique

The sample size was estimated using the following formula provided by Cochran (1977):

$$SS = p * (1 - p) * (\frac{Z}{e})^2 \quad \text{.......................... Equation (3)}$$

Where, SS *is* the sample size, p is the estimated proportion, Z is the Z-score corresponding to the desired confidence level and e is the margin of error. Assuming 95% confidence level (Z=1.96), margin of error of ±5% and population proportion of 50%, we get sample size as 384.16, which was rounded to 384. However during data collection, 1043 data were recorded, out of which 522 responses belong to work-based trips and 521 belong to education-based trips. The study adopted a multistage stratified sampling strategy for mode choice analysis. First, the total sample was divided proportionally as per population size in each ward. Afterwards, respondents were stratified proportionally by gender on the basis of the ward-level gender population distribution. At last, trip purpose stratification was conducted on the basis of work and educational trip purposes.

2.2 Study Area

Budhanilkantha municipality, situated on the northern boundary of the Kathmandu valley was considered as the area of study (Sapkota, 2025). As per NSO (2021), the municipality has a total population of 177,557 out of which 87,337 are males and 90,220 are females. There are a total of 46,930 households.

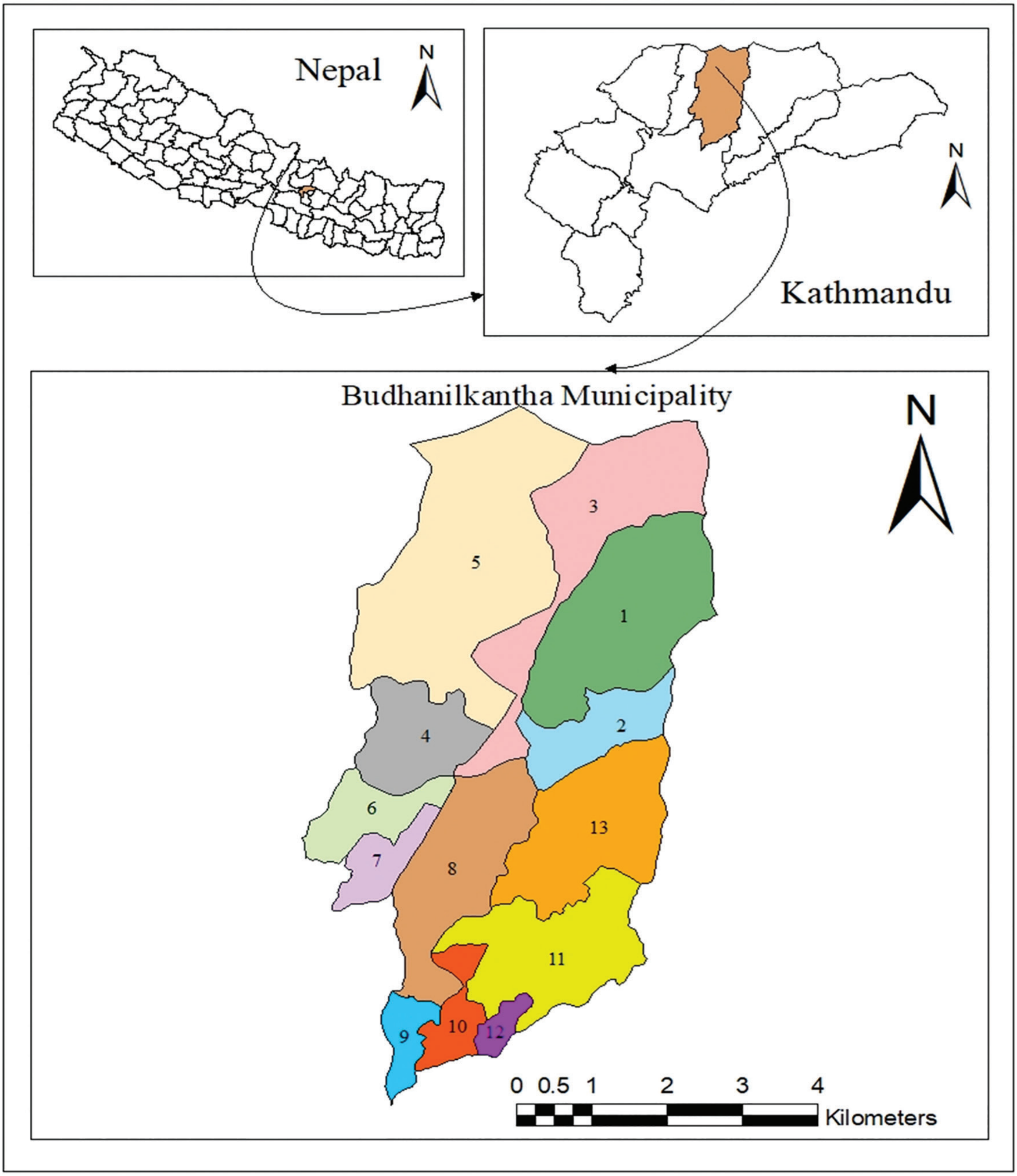

Figure 1: Study Area Map

2.3 Data Analysis

The data analysis of this study involves the development of the utility function and the determination of mode choice probabilities through prediction accuracy.

2.3.1 Development of Utility Function

For the development of the utility functions, socio-economic variables included were age, gender, monthly income, family size, license ownership and vehicle ownership whereas trip characteristics were travel cost, travel time and trip distance. Mulyanto (2022) explained that the Variance Inflation Factor (VIF) can be adopted to measure the presence of multicollinearity between the variables. The VIF value greater than 5 indicates the presence of multicollinearity and can be computed as:

$$VIF = \frac{1}{1-R^2} = \frac{1}{Tolerance} \text{........................ Equation (4)}$$

Where, R^2 is the coefficient of determination.

In our study, the independent variables with VIF values lesser than 5 were taken for the development of the utility function. The VIF calculation was done in Python. After the removal of the variables with high multicollinearity, the software named the Statistical Package for the Social Science (SPSS) was adopted for the development of the utility function.

2.3.2 Determination of Mode Choice Probabilities

After the development of the utility function for both trips, the mode choice probabilities were determined using the confusion matrix. SPSS was used for the determination of the prediction accuracy of the developed utility functions.

2.4 Model Validation

The developed utility function was validated to ensure that it represents the real world behavior. The obtained Likelihood Ratio (LR) value was evaluated with its corresponding chi-square value at the 5% level of significance. If the significance value is less than 0.05, the model is said to be statistically significant, indicating that the inclusion of independent variables provides a significantly better fit than the intercept-only model. The LR is obtained by (Peker et al., 2024):

$$LR = -2(LL_R - LL_F) \text{ .... Equation (5)}$$

Where LL_R is the log-likelihood of the reference or intercept-only model and LL_F is the log-likelihood of the full model containing independent variables. The pseudo R^2 from the Cox and Snell, Nagelkerke and McFadden indices were evaluated to check whether the developed model showed satisfactory explanatory capability in representing work and education-based travel mode choice behavior.

The LR, along with the R^2 values of Cox and Snell, McFadden and Nagelkerke indices were obtained from SPSS.

3. Results and Discussion

3.1 Features Screening for Utility Function Development

This stage involves the screening of both dependent and independent variables that were used for the development of utility function.

3.1.1 Mode Frequency and Proportions

Table 1 illustrates the distribution of mode choice across the work-based and education-based trips in terms of frequency and percentage. Two-wheelers are the dominant mode in work-based trips accounting for

46.36% whereas bus usage is highest in education-based trips with 47.21%.

Table 1: Mode Frequency and Proportion

Mode Used	Work-Based Trips		Educational Trips	
	Frequency	Proportion (%)	Frequency	Proportions (%)
Two-Wheeler	242	46.36	160	30.71
Bus	149	28.54	247	47.41
Walk	82	15.71	89	17.08
Private Car	21	4.02	-	-
Microbus	16	3.07	19	6.65
Tempo	12	2.3	6	1.15
Total	522	100	521	100

Rainey and McCaskey (2021) explained that smaller sample size often leads to inefficiency and biasness in estimating parameters in logit models. Therefore, the present study focuses on developing utility functions for the modes with proportion greater than 5% in each trip purpose. The modes with proportion greater than 5% in each trip purpose are given below with their respective proportions out of 100% indicated in the parentheses.

Work-Based Trips: Two Wheeler (46.36%), Bus (28.54%) and Walk (15.71%).

Educational Trips: Bus (47.41%), Two Wheeler (30.71%) and Walk (17.08%).

3.1.2 Multicollinearity Assessment Using VIF

The study adopted Equation (4) for the computation of VIF and the corresponding trip purpose wise VIF values of the independent variables are listed in Table 2.

Table 2: VIF Values of Independent Variables

Independent Variables	VIF Values	
	Work-Based Trips	Educational Trips
Gender	1.0895	1.0411
Age	1.4689	1.1203
Monthly Income	1.7257	-
Family Size	1.0248	1.0073
Vehicle Ownership	6.7779	14.0350
License Ownership	6.8524	11.8662
Travel Time	2.9861	2.9135
Trip Distance	2.9824	4.6688
Travel Cost	1.5823	5.0978

The VIF values shown in Table 2 indicate that vehicle ownership and license ownership exceeded the threshold value of 5 in both trip purposes while travel cost exceeded in education-based trips. Hence, these variables were removed from the model prior to the development of the utility function to avoid instability in parameter estimation.

3.2 Mode Choice Models for Work-Based and Education-Based Trips

In this study, an initial MNL model was developed considering mode choice as dependent variables along with socio-economic and trip characteristics variables as independent. The significance of the independent variables was assessed using a likelihood ratio test, the insignificant variables were removed and the final utility functions were developed for each mode with the remaining significant variables. In MNL, one of the alternatives is normalized to ensure model identification and the parameters of the remaining alternative are interpreted with reference to that alternative (de Grange et al., 2024). Our study adopted bus as the reference alternative and the utility functions for other modes were determined with respect to it. Bus was chosen as the reference alternative because it represents the primary form of public transportation in the municipality as indicated by mode frequency in Table 1. Furthermore, the study aims to develop strategies for improving public transport efficiency and enhancing transportation planning based on traveler's behavior within the study area.

3.2.1 Mode Choice Models for Work-Based Trips

Table 3 presents the initial model fitting results for the MNL model developed for work-based trips.

Table 3: Initial Model Fitting Information for Work-Based Model

Model	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	945.185			
Final	170.290	774.895	14	p<0.001

The intercept-only model produced a −2 Log Likelihood value of 945.185, while the model containing independent variables showed a reduced value of 170.290. The likelihood ratio chi-square statistic was 774.895 with 14 degrees of freedom and a significance value of $p<0.001$. The obtained significance value was lower than 0.05, so the developed model was considered statistically significant demonstrating that the explanatory variables provided a better fit than the intercept-only model.

Table 4 represents the likelihood ratio test results for the independent variables included in the MNL model for work-based trips.

Table 4: Likelihood Ratio Test for Work-Based Model

Effect	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood of Reduced Model	**Chi-Square**	**df**	**Sig.**
Intercept	-	-	-	-
Age	172.948	2.658	2	0.265
Gender	180.548	10.258	2	0.006
Family Size	171.529	1.239	2	0.538
Monthly Income	177.488	7.198	2	0.027
Travel Time	189.778	19.489	2	p<0.001
Trip Distance	200.830	30.540	2	p<0.001
Travel Cost	673.036	502.746	2	p<0.001

Age and family size were found to be statistically insignificant as their significance values were greater than 0.05. Therefore, these insignificant variables were excluded from the final model development.

Table 5 represents the final model fitting information after the removal of the insignificant variables from likelihood ratio test. Compared to the initial model, the final model demonstrated improved performance after the removal of statistically insignificant variables.

Table 5: Final Model Fitting Information for Work-Based Model

Model	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood	**Chi-Square**	**df**	**Sig.**
Intercept Only	945.185			
Final	157.590	771.428	10	p<0.001

The −2 Log Likelihood value decreased from 170.290 in the initial model to 157.590 in the final model, indicating better agreement between the model and the observed data. The likelihood ratio chi-square statistic for the final model was 771.428 with 10 degrees of freedom and a significance value of $p<0.001$. Since the significance value was lower than 0.05, the final MNL model was found to be statistically significant.

Table 6 represents the pseudo R^2 values of the developed model and Table 7 represents the parameter estimates of the developed model considering Bus as reference alternative.

Table 6: Pseudo R-Square Values of Work-Based Model

Pseudo R-Square	
Cox and Snell	0.806
Nagelkerke	0.929
McFadden	0.812

Table 7: Parameter Estimates for Work-Based Model

Mode Used[a]		B	Std. Error	Wald	df	Sig.	Exp (B)	95% Confidence Interval for Exp(B)	
								Lower Bound	Upper Bound
Two-Wheeler	Intercept	-1.317	0.809	2.652	1	0.103			
	Gender	1.164	0.429	7.381	1	0.007	3.204	1.383	7.422
	Monthly Income	0.029	0.014	4.528	1	0.033	1.029	1.002	1.057
	Travel Time	-0.184	0.040	20.796	1	p<0.001	0.832	0.769	0.901
	Trip Distance	-1.296	0.242	28.777	1	p<0.001	0.274	0.170	0.439
	Travel Cost	0.327	0.039	70.320	1	p<0.001	1.386	1.284	1.496
Walk	Intercept	4.412	2.760	2.555	1	0.110			
	Gender	-1.422	1.618	0.772	1	0.380	0.241	0.010	5.757
	Monthly Income	0.032	0.068	0.216	1	0.642	1.032	0.903	1.180
	Travel Time	-0.067	0.104	0.410	1	0.522	0.935	0.762	1.148
	Trip Distance	0.761	1.231	0.382	1	0.536	2.140	0.192	23.871
	Travel Cost	-0.611	0.190	10.356	1	0.001	0.543	0.374	0.787

a. *The reference alternative is: Bus.*

The developed utility functions for work-based model are listed below:

U_{Bus}= 0 …………………………………..………………… Equation (6)

$U_{Two\text{-}Wheeler=}$ 1.164 (Gender) + (0.029) Monthly Income – 0.184 (Travel Time) -1.296 (Trip Distance) + 0.327 (Travel Cost)……………………………….. Equation (7)

$U_{Walk=}$ -0.611 (Travel Cost) ……………………………… Equation (8)

Equation (7) indicates that gender, monthly income, and travel cost positively influence the likelihood of choosing two-wheelers over bus for work-based trips whereas travel time and trip distance negatively influence mode choice. Similarly, Equation (8) shows that increasing travel cost decreases the likelihood of choosing walking over bus for work-based trips.

Table 8 represents the prediction accuracy of the developed model through confusion matrix. The overall percentage row indicates that 31.0 percent of the observations were predicted as Bus, 51.8 percent as Two-Wheeler and 17.2 percent as Walk, with an overall correct prediction percentage of 93.2 percent.

Table 8: Prediction Accuracy of Work-Based Model

Observed	Predicted			
	Bus	Two-Wheeler	Walk	Percent Correct
Bus	131	16	1	88.5%
Two-Wheeler	14	228	0	94.2%
Walk	1	0	80	98.8%
Overall Percentage	31.0%	51.8%	17.2%	93.2%

3.2.2 Mode Choice Models for Education-Based Trips

Table 9 presents the initial model fitting results for the MNL model developed for education-based trips. The likelihood ratio chi-square statistic was 368.699 with 10 degrees of freedom and a significance value of $p<0.001$. Since the obtained significance value was lower than the 0.05, the developed model was considered statistically significant.

Table 9: Initial Model Fitting Information for Education-Based Model

Model	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	884.140			
Final	515.441	368.699	10	p<0.001

Table 10 represents the likelihood ratio test results for the independent variables included in the MNL model for education-based trips. Family size was found to be statistically insignificant since its significance value is greater than 0.05. Hence, it was removed prior to the development of the final model. Meanwhile, gender, age, travel time and trip distance were the significant determinants of mode choice with respect to education-based trips.

Table 10: Likelihood Ratio Test for Education-Based Model

Effect	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	-	-	-	-
Gender	522.763	7.323	2	0.026
Age	548.287	32.847	2	0.000
Family Size	518.108	2.668	2	0.263
Travel Time	676.552	161.111	2	p<0.001
Trip Distance	816.906	301.466	2	p<0.001

Table 11 represents the final model fitting information for the MNL model developed for education-based trips after the removal of statistically insignificant variables.

Table 11: Final Model Fitting Information for Education-Based Model

Model	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	884.140			
Final	376.456	366.031	8	$p<0.001$

Table 12 represents the pseudo R^2 values of the developed model and Table 13 represents the parameter estimates of the developed model, considering Bus as reference alternative.

Table 12: Pseudo R-Square Values of Education-Based Model

Pseudo R-Square	
Cox and Snell	0.522
Nagelkerke	0.600
McFadden	0.362

Table 13: Parameter Estimates for Education-Based Model

Mode Used[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
								Lower Bound	Upper Bound
Two-Wheeler	Intercept	-3.276	0.603	29.491	1	$p<0.001$			
	Gender	0.613	0.227	7.302	1	0.007	1.846	1.183	2.879
	Age	0.127	0.025	26.660	1	$p<0.001$	1.136	1.082	1.192
	Travel Time	-0.101	0.020	25.454	1	$p<0.001$	0.904	0.869	0.940
	Trip Distance	0.484	0.090	28.928	1	$p<0.001$	1.622	1.360	1.935
Walk	Intercept	1.596	1.207	1.751	1	0.186			
	Gender	0.050	0.388	0.016	1	0.899	1.051	0.491	2.249
	Age	-0.051	0.054	0.899	1	0.343	0.950	0.855	1.056
	Travel Time	0.327	0.048	46.876	1	$p<0.001$	1.386	1.263	1.522
	Trip Distance	-3.261	0.413	62.466	1	$p<0.001$	0.038	0.017	0.086

a. *The reference alternative is: Bus.*

The developed utility functions for education-based model are as follow:

$U_{Bus}=0$ …………………….………………… Equation (9)

$U_{Two\text{-}Wheeler} =$ -3.276 + 0.613 (Gender) + 0.127 (Age) – 0.101 (Travel Time) + 0.484. (Trip Distance) ………………………..……………………………Equation (10)

$U_{Walk=}$ 0.327 (Travel Time) – 3.261 (Trip Distance)…..………… Equation (11)

Equation (10) indicates that gender, age and trip distance positively influenced the likelihood of choosing two-wheelers over bus for education-based trips, whereas travel time negatively influenced mode choice. Similarly, Equation (11) shows that travel time positively influences the likelihood of choosing walking over bus for education-based trips, whereas trip distance negatively influences mode choice. Table 14 represents the prediction accuracy of the developed model through confusion matrix. The overall percentage row indicates that 59.1 percent of the observations were predicted as Bus, 21.2 percent as Two-Wheeler and 19.8 percent as Walk, with an overall correct prediction percentage of 69.2 percent.

Table 14: Prediction Accuracy of Education-Based Model

Observed	Predicted			
	Bus	**Two-Wheeler**	**Walk**	**Percent Correct**
Bus	197	34	16	79.8%
Two-Wheeler	86	69	5	43.1%
Walk	10	2	77	86.5%
Overall Percentage	59.1%	21.2%	19.8%	69.2%

4. Conclusions

This study developed and analyzed transport mode choice models for work-based and education-based trips in Budhanilkantha Municipality using the MNL approach based on RP survey data. The results demonstrated that both socio-economic and trip characteristics significantly influence traveler's mode choice behavior. Gender, monthly income, travel time, trip distance and travel cost significantly affected work-based trips whereas gender, age, travel time and trip distance were significant determinants for education-based trips. The work-based and education-based models achieved overall prediction accuracies of 93.2% and 69.2%, respectively. The findings revealed distinct travel behavior across trip purposes, with two-wheelers dominating work-based trips and buses being the preferred mode for education-based trips. These results suggest that transportation policies should account for trip purpose specific travel behavior. Improving the reliability, accessibility and efficiency of public transportation particularly by reducing travel time and enhancing service quality during peak commuting periods could encourage greater use of public transport modes. In addition, improving pedestrian infrastructure would further support safe and sustainable urban mobility within the municipality.

Future research may incorporate latent behavioral factors such as perceptions of comfort, safety and environmental awareness through latent variable or hybrid choice modeling approaches to better understand traveler decision making. In addition, alternative discrete choice modeling approaches such as mixed logit or nested logit models could be applied to better capture unobserved heterogeneity and correlations among transport alternatives.

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