Analysis of factors influencing mode shift to public transit in a developing country

R Devika¹ and M Harikrishna²
¹Former M.Tech.student, Department of Civil Engineering, National Institute of Technology Calicut, Kerala, India
²Assistant Professor, Department of Civil Engineering, National Institute of Technology Calicut, Kerala, India

Abstract. Vehicles are a major invention having significant impact on human progress. However, increasing private vehicle usage can cause many threats to the society like congestion, depleting environmental quality etc. The study is taken up to identify the factors influencing usage of private and public modes, with the help of mode choice models. The influence of psychological factors based on the ‘Theory of Planned Behaviour’ were analysed in the study. The variables considered for the study include service attributes like travel cost, travel time, waiting time, comfort and latent variables like ‘attitude’, ‘subjective norm’, ‘perceived behavioural control’ etc. Revealed preference survey was adopted to know the sociodemographic details and a stated preference survey was adopted to study the mode shift of people to a better public transit facility. Travel time, waiting time and travel cost had negative influence in the utility of new public transit mode. Comfort and perceived behavioural control had positive influence in utility of a new public transit service. The study was useful in developing a better understanding of mode choice behaviour and developing insights for policy formulations for improving the public transit.

1. Introduction
Automobile usage has given flexibility of movement and increased mobility to the users. Improvements in economic condition of people have resulted in increased affordability of private vehicles. A significant increase in private vehicle ownership and usage is observed among citizens of developing nations, like India. The total registered vehicles in India grew at a Compound Annual Growth Rate (CAGR) of 9.9% between 2001 and 2011. Two-wheelers accounted for 72 percent in the total vehicle population followed by passenger cars at 13.5%, buses at 1.05%, goods vehicles at 4.8% and other vehicles at about 8.25% as on 31st March 2012. Increase in private vehicle usage is also a threat to the concept of sustainability. One of the remedies to this problem is enhancing and improving public transport facilities, thereby promoting public transport patronage. The objectives of this study are to identify the factors that influence the mode choice of private and public transport modes and to formulate mode choice models incorporating psychological factors. The objectives also include identifying the potential strategies that can lead to mode shift from private to public transport.

Beirao and Cabral identified travel time, comfort, availability of information, car dependence, attachment to cars, convenience and flexibility, environmental concerns etc, as key factors influencing the mode choice [1]. They concluded that the public transport should be promoted as a positive experience. Chen and Chao presented an integrated model, based on the Theory of Planned Behaviour.
(TPB), by taking into account both rational and habitual variables for mode choice [2]. The variables considered include attitude to public transit, subjective norm, perceived ease of use, intention to use public transit etc. Idris studied the effect of psychological factors and the relative importance of attributes of the service (Customer Oriented Transit Service attributes) in determining the mode choice behaviour [3]. Multinomial logit model was used for mode choice analysis and Structural Equation Modelling was used for incorporating the effects of psychological factors.

Wang et al. examined the perceptions of public transit service performance, private car service performance and the attribute’s importance degree during commuting [4]. Attributes considered were comfort level, timeliness, reliability, convenience, relaxation, cost, and security. Fu and Juan worked on a latent segmentation approach to segment the people based on their attitude and potential for transit usage [5]. The user population were classified into six clusters, each cluster characterized by distinct combinations of latent factors, including attitude, habit, perception and intention to use public transit. Jou and Chen investigated the relationship between public transportation, car, and motorcycle use and analysed the important factors that affect the usage of these modes [6]. The study concluded that the regional economic and development conditions, population density, and the characteristics of public transport services all have a significant impact on the usage of public transportation, cars, and motorcycles.

Based on the Theory of Planned Behaviour, Kaewkluengklom et al. used psychological factors and habit as latent variables, along with service attributes such as travel time, travel cost etc. as explanatory variables in mode choice modelling [7]. The study concluded that models with latent variables are better than conventional models. Sohoni et al. considered attributes like waiting time, travel time, travel cost, transfers, discomfort level in a stated preference study for the mode shift behaviour towards a newly operational metro rail mode in Mumbai city, India [8].

Considering the fact that travel behavior of medium sized cities in India like Calicut are less explored and these cities are facing rapid urbanization, the current study is aimed at a better understanding of mode choice behaviour of commuters of Calicut city. The objectives of this study are to identify the factors that influence the mode choice of private and public transport modes and to formulate mode choice models incorporating psychological factors. This would help in identifying the potential strategies that can lead to mode shift from private to public transport. The subsequent sections detail the methodology adopted for the study and the models developed.

2. Methodology

2.1. Study area
Calicut city, one of the largest cities in Kerala, is taken as the study area. Calicut is the largest urban area in the state. The total population under the Municipal Corporation limits is 550,440. The city has a reasonably well developed transport infrastructure.

2.2. Data collection
Mainly work place interview was adopted for the study since the study focus on the commuter trips. The method of data collection adopted for the study was face-to-face interview technique. Data collection for the study was done at two stages- a Revealed Preference (RP) survey, followed by a Stated Preference (SP) survey. Questionnaire was developed based on the factors influencing the mode choice identified from the literature review. Questionnaire was designed to collect household information, personal information and travel related information. Household information include details like household size, household monthly income, vehicle ownership etc. Personal information collected include age, gender, education, personal monthly income etc. Travel related information like origin and destination of trips, travel mode used, travel time, travel cost etc. was also collected.

The data on psychological factors influencing the mode choice decision was collected. The Theory of Planned Behaviour (TPB) was adopted as a theoretical foundation to consider the effects of psychological factors in mode choice modelling. The TPB standard direct measurements involved
measuring four variables including ‘attitude’, ‘subjective norm’, ‘perceived behavioural control’ and ‘intention’. A total of fourteen statements were used for the measurement of the above variables and the respondents were asked to rate the statements in a five point Likert scale from ‘strongly agree’ to ‘strongly disagree’. The statements used are given in Table 1. The first four statements were used to measure the ‘attitude’ of people to public transit. Average of ratings for the first four statements give the ‘transit favouring’ score for a particular person. Likewise, score for other factors such as ‘car dependence’, ‘subjective norm’, ‘perceived behavioural control’ etc. were calculated. The dominant travel attitude of the person is identified by comparing individual score for ‘transit favouring’ and ‘car dependency’ with their weighted average score for the whole population.

Table 1. Statements used to measure the psychological factors.

| Statement                                                                 | Psychological Factors         |
|---------------------------------------------------------------------------|-------------------------------|
| 1. I like travelling by public transit                                   | Transit Favouring Attitude    |
| 2. I think public transit can sometimes be easier than driving           |                               |
| 3. For me to use public transit is beneficial                           |                               |
| 4. I am satisfied with the public transit facilities                    |                               |
| 5. I need a car / two-wheeler to do many things I like to do             | Car Dependent Attitude        |
| 6. I feel that travelling by a car / two-wheeler is safer than by bus    |                               |
| 7. I feel that getting to work without a car / two-wheeler is irritating |                               |
| 8. I think that owning a car/two-wheeler is a symbol of prestige        |                               |
| 9. Most people who are important to me would support me using public transit | Subjective Norm               |
| 10. I am confident that if I want to I could take the public transit    | Perceived behavioural control |
| 11. For me to take the public transit would be easy                      |                               |
| 12. Whether or not I intend to take the public transit is completely upto me |                               |
| 13. I will make an effort to use public transit                         | Intention                     |
| 14. My intention to use the public transit is strong                     |                               |

RP survey was adopted to get information on the current choice scenario. The RP survey collected currently experienced attribute levels for various attributes like travel cost, travel time, waiting time etc. Moreover, the most important reasons for not using the public transit were identified. These were ‘uncomfortable seating and crowd inside the bus’, ‘comparatively more travel time’ and ‘less frequency of bus service’. The RP survey was done at workplaces in Calicut with a sample size of 250 individuals. Based on the data collected from the RP survey, cumulative frequency curves were plotted for travel time and travel cost for various modes. This was used for identifying the range of variation of attribute levels.

Based on the currently experienced attribute levels, the Stated Preference (SP) experimental design was done and the SP questionnaire was developed. The variables considered for the SP design were identified from the RP survey and their attribute levels are as shown below:

- Travel cost (increase by 10%, 20% and 30%)
- Travel time (reduce by 30%, current travel time, increase by 30%)
- Waiting time (5 minutes, 10 minutes)
- Comfort level (assured comfortable seating, standing comfortably, no seat and crowded)

Main effects only fractional factorial design was done using a statistical software package. Nine choice sets were created. The SP questionnaire was designed such that each respondent was asked to...
compare their existing primary mode of travel for work trips with a hypothetical improved public transit alternative and to give their choice of preference. An initial pilot study was done and based on the inferences, two dominant alternatives were eliminated and number of choice sets was reduced to seven. The SP survey was also done at workplaces in Calicut city with a sample size of 400 respondents.

3. Data analysis

3.1. Preliminary analysis
The RP and SP data collected were subjected to preliminary analysis to identify the sample characteristics and to compare with the population characteristics. The average household size is 4.31 for the sample. The average vehicle ownership per household is 1.74. In case of personal data analysis, 37.25% are females and 62.75% are males. About 42.75% of the sample are in the age group of 41-60 years. About 50% of the sample are in the personal monthly income range of Rs.20,000-Rs.50,000. About 48% of the trips are by bus, 37.8% by two-wheeler and 14.2% are by car.

3.2. Model development
Mode choice models were developed separately for the public transit users and the private vehicle users. The model considered service attributes like travel time, travel cost etc., socioeconomic characteristics and the latent variables namely ‘attitude’, ‘subjective norm’ and ‘perceived behavioural control’ as the explanatory variables. Effects coding was adopted for the qualitative attribute ‘comfort’. Effects coding accounts for the non-linear effects in the levels of the attributes. This is attained by creation of number of variables for each attribute being coded. The number of new variables created is equal to the number of levels of the attribute being coded minus one. The qualitative attribute comfort is characterized by three levels as

- Level 1 - No seat, Crowded
- Level 2 - Standing comfortably, no crowd
- Level 3 - Assured comfortable seating

Two new variables are created: com1 and com2. The effects coding structure is as shown in table 2.

| Attribute level                  | Com1 | Com2 |
|----------------------------------|------|------|
| Assured comfortable seating      | 1    | 0    |
| Standing comfortably              | 0    | 1    |
| No seat, crowded                 | -1   | -1   |

The model developed for the private vehicle users are given below in table 3 and for the public transit users are given in table 4. Travel time and travel cost were used as alternative specific variables for private and public transit users. Household monthly income was added as a variable in the utility equation of private vehicle, while ‘attitude’, ‘perceived behavioural control’ and ‘subjective norm’ were added in the utility equation of new public transit. From table 3, it is inferred that travel time and travel cost have negative influence on the utility of any mode irrespective of whether it is a private mode or public mode. The positive sign of household income for private vehicle users indicate that as household income increases, the utility of private vehicle increases. Considering the four service attributes considered for the SP design, comfort and travel time have higher t-statistics, which implies higher significance, and travel cost has least significance. It can be inferred that private vehicle users may shift to public transit mode which is characterised by less travel time and good comfort level like
‘assured comfortable seating’. A reduction in travel cost may not attract the private vehicle users to public transit.

Table 3. Binary Logit model for private vehicle users.

| Variable                                         | Parameter Estimate | Relevance of the variable |
|--------------------------------------------------|--------------------|---------------------------|
| Travel cost for private vehicle                  | -0.00328(-0.449)*  | Alternative specific variable |
| Travel Time for private vehicle                  | -0.10989(-8.550)   | Alternative specific variable |
| Household monthly income                         | 0.09537(1.821)*    | Alternative specific variable for private vehicle |
| Travel cost for new public transit               | -0.02178(-1.457)*  | Alternative specific variable |
| Travel time for new public transit               | -0.09812(-8.699)   | Alternative specific variable |
| Waiting time for new public transit              | -0.17103(-4.891)   | Alternative specific variable |
| Comfort for new public transit (com1)            | 1.42328(10.786)    | Alternative specific variable |
| Comfort for new public transit (com 2)           | 0.15960(1.355)*    | Alternative specific variable |
| Perceived behavioural control                    | 0.31960(1.694)*    | Alternative specific variable for new public transit |
| Subjective norm                                  | 0.21995(1.164)*    | Alternative specific variable for new public transit |
| Attitude                                         | 0.71359(4.061)     | Alternative specific variable for new public transit |
| Constant                                         | 0.00196(0.005)*    | Alternative specific |
| Log-Likelihood of estimated model                | -498.4816          |                           |
| Log-Likelihood of constants only model           | -670.1049          |                           |
| Rho-square value                                 | 0.256              |                           |
| Adjusted Rho-square value                        | 0.239              |                           |

*Not significant at 95% confidence level. Values in parenthesis are t-statistics

Among the latent factors considered, only ‘attitude’ was significant at 95% confidence level. The positive sign of the ‘attitude’ indicates that as private vehicle users become more transit favouring, the utility of improved public transit service increases. The positive sign of the ‘subjective norm’ indicates that as people get good support from family and society for using public transit, they show more chance of using the public transit. This can be attained by developing good perception about the public transit in the society. Public transit should be made a positive experience for the society. It should be more safe and reliable to use. The positive sign of the ‘perceived behavioural control’ shows that as public transit becomes more user friendly so that people perceives it as easy to use, the probability of shifting to public transit increases. The model has rho-squared value of 0.256, which is acceptable as a reasonable goodness-of-fit for discrete choice models.
Table 4. Binary Logit model for Public transit users.

| Variables                           | Parameter Estimate | Relevance of the variable                      |
|-------------------------------------|--------------------|------------------------------------------------|
| Travel cost for public transit      | -0.04889 (-2.45)   | Generic Variable                               |
| Travel time for public transit      | -0.03530(-7.405)   | Generic Variable                               |
| Waiting time for public transit     | -0.03316(-2.908)   | Generic Variable                               |
| Comfort for public transit (com 1)  | 0.40864 (5.282)    | Generic Variable                               |
| Comfort for public transit (com 2)  | 0.03962 (0.386)*   | Generic Variable                               |
| Household monthly income            | -0.17146(-2.979)   | Alternative specific for existing mode         |
| Gender                              | 0.32251 (1.926)*   | Alternative specific for existing mode         |
| Perceived behavioural control       | 0.35157 (2.000)    | Alternative specific for new mode              |
| Subjective norm                     | 0.03442 (0.193)*   | Alternative specific for new mode              |
| Attitude                            | -0.43952(-2.257)   | Alternative specific for new mode              |
| Constant                            | -0.74977(-2.123)   | Alternative specific                           |
| Log-Likelihood of estimated model   | -487.3571          |                                                |
| Log-Likelihood of constants only model | -597.6027      |                                                |
| Rho-square value                    | 0.185              |                                                |
| Adjusted Rho-square value           | 0.167              |                                                |

*Not significant at 95% confidence level. Values in parenthesis are t-statistics

In the model developed for public transit users, travel cost and travel time have a negative significant influence on choice of the public transit. Considering the t-statistics, travel time and comfort have greater significance. Household monthly income and gender are added as variables in the utility equation of existing public transit facility. The negative sign of the household income implies that as household income increases the probability of choosing the public transit decreases. The positive sign of the variable ‘gender’ indicates that the females have more preference toward the public transit. Among the psychological variables, ‘attitude’ and ‘perceived behavioural control’ were significant in the mode shift of people from the current public transit system to a new improved public transit. The rho-squared value of 0.185, which is acceptable as a reasonable goodness-of-fit for discrete choice models.

4. Summary and conclusions

Mode choice models are useful for identifying the influence of various factors on mode choice decision making. The study focussed on the factors influencing the mode choice of private and public transport. A stated preference method was adopted to study the willingness to pay of commuters for a better public transit service alternative. The attributes considered for the stated preference design were travel cost, travel time, waiting time and comfort of the hypothetical transit service. Recent studies have identified that the incorporation of latent factors in mode choice models can give better results. Considering the Theory of planned behaviour as a theoretical foundation, the influence of latent factors such as ‘attitude’, ‘subjective norm’, ‘perceived behavioural control’ were studied. The effect of sociodemographic characteristics like household income, gender etc. were also studied.

Among the transit service attributes considered for the study, travel time and comfort were shown to have high significance in mode shift toward an improved public transit alternative. This implies that new public transit options with reduced travel time and more comfortable travel experience could
cause a shift from private vehicle usage to public transit modes. Effects coding for the qualitative variable ‘comfort’ was helpful, to identify the influence of different levels of comfort offered by the public transit, on utility of the public transit mode. ‘Subjective norm’ and ‘perceived behavioural control’ have a positive influence on attracting the private vehicle users towards the public transit. There is a necessity to project public transit as an alternate mode for commuters, by improving the perception of public transit systems. The ‘Transit favouring’ attitude of private vehicle users has positive influence in the mode shift of private vehicle user to public transit. Most public transit systems are traditionally viewed upon as less comfortable, non-reliable and less user friendly. This calls for improvement in vehicle body design, improved facilities in bus shelters, promptly followed transit schedules and better behaviour from the crew towards bus users. Females are identified as a target population for public transit service. The study was useful for developing insights for policy formulation for improving the transit ridership.

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