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Identification of Major Latent Variables Influencing Mode Choice Behaviour of Non Work Trips in Medium Sized cities

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Abstract

In order to plan a sustainable efficient transportation system, commuter's attitude and behavioural traits while making non-work trips have to be considered by the transportation planners for understanding their preference of mode along with the socio economic characteristics of the commuter and trip attributes of the mode. The study aims to identify major latent variables influencing the mode choice behaviour of non-work commuters as well as to analyse the mode choice behaviour of the commuters undertaking non-work trips.Revealed preference survey was conducted to study the travel pattern of the non-work commuters in the current situation. The immeasurable attributes influencing the selection of travel modes were analysed separately using the semantic differential technique with a five-point bipolar adjective scale. Exploratory Factor Analysis was done to identify the major latent variables influencing the mode choice which were the service characteristics, concern about costs, operational characteristics and ridership characteristics. Confirmatory Factor Analysis was finally done to check the validity and reliability of these measured variables with the latent variables. It was found that majority of the commuters (66%) considered service characteristics as their priority when making a mode choice followed by operational characteristics. It was also found that less than 15% of choice riders chose public transport as their mode for travel in Thiruvananthapuram City. More commuters can be attracted towards public transport by improving service characteristics of transport such as reliability, cleanliness, comfort and safety.

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*Keywords:*Non-work trips;Commuters;Mode choice;Exploratory;Confirmatory;Revealed preference

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1. Introduction

Transportation planning is the process of defining future policies, goals, investments, and designs to prepare for future needs to move people and goods to destinations. Transport planning is crucial in planning sustainable developments and ensuring accessibility for all individuals. Mode choice behaviour of commuters plays an important role in transportation planning decisions. Mode choice models generally form a critical part in analyzing the travel demand of a study area. Mode choice analysis helps the transportation planner to predict the mode of transport used and the resulting modal share.A proper analysis of the mode choice decisions can help in addressing issues such as forecasting demand for new modes of transport, mitigating traffic congestion, allocating resources, examining the general efficiency of travel, and will provide insight into the traveller's behaviour characteristics.

Non-work trips are trips made between a person's home and other destinations which are not for the purpose of working. In order to plan a sustainable efficient transportation system, commuter's attitude and behavioural traitswhile making non-work trips have to be considered by the transportation planners for understanding their preference of mode along with the along with the socio economic characteristics of the commuter and trip attributes of the mode.It is obvious that in case of non-work trips, individual perception and attitude to different transport modes differ due to their different socioeconomic status and different intrinsic characteristics of transport modes, which cannot be directly observed or measured. Therefore, latent variables should be added in the model to include the subjective factor's influence on transport mode choice. The measurement model of a latent variable with effect indicators is the set of relationships in which the latent variable is set as the predictor of the indicators.

Understanding the preference of trip makers in selecting a travel mode by considering their attitude and perception towards a mode is necessary to make decisions about the future transportation scenario. The analysis in this regard will help in accurately predicting the mode wise demand for travel. A proper analysis of the mode choice decisions can help in addressing issues such as forecasting demand for new modes of transport, mitigating traffic congestion, allocating resources, examining the general efficiency of travel, and will provide insight into the traveller's behaviour characteristics. The major objectives of the study are:

- To identify the major latent variables influencing the mode choice behaviour of non-work commuters
- To analyse the mode choice behaviour of the commuters undertaking non-worktrips

2. Literature review

A detailed literature survey had been conducted to investigate the various studies conducted on the integration of multi modal systems in various cities. The study by Ashalatha et al (2013) used multinomial logistic regression to analyze the mode choice behaviour of commuters in Thiruvananthapuram, a typical Indian city. The major socio-economic variables considered were mode of conveyance, age, gender, monthly income, vehicle ownership whereas the major transport system variables were distance, travel time and travel cost. The findings from the study revealed that as age increases, preference to car increases and preference to two-wheelers decreases in comparison with public transport. Increase in time per distance and increase in cost per distance cause the commuters to switch to car and two-wheelers from public transport. Another study by Santos et al (2013) attempted to identify factors that influence modal split for journeys to work in 112 medium size cities in Europe. , it was found that : (a) car share increases with car ownership and GDP per capita; (b) motorcycle share decreases with petrol price and increases with motorcycle ownership; (c) bicycle share increases with the length of the bicycle network in the city; (d) public transport share increases with resident population, GDP per capita and the number of buses (or bus equivalents) operating per 1000 population.

The major aim of the study conducted by Van et al (2011) was to do an exploratory investigation of dimensions of attitudes towards car and public transport in six Asian countries (Japan, Thailand, China, Vietnam, Indonesia, and the Philippines). The second aim was to find out determinants of the dimensions as well as of the possible differences of attitudes across countries. Attitudes toward car and public transport by 1,118 respondents in six countries were measured by 31 beliefs in form of pairs of opposite adjectives. The results of principle component analysis yielded three factors of attitudes toward car and public transport, namely: Symbolic affective, Instrumental, and Social orderliness.The study conducted by Daya (2009) aimed to study the mode choice behavior in case of leisure trips. Mode choice analysis was carried out using software SPSS. It was observed from the study that the

major variables found to be significant in the developed model were income, number of persons accompanying, travel cost, travel time and vehicle ownership.

3. Study Area

Thiruvananthapuram, also known as Trivandrum, is one of the major cities in Kerala State and derives its importance being the capital city of the State. It is located on the west coast of India near the extreme south of the mainland. Thiruvananthapuram Corporation has an area of 215 sq km and supports population of around 9.86 lakh as per census 2011 and is the most populous city corporation in Kerala. It is a major Information Technology hub in India and contributes a majority of Kerala's software exports as of Thiruvananthapuram is located on the west coast of India near the extreme south of the mainland.

4. Methodology

The present study aims to analyze the mode choice behaviour of non-work commuters in Thiruvananthapuram city. It also aimed at identifying the relevant factors that contribute to the selection of a particular mode by a non-work commuter in the city of Thiruvananthapuram.The data for the study were collected by directly interviewing the commuters visiting leisure locations, religious institutions, shopping malls and major hospitals located in the city of Thiruvananthapuram.The flowchart depicting the methodology is shown in **Fig. 1**

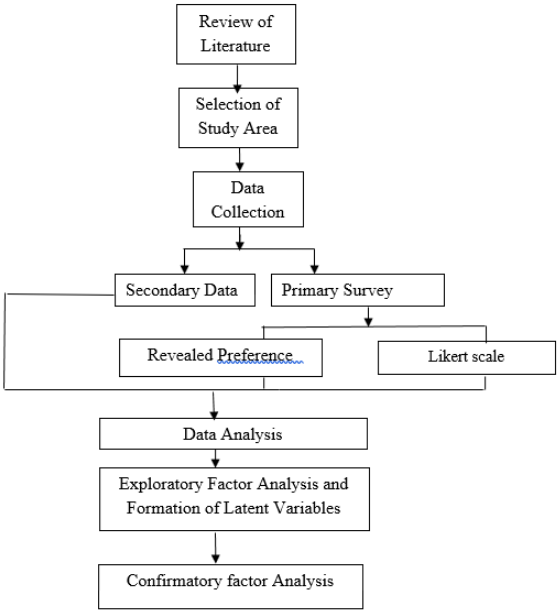

Fig. 1 Flowchart depicting methodology

4.1 Revealed Preference Survey

Revealed preference survey was conducted to study the travel pattern of the non-work commuters in the current situation. It was adopted in the study to determine the travel patterns of all available modes in the city. For the present study, a total of 1000 samples were collected. It was ensured that the data represented all age groups and all sections of society (low income to high income). Both genders had almost equal representation. Coding of data was done to facilitate easy handling of information. The questionnaire used for the survey consisted of two parts. The first part collected the details regarding the socio-economic profile of the commuter while the second part collected the travel information of the commutersas well as the trip-related variables represented by conveyance

mode. The socioeconomic characteristics that were collected included age, gender, nature of job, monthly income, and vehicle ownership. Travel characteristics included distance from home to office, mode of conveyance, reasons for choosing the mode, waiting time, in-vehicle travel time, cost of travel, etc.

Attitude towards travel modes was collected separately using the semantic differential technique with a five-point bipolar adjective scale. Indicator variables were analysed by conducting Exploratory Factor Analysis (EFA) using statistical software SPSS to reduce the number of indicator variables and to identify the latent variables which have influence on the attitude and behaviour of the non-work commuters. Confirmatory Factor Analysis (CFA) was also finally done using SPSS AMOS to confirm the factor structures identified by EFA and also to relate indicator variables and later variables.

4.2 Semantic Differential Scale

Semantic differential questions allow for measuring the attitudes or feelings of the commuters that might not be revealed through traditional survey question types. Information on attitudes toward travel modes was collected using the semantic differential technique with a five-point bipolar adjective scale. For example, for the pair ‘‘very cheap-very expensive’’, ‘‘very cheap’’ was written on the utter left and ‘‘very expensive’’ was placed on the utter right side of the five-point scale. Accordingly, respondents can choose one out of five checkboxes to imply whether the image of the mode they choose is nearer to ‘‘very cheap’’ or ‘‘very expensive’’. The questionnaire then showed randomly arranged beliefs in the form of pairs of opposite adjectives, which covered several aspects of travel modes such as the service attributes, ridership attributes etc. In total, 14 beliefs were used in the study. For example, ‘‘stressed–relaxed’’ was used to measure the service attributes of public transport, ‘‘high income-low income” for the concern about costs, ‘‘less accessible-highly accessible” for the ridership attributes and ‘‘crowded-spacious” for the operational attributes. The 14 beliefs measured using the survey are:Income, Quality of Service, Comfort, Vehicle ownership, Environment Friendliness, Safety and Security, Transfers, Waiting Time, Journey time, Affordability, Reliability, Crowdness, Cleanliness and Accessibility.

4.3 Exploratory Factor Analysis

The key concept of factor analysis is that multiple observed variables have similar patterns of responses because they are all associated with a latent i.e. not directly measured variable. In every factor analysis, each factor captures a certain amount of the overall variance in the observed variables, and the factors are always listed in order of how much variation they explain. Exploratory Factor Analysis (EFA) is a statistical method used to uncover the underlying structure of a relatively large set of variables. EFA is a technique within factor analysis whose goal is to identify the underlying relationships between measured variables. It is commonly used by researchers when developing a scale (a scale is a collection of questions used to measure a particular topic) and serves to identify a set of latent constructs underlying a battery of measured variables. Measured variables are any one of several attributes of people that may be observed and measured. Researchers must carefully consider the number of measured variables to include in the analysis. EFA procedures are more accurate when each factor is represented by multiple measured variables in the analysis. It is also used in general to reduce a larger set of variables to a smaller set of variables that explain the important dimensions of variability.

Extraction, interpretation, rotation and choosing the number of factors or components are the following steps in Exploratory Factor Analysis. Here, exploratory factor analysis using principal component method was used to reduce a large set of items to a smaller number of dimensions and components. Principal Component method is an extraction method capture the variance in variables in a smaller set and also assess the validity of the questionnaire. EFA was carried out for the response data of 14 indicator variables included in the questionnaire.

The rotated component matrix, sometimes referred to as the loadings, is the key output of principal components analysis. It contains estimates of the correlations between each of the variables and the estimated components. The purpose of rotation is that they can create factors that are correlated or uncorrelated with each other. Rotations that

allow for correlation are called oblique rotations; rotations that assume the factors are not correlated are called orthogonal rotations.

A varimax rotation is used to simplify the expression of a particular sub-space in terms of just a few major items each. The actual coordinate system is unchanged, it is the orthogonal basis that is being rotated to align with those coordinates. The sub-space found with principal component analysis or factor analysis is expressed as a dense basis with many non-zero weights which makes it hard to interpret. Varimax is so called because it maximizes the sum of the variances of the squared loadings (squared correlations between variables and factors).

The rotated component matrix revealed that there is an existence of four latent variables with Eigen value greater than 1. It also showed that out of the 14 indicator variables, only 11 variables have been identified. The initial EFA showed lower loadings and cross loadings on the remaining 3 items and hence, these four factors were removed before CFA. All the identified variables are grouped under four latent variables based on the factor loadings and components. These indicator variables and three latent variables identified from EFA are shown in the **Table 4.1**.The four identified latent variables are: service characteristics, concern about costs, operational characteristics and ridership characteristics.

Table 4.1 Exploratory Factor Analysis

Latent Variables	Components			
	1	2	3	4
Service	.727	-.040	-.054	-.203
Safety	.722	-.043	.032	-.052
Cleanliness	.704	-.149	.025	-.109
Environment friendliness	.601	-.009	.043	.145
Reliability	.585	.139	-.309	-.019
Cost	-.036	.833	-.008	-.053
Income	.063	-.726	-.157	-.089
JT	.145	.025	.782	.112
Crowdness	-.205	.136	.673	-.142
Accessibility	-.072	-.347	.275	.661
Vehicle ownership	-.261	.116	-.125	.547

4.4 Confirmatory Factor Analysis

Confirmatory Factor Analysis (CFA) is a multivariate statistical procedure that is used to test how well the measured variables represent the number of latent constructs or it is a special form of factor analysis used to test whether measures of a construct are consistent with the nature of that construct (factor). CFA allows the researcher to test the hypothesis that a relationship between observed variables and their underlying latent constructs exists. Confirmatory Factor Analysis (CFA) and exploratory factor analysis (EFA) are similar techniques, but in exploratory factor analysis (EFA), data is simply explored and provides information about the numbers of factors required to represent the data. In exploratory factor analysis, all measured variables are related to every latent variable but in confirmatory factor analysis (CFA) researcher can specify the number of factors required in the data and which measured variable is related to which latent variable. Confirmatory factor analysis (CFA) is a tool that is used to confirm or reject the measurement theory.

Model Fit Indices

Model fit indices represents the issue of how the model that best represents the data reflects underlying theory. A variety of fit indices which can be used as a guideline for prospective structural equation modeling to avoid errors. In SEM, the most widely respected and reported fit indices are covered here and their interpretive value in assessing model fit is examined.

Absolute fit indices

Absolute fit indices determine how well a model fits the sample data. These measures provide the most fundamental indication of how well the proposed theory fits the data. Absolute fit indices determine how well the model fits or reproduces the data. Absolute fit indices include, but are not limited to, the Chi-Squared test, RMSEA, GFI, AGFI.

Chi-squared test

In SEM, chi-squared test is also called min discrepancy (CMIN) which is nothing but chi-square value divided by degrees of freedom (df). The chi-squared test indicates the difference between observed and expected covariance matrices.The chi-square value obtained was 82.076 and the degrees of freedom was observed to be 39. Hence, the value of chi-square/degrees of freedom was obtained as 2.104.A value less than 3 indicates a good model fit.

Root mean square error of approximation (RMSEA)

RMSEA calculates the size of the standardized residual correlations, theoretically ranges from 0 (perfect fit) to 1 (poor fit), considered satisfactory when < 0.06. RMSEA value was found to be 0.06 and the value indicates a moderate model fit.

Other Indices

a) P-value of the model obtained was 0.0001. The p-value being less than 0.05 indicates a good model fit.
b) Confirmatory Factor Index (CFI) value was obtained to be 0.883. It generally ranges from 0 to 1 and values closer to 1 indicates a better model fit.

Assessing the measurement model validity occurs when the theoretical measurement model is compared with the reality model to see how well the data fits. The results of confirmatory factor analysis of the final measurement model for study provides a good fit as per the fit statistics. Chi-squared test value ($\chi 2$ /df) = 2.104; confirmatory factor index (CFI) =0.833; and root mean square error of approximation (RMSEA) = 0.06. Model fit measures could then be obtained to assess how well the proposed model captured the covariance between all the items or measures in the model. If the constraints has imposed on the model are inconsistent with the sample data, then the results of statistical tests of model fit will indicate a poor fit, and the model will be rejected. If the fit is poor, it may be due to some items measuring multiple factors. It might also be that some items within a factor are more related to each other than others.

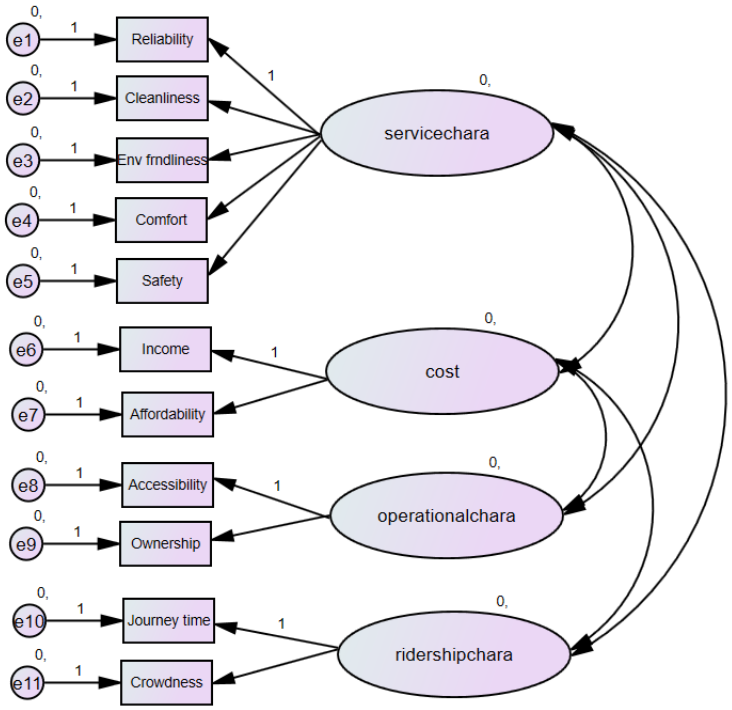

Fig. 2 Path Diagram of Measurement Model

From the revealed preference survey, it was observed which type of latent variables identified from the likert scale survey were the most influencing variables for the mode choice of non-work trips in Thiruvananthapuram city. About half of the commuters (45%) performing non-work trips such as leisure, medical, shopping and religious were giving importance to the service characteristics selected for their trips. It was also found that the operational characteristics were considered as priority by 30% of the commuters. Meanwhile, another 25% of commuters were giving importance to cost and ridership attributes for selecting the mode of travel.

5. Analysis of Revealed Preference Survey

The following are the major observations obtained from the revealed preference survey conducted for the non-work types in Thiruvananthapuram city.

1. Majority of the commuters (67%) performing non-work trips chose car as their prime mode of travel followed by two wheelers. It was also found that very less percentage of about 15% of choice riders chose public transport as their mode for travel.
2. Gender-wise comparison among the commuters revealed female groups preferred bus more than private vehicles.
3. It was also observed that preference to two wheelers decreases with age and preference to cars increases with age when compared with public transport.
4. With increase in trip distance, commuters were found to give more preference to car than bus.
5. It was also observed that with increase in income, the commuters were switching to personalized vehicles.

6. Conclusions

Attitude of commuters towards various travel modes was collected separately for non-work trips using the semantic differential technique with a five-point bipolar adjective scale. Exploratory Factor Analysis was done as a data reduction technique which identified the existence of four latent variables from the 14 distinct variables considered in the semantic differential scale. Confirmatory Factor Analysis was finally done to check the validity and reliability of these measured variables with the latent variables and a model fit is obtained. The results of confirmatory factor analysis of the final measurement model for study provided a good fit as per the fit statistics

The four categories of latent variables identified using exploratory factor analysis that influenced the mode choice behavior of non-work commuters were service characteristics, concern about costs, operational characteristics and ridership characteristics. About half of the commuters (45%) performing non-work trips such as leisure, medical, shopping and religious were giving importance to the service characteristics selected for their trips. It was also found that the operational characteristics were considered as priority by 30% of the commuters.

Majority of the commuters (67%) performing non-work trips chose car as their prime mode of travel followed by two wheelers. It was also found that less than 15% of choice riders chose public transport as their mode for travel. Gender-wise comparison among the commuters revealed female groups preferred bus more than private vehicles. It was also observed that preference to two wheelers decreases with age and preference to cars increases with age when compared with public transport.With increase in trip distance, commuters were found to give more preference to car than bus. It was also observed that with increase in income, the commuters were switching to personalized vehicles.

In cities like Trivandrum, where there is a predominant share of two-wheeler and four-wheeler traffic, improving public transport is the only measure likely to attract more commuters to public transport and which will finally lead to significantreduction in traffic volume on the plying roads. Transport planners must also ensure that travel time and travel costs are kept to the minimum to win over more commuters to the public transport system. More commuters can be attracted towards public transport by improving service characteristics of transport such as reliability, cleanliness, comfort and safety.

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