

Mode Choice Behaviour of Students Using Structural Equation Modelling



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Abstract Transportation is one of the most significant aspects in the overall growth of a nation, requiring serious consideration in transportation planning. The planning and management of any transportation system involve a thorough examination of the mode choice behaviour of people. It enables one to determine the demands and most preferred modes of transportation. Since, students make up a major portion of the population whose travel behavior is extremely distinctive and flexible, making them receptive to a variety of different travel modes is necessary in order to construct the travel demand model for a region. This study aims to examine the mode choice behaviour of students using the activity-travel data of Calicut city, Kerala state, India. Structural Equation Modelling was adopted to test the separate effect of household characteristics, personal characteristics and a combined effect of both personal and household characteristics and the effect of travel time, travel distance and travel cost on the mode choice of students.

Keywords Structural equation modelling · Students · Mode choice

1 Introduction

Urban regions are seeing a tremendous expansion in the number of schools and colleges due to a growing demand for education. The morning and evening peak hours of the working day in a growing nation like India cause considerable traffic congestion for all commuter groups. Student commuters make up a considerable share of the traffic jams, although they are underrepresented in the majority of travel research.

Students exhibit a distinct way of travelling and are more eager to try out different travel modes. Moreover, their travel behaviour shows some amount of uncertainty, which distinguishes them from the general population. Students' travel needs have an impact on the travel behaviour of other household members. School students in

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particular rely heavily on household adults or other adults to drive them to activities. College and university students, however, have complicated and diverse travel behaviour. They have autonomy in their decision-making regarding their activities and travel. Additionally, the daily activities of a student are highly influenced by their peers. Therefore, in order to create an appropriate travel demand model for a region, a research that takes into account how the students commute is required. This is crucial for places with large universities or lots of colleges and schools since many students and staff will be travelling during certain hours of the day, which may cause congestion in the area. Exploration of students' travel behaviour can be instructive and reveal valuable information about associations with the built environment and the extent of differences in travel (e.g., trip generation and mode choices) compared with the general population [1]. Hence, by better understanding the travel behavior of students, urban planners can propose suitable policy measures to promote a more comfortable travelling environment for other population segments as well.

The objective of this study is to investigate the impact of household and personal characteristics and other travel characteristics of students on their mode choice. This study also attempts to identify the potential policy factors that might encourage students to utilise sustainable modes of transportation.

2 Literature Review

Mode choice models are frequently used to determine the impact of socio-demographic characteristics, service features, etc. on the decision-making process for mode selection. Various socio-demographic and service factors, such as travel time, travel cost, gender, age, driving privileges, residential location, waiting times, the number of transfers required when using public transport, comfort, etc., are significant and often employed in most research [2]. Studies have indicated that adding land use or built-environment factors to the traditional parameters, such as personal and household socio-economic characteristics, and features of the activities that people travel for, can enhance the travel demand model. One of the factors influencing a commuter's choice of travel route is likely to be one of the residential site features, which are included in the category of residential location characteristics.

A study in Gainesville, Florida, examined a wide range of factors. These factors included overall density, the balance of jobs and residents, the job mix, the commercial floor area ratio, sidewalk coverage, bike lane and paved shoulder coverage, street tree coverage, and accessibility measures, in addition to household income, auto ownership, license ownership, and walk time and bike time. According to the findings, students are more likely to walk or bike to smaller schools in walkable areas than to larger schools in distant areas [3]. According to Danish surveys, kids aged 5–8 are equally likely to get to school on foot, on bicycle, by automobile or by public transport, whereas students aged 15–16 are more likely to bike. All ages could walk and use public transport equally. They discovered that whereas males were more likely to ride to school, girls were more likely to walk and take

public transport. The findings showed that students' choice of transport mode is not substantially influenced by family type or financial level [4]. Another study revealed that socio-demographics, household mobility alternatives, social/cultural norms, and traffic safety may all be equally significant [5]. In Toronto, Canada, the effects of the built environment and household interactions on the school travel behaviour of 11-year-old students were examined. A Multinomial Logit model with geographic weighting was employed to investigate mode choice behaviour. The results of this study revealed that the students' decision to choose a certain mode of transportation was most significantly influenced by travel distance.

According to a study conducted in Kochi, India, school buses were chosen by elementary and secondary school students over public buses when it came to their safety and the household's monthly income. School children prefer school buses more when the distance between their location and the destination rises, whereas high school and college students like public transportation and two-wheelers, respectively. Gender was a less important factor for the mode choice decision of higher secondary students compared to the school and college students. Household size and number of employees per household were significant for the mode choice behaviour of school students but not for the other two categories [6].

3 Methodology

The data for this study comes from a 2010–2011 activity-travel survey conducted in Kozhikode city of state Kerala, India, through a home-interview survey. For data collection, random sampling scheme was adopted. The database includes household information, personal information and one-day activity-travel details of all individuals [7]. Details pertaining to 4700 students were extracted from the main database, for carrying out the study.

As the present study, the aims to examine the direct effects, indirect effects and total effects among various variables, a structural equation model for mode choice is developed. Mode choice is considered an endogenous (dependent) variable. Household characteristics and personal characteristics as latent exogenous variables. Travel time, travel distance and travel cost as observed exogenous variables. All the exogenous variables are selected on trial basis to get a stable and only the statistically significant variables. The details of endogenous and exogenous variables used in the study are shown in Table 1.

For the purpose of thorough understanding and to gain a full grasp of the impact of socio-demographic characteristics of students on mode choice, hypotheses are formulated as follows:

Hypothesis 1: Personal characteristics influence mode choice.

Hypothesis 2: Household characteristics influence mode choice.

Hypothesis 3: Both personal and household characteristics influence mode choice.

Hypothesis 4: Travel distance affects mode choice.

Hypothesis 5: Travel time affects mode choice.

Table 1 Endogenous and exogenous variables used in the study

Variable	Notation used	Description and code used in the dataset
Mode choice	MODE	Type of mode chosen (1-car, 2-two-wheeler, 3-autorickshaw, 4-bus, 5- cycle, 6-walk)
Personal characteristics		
Age	AGE	Age of student
Gender	GENDER	Gender of the individual (1-Female, 0-Male)
Education	EDUCATION	Education level (6-Post graduate and above,5-Graduate,4-Higher Secondary, 3-High School, 2-Primary school, 1-Kindergarten, 0-No education)
Personal Income	PERINC	Personal monthly income
License availability	LICAVAIL	License status (1-Yes, 0-No)
Type of vehicle	TYPVEH	Type of vehicle owned (6- Only Cycle, 5- Only HMV, 4- Both Car and TW, 3-Only auto rickshaw, 2-Only Two-wheeler, 1-Only car, 0-No vehicle)
Exclusive vehicle	EXCLUSIVE	Vehicle available for exclusive use (1-Yes, 0-No)
Type of exclusive vehicle	TYPE EXVEH	Type of vehicle available for exclusive use (3-Only cycle, 2-Only car, 1-Only 2W, 0- No vehicle)
Household Characteristics		
Household size	HHSIZE	Number of household members
Dwelling unit	DWELL	Type of dwelling unit (1-apartment, 0-independent)
House ownership	OWNER	House ownership (0-own, 1- rented, 2- Govt. quarters, 3-others)
Household income	HHINC	Household monthly income
Students	STUD	Number of students in household
Vehicles in household	HHVEHICLE	Number of vehicles in household
Employed persons in the household	HHEMPLOY	Number of employed persons in the household
Travel details		
Travel distance	TD	Travel distance (in km)
Travel time	TT	Travel time (in minutes)
Travel cost	TC	Travel cost (INR)
Travel time per km	TT per km	Travel time per km (in minutes)
Travel cost per km	TC per km	Travel cost per km (INR)

Hypothesis 6: Travel cost affects mode choice.

4 Data Summary

The average household size of the study area was found to be 4, with a minimum of 1 and a maximum of 13 members per household. Around 41% of households own at least one automobile. In the dataset, 51% were females and 49% were males. About 24% of the sample were students. Table 2 summarizes the descriptive statistics of the sample data.

Table 3 presents the summary statistics of travel details, based on various travel modes. From the analysis, it was observed that for long distance travel, bus is preferred which takes the maximum time as well.

Table 2 Descriptive statistics of the sample data

Variable	Percent	Mean	Std. Dev
Gender	Female: 51 Male: 49	–	–
Age	–	12.90	4.72
Has driving license	28	–	–
Has vehicle available for exclusive use	10	–	–
Household size	–	4	1.64
Household income (INR)	–	23,707	23,205
Number of employed persons in household	–	1.29	0.88
Number of vehicles in household	–	0.98	0.94

Table 3 Summary statistics of travel details

		Car	TW	AR	Bus	Cycle	Walk
Mode share, %		10.97	23.90	7.89	38.80	1.33	17.12
Travel Time (TT), minutes	Maximum	30	30	35	60	40	30
	Minimum	5	5	5	5	3	5
	Mean	11.57	10.76	10.89	20.36	14.87	10.59
Travel Distance (TD), kilometre	Maximum	18	18.8	17.5	21.1	11.4	9.8
	Minimum	0.3	0.3	0.3	0.3	0.3	0.3
	Mean	5.30	4.70	3.79	5.74	1.77	0.88
Travel Cost (TC), INR	Maximum	73	30	49	15	0	0
	Minimum	2	1	12	5	0	0
	Mean	21.77	7.76	24.93	5.64	0	0

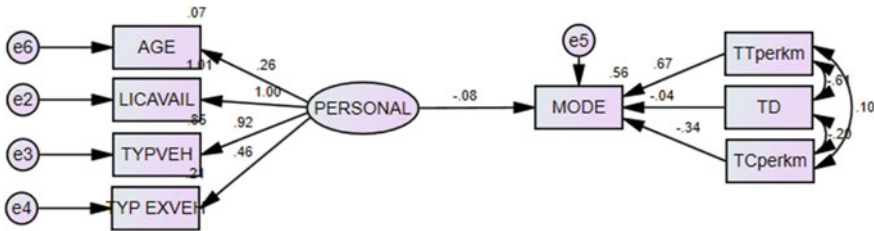


Fig. 1 Structural model based on Personal Characteristics

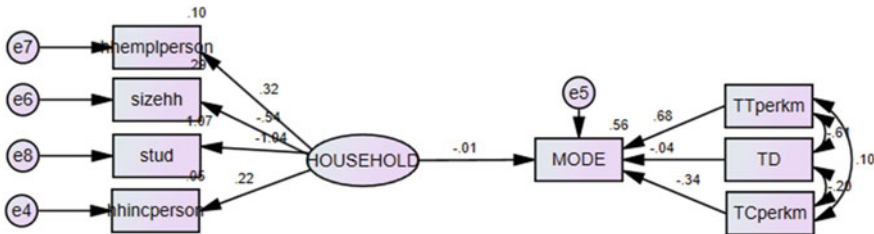


Fig. 2 Structural model based on household characteristics

5 Mode Choice Modelling

In order to determine the impact of socio-demographic characteristics of students on mode choice, structural equation models are developed. Number of samples used for model development is 4700. The structural models developed for students based on personal characteristics and household characteristics separately are shown in Figs. 1 and 2, respectively. Figure 3 shows the structural model developed for the combined effect of personal and household characteristics on mode choice. The standardized regression weight estimates, critical ratio and p-values, along with the goodness of fit measures are tabulated in Tables 4, 5 and 6. The level of significance is based on the critical ratio of the regression estimate. The statistic formed by dividing an estimate by its standard error is called the critical ratio (CR). Thus, when critical ratio values are greater than or equal to 1.96, it indicates a 95 percent level of significance.

6 Discussions

The effect of personal variables on mode choice shows that age has a positive influence. This implies that as the age of the student increases, they are more likely to prefer bus, cycle and walk. A similar finding was previously reported in a study conducted in Southern California [8]. This may be attributed to the fact that parents feel more comfortable letting older children use these modes. In addition to this, it

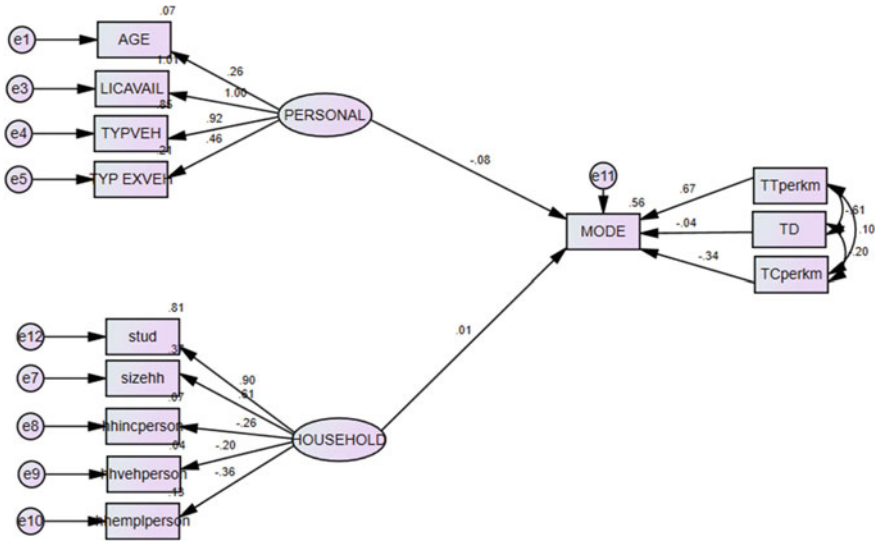


Fig. 3 Structural model based on both personal and household characteristics

Table 4 Model result (Personal characteristics)

	Estimate	CR	p
AGE ← PERSONAL	0.261	18.296	***
LICAVAIL ← PERSONAL	1.004		
TYPVEH ← PERSONAL	0.922	86.418	***
TYPEXVEH ← PERSONAL	0.463	33.725	***
MODE ← PERSONAL	-0.080	-8.282	***
MODE ← TT per km	0.675	55.278	***
MODE ← TD	-0.044	-3.533	***
MODE ← TC per km	-0.339	-34.394	***
Goodness of Fit Measures			
Comparative Fit Index (CFI)	0.975		
Tucker Lewis Index (TLI)	0.959		
Root Mean Square Error of Approximation (RMSEA)	0.073		

may be assumed that at graduation and post-graduation level, students are ready to travel more distance than they travelled for their schooling, causing them to prefer bus, cycle and walk as travel mode. Gender did not show any effect on their mode choice decision, which contradicts the result obtained by a study conducted in Iran [1]. The type of vehicle owned and the type of exclusive vehicle owned have a positive impact on the mode choice. Household size and the presence of students in a

Table 5 Model result (Household characteristics)

	Estimate	CR	p
SIZEHH ← HOUSEHOLD	-0.535	-17.992	***
HHINCPERSON ← HOUSEHOLD	0.218	11.269	***
HHEMPLPERSON ← HOUSEHOLD	0.322		
	Estimate	CR	p
STUD ← HOUSEHOLD	-1.035	-12.331	***
MODE ← HOUSEHOLD	-0.005	-0.470	0.638
MODE ← TT per km	0.678	55.389	***
MODE ← TD	-0.044	-3.569	***
MODE ← TC per km	-0.336	-34.025	***
Goodness of Fit Measures			
Comparative Fit Index (CFI)	0.996		
Tucker Lewis Index (TLI)	0.991		
Root Mean Square Error of Approximation (RMSEA)	0.021		

Table 6 Model result (Personal and Household characteristics)

	Estimate	CR	p
AGE ← PERSONAL	0.261		
LICAVAIL ← PERSONAL	1.004	18.297	***
TYPVEH ← PERSONAL	0.922	18.510	***
TYPEXVEH ← PERSONAL	0.463	16.541	***
SIZEHH ← HOUSEHOLD	0.610		
HHINCPERSON ← HOUSEHOLD	-0.256	-13.297	***
HHVEHPERSON ← HOUSEHOLD	-0.197	-10.378	***
HHEMPLPERSON ← HOUSEHOLD	-0.360	-18.248	***
STUD ← HOUSEHOLD	0.898	19.709	***
MODE ← PERSONAL	-0.080	-7.604	***
MODE ← HOUSEHOLD	0.009	0.693	0.488
MODE ← TT per km	0.675	55.302	***
MODE ← TD	-0.044	-3.534	***
MODE ← TC per km	-0.339	-34.409	
Goodness of Fit Measures			
Comparative Fit Index (CFI)	0.963		
Tucker Lewis Index (TLI)	0.944		
Root Mean Square Error of Approximation (RMSEA)	0.050		

household are having a negative effect on mode choice which indicates that as the household size and the number of students in a household increases preference for car increases. The probable reason may be getting accompanied by any other person or an adult from the household. The number of employed persons per household size is negatively influencing the mode choice of students. That means, increase in the number of employed persons in households increases the chance of choosing a car and two-wheeler as travel modes. This may be because the students are dropped off/picked up by car and two-wheeler by household members while going to work. The household income per person has a positive impact on mode choice. This implies that as the household income per person increases, the more likely is the chance to prefer the bus. The number of employed persons per household size is negatively influencing the mode choice of students. That means, an increase in the number of employed persons in households increases the chance of choosing a car as a travel mode.

Among the travel attributes, travel distance and travel cost per kilometer have a negative value, indicating the preference for car for long-distance trips. Travel time per kilometer is positively influencing the mode choice. Results obtained from the present study and study conducted in Ahmedabad, Gujarat, India [9] simply that travel time, travel distance and travel cost were found to be significant in the mode choice of students. Private cars and two-wheelers were found to be the most preferable mode choice among students. Similar observations were also made in a study conducted in Malaysia [3]. The model results of the combined effect of personal and household characteristics show that the effect of household characteristics is not significant on mode choice. Table 7 shows the result of formulated hypotheses.

Commenting on the model fit, all the models have Comparative Fit Index (CFI) values and Tucker Lewis Index (TLI) values closer to 1. Moreover, the Root Mean Square Error of Approximation (RMSEA) values for all the models are less than 0.08 which is a quite satisfactory value and indicates a very good model fit.

Table 7 Hypothesis result

Hypothesis	Significance
H1: Personal characteristics influence mode choice	***
H2: Household characteristics influence mode choice	–
H3: Both personal and household characteristics influence mode choice	–
H4: Travel distance affects mode choice	***
H5: Travel time affects mode choice	***
H 6: Travel cost affects mode choice	***

(***Significant at 95% level of significance)

7 Policy Implications and Future Directions

This paper provides valuable insights into the mode choice behaviour of students. Mode choice models developed for students revealed that the majority of them prefer cars and two-wheelers. In order to attract more students to switch to non-motorized modes (cycling and walking) and to ensure safe and secure walking, particularly for short-distance trips, pedestrian facilities should be improved. More pedestrian-crossing facilities and more pedestrian-crossing intervals are all expected to encourage walking and the likelihood of using bicycles. The use of sustainable modes should be promoted, for an overall reduction in road congestion and improvement of air quality parameters.

The future research of this study can be expanded in several aspects. Firstly, the data collection can be done in different seasons, so that the effect of weather on the travel mode choice of students can be understood more clearly. Secondly, the location of schools, whether it is located in a rural or urban area, can be considered in students' mode choice behaviour as well.

8 Conclusions

This study has identified the impact of personal characteristics, household characteristics and travel characteristics on the mode choice of students. Data of 4700 students was used for analysis. This work aimed at understanding and modelling students' mode choice behaviour.

The structural equation models developed for the mode choice of students revealed that among the personal characteristics that showed a significant impact on the mode choice decision of students are age, license availability, type of vehicle owned and the type of exclusive vehicle owned. The number of members and number of students in a household significantly influence the preference for cars and two-wheelers. The combined effect of personal and household characteristics revealed that household characteristics have no significant impact on the mode choice decision of students. Travel distance, travel time and travel cost are the travel characteristics that showed a significant effect on students' mode choice. Bus is the least preferred mode as the travel cost per kilometer is considered. For longer travel distances, the preference for cars increases.

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