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Factors Influencing Mode Choice Towards Kochi Water Metro: A Latent Variable Approach

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Abstract

Understanding the key factors influencing the mode choice behaviour of commuters is essential for planners to develop an efficient transportation network. Traditionally, mode choice models use socio-demographic characteristics and modal attributes as explanatory variables. But there are also unobserved variables / latent variables which influence the mode choice behaviour of individuals. The present paper focuses on the factors influencing the mode choice behaviour of the commuters in the Vytilla-Infopark area in the state of Kerala, India, with the introduction of the Kochi Water Metro. A questionnaire survey was conducted based upon which factor analysis was done using Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA). By conducting EFA, indicator variables were analyzed to identify the latent variables which influence the attitude and behaviour of commuters. After CFA the significant latent variables that influence mode choice are comfort and convenience of the mode, concern about travel cost and travel time, the lifestyle of the commuter, and habit of the commuter. CFA was done to confirm the factors identified by EFA. The validity and reliability of these indicator variables with the latent variables are also checked after CFA to find the model fit as per the model fit indices.

Keywords

Mode Choice; Commuters Travel Behaviour; Water Metro; Latent Variable Approach; Factor Analysis, Transportation

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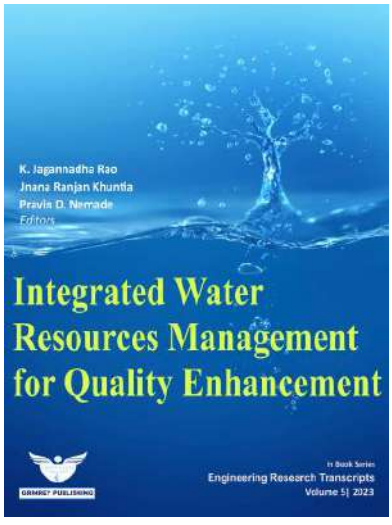

1. Introduction

Kochi, Kerala's commercial capital, is one of the state's most heavily populated areas and the limited available road space is being clogged with the influx of private vehicles. Cities all over the world are being compelled to adopt more sustainable mass public transportation options such as metro rail systems, bus rapid transit systems, and so on. Another alternative for cities is to return to ancient routes of transportation, such as the waterways in Kerala, particularly the city of Kochi.

Kochi Metro Rail Limited (KMRL) proposed an Integrated Water Transport System for Kochi City, to connect the mainland to all of the islands in the Kochi area and restore a sustainable traditional means of public transportation. The Kochi Water Metro envisioned a 76-kilometer route network with 16 routes connecting 38 jetties across 10 island communities. Eighteen of the 38 jetties will be constructed as major jetties or main boat hubs, while the other 20 will be developed as minor jetties for water transportation services. Although the entire water transport project was expected to be completed by 2019, only a portion of the first section (Vyttila-Kakkanad) of the Kochi Water Metro was inaugrated in February 2021, but the boat operation has yet to start. [10] In this study we have considered Vytilla to Infopark stretch as study area and mainly focuses on the factors affecting the mode choice of the commuters in the Vytilla-Infopark area with the introduction of Kochi water metro.

1.1 Relevant Studies on Factors Influencing Mode Choice

Some of the existing works already done about the mode choice of commuters are referred to identify the factors influencing mode choice behaviour. The literature review has revealed a number of factors influencing the mode choosing behaviour, which are given in Table 1.

The variables chosen for predicting mode choice behaviour are grouped into four categories based on the extensive literature review: sociodemographic, activity, trip characteristics, and attitude and behavior.

1.2.1 Study Area

The study area is located between Vytilla and Infopark region via Kakkand. The waterway connecting Vytilla and Kakkand is the Champakkara canal which comes under National waterway 3. Champakkara canal is a tributary of Periyar river connecting industrial township of Ambalamugal and Kochi. The river that connects kakanad to infopark area is Kadambrayar river, which takes off from the Champakkara canal in Brahmapuram area which is approximately 2 km upstream of Chitrapuzha road bridge (Airport-Seaport Road). Passenger boat service existing between Vyttila mobility hub and Kakkanad is operated by State Water Transport Department. By extending the waterway through Kadambrayar river will give a boost in passenger transport and tourism activities taking place in that area.

The main institutions and tourist places in that area are:

- Infopark
- Smart city
- Rajagiri college of Management and Applied Sciences
- Wonderla kochi
- Cochin Special Economic Zone - CSEZ
- Kadambrayar Eco-tourism project

Table 1. Literature Review on Different variables affecting the mode choice behavior

Factors	Ref.
Sending children to school, irregularities in working hours, stress levels, personal circumstances, and privacy concerns, are all factors considered alongside aspects such as travel time, travel expenses, and the nuanced evaluation of convenience, comfort, safety, and security. Notably, comfort, convenience, safety, and security are latent variables embedded within this comprehensive analysis.	[1]
Individual and familial characteristics (including age, gender, employment or student status, etc.), distinctions in transportation modes (such as in-vehicle time, out-vehicle time, transit fare, etc.), underlying factors that may not be directly observable (e.g., preferences for water transit, environmental considerations, comfort preferences, etc.), and variables that exhibit mutual influences (such as interactions between in-vehicle time and latent variables, as well as out-vehicle time and latent variables).	[2]
Social and economic background, mode of transportation, waiting and travel durations, cost of travel, and level of discomfort (old and new mode)	[3]
Features of the trips, such as the purpose of the trip, time of the trip, and trip distance; features of the transport facility, such as travel time, costs, quality of service, and parking space availability. Features of the travellers, such as traveler's background, household structure and income, vehicle ownership, and availability of choice of vehicle.	[4]
Age group of the respondents, gender, marital status, level of education, frequency of use, cost, and payment, attitude and behaviour of the staff, security and safety, comfort and hygiene, food and decoration, availability of service, and time management. (Cost and payment, employee demeanour and behaviour, safety and security, etc. are taken into account when determining consumer satisfaction.	[5]
Indicator variables considered to find quality of service are Assurance, Empathy, Reliability, Responsiveness, Tangibles, Comfort, Convenience and Connection on Fast Ferry services.	[6]
Size of household, head of household, number of children in the family, age range, Gender, relationship status, vehicle ownership, Education, employment, activity, and travel characteristics like work duration, start time, trip distance, and time, as well as latent variables like habit of the commuter, concern about travel costs and time, safety concerns, and cleanliness concerns, among others.	[7]

The research area's location is depicted in Fig. 1. The waterways from Vytilla hub to Kakkanad ferry (5 km) are indicated in the region with a blue band, while the waterways from Kakkanad ferry to the Infopark area are indicated in the area with a yellow band (3.8 km).

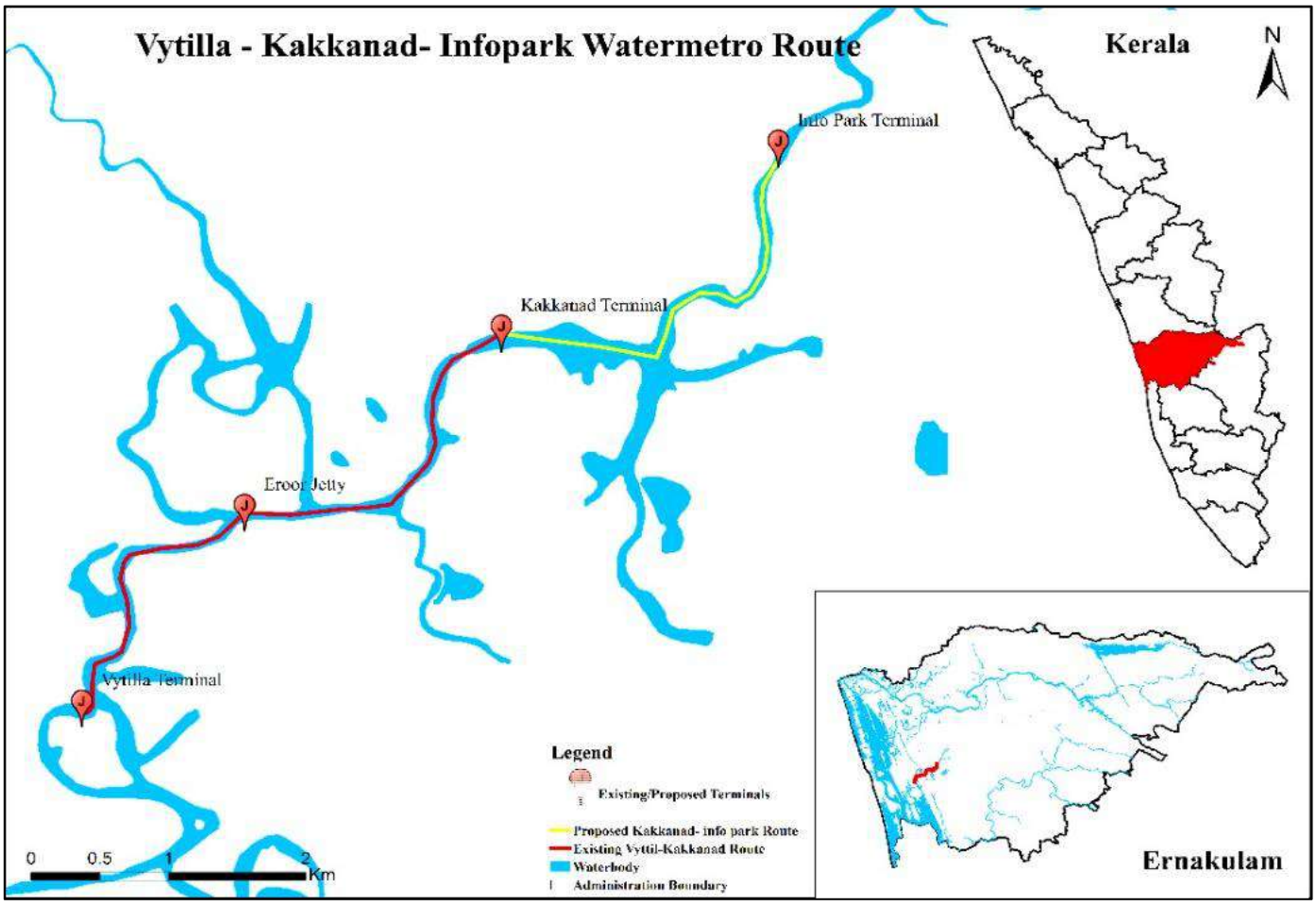

Fig. 1 Study Location

2. Methodology

2.1 Questionnaire

The questionnaire consists of four categories such as socio-demographic, activity, trip characteristics and attitude and behavior. The variables selected under these categories are listed below.

2.1.1 Socio-demographic characteristics

It includes details about Age, gender, marital status, level of education, and employment income each month, ownership of a vehicle, driving license, Whether the household's head, number of residents in the home, Number of working members in the household and address.

2.1.2 Activity characteristics

It includes details regarding Location of work, work start and end time.

2.1.3 Trip characteristics

Includes details about Regular mode for trip, purpose of trip, origin and destination, travel time, Daily travel expense for trip and distance travelled.

2.1.4 Attitude and behavior

Latent variables are variables that are not directly observed but can be inferred from other directly observed variables. For example, variables like comfort, convenience, safety, etc cannot be directly measured and hence these are measured with the help of attitudinal and behavioral questions aka indicator variables.

19 indicator variables based on six latent variables were considered for this study. These latent variables were selected based on the literature review. The six latent variables selected are;

1. Comfort and convenience of the mode
2. Safety of the mode
3. Life style of the commuter
4. Reliability of the mode
5. Concern of the commuter about travel cost
6. Concern about travel time

The commuters were asked to give responses for 19 attidunial and behavioral questions on a five-point scale from 1 to 5, where 1 represents I strongly disagree to 5 represents I strongly agree.

2.2 Data Collection

Site interviews and home interviews were conducted to collect the data. These interviews might have taken place in person or online. Google form was used to carry out the online survey. An online survey was adopted due to the absence of data during the Covid scenario. The survey was conducted in the following locations Vytilla mobility hub, Kakkanad, Infopark campus and Smartcity. A total of 450 (327 offline and 123 online) samples were collected and after data cleaning and removing irrelevant data, a sample of 387 is considered for study. The interviewing of a single respondent took roughly 10-12 minutes offline.

2.3 Exploratory Factor Analysis

Exploratory Factor analysis (EFA) is a statistical technique for determining the underlying structure of a large number of variables. It helps to reduce a large number of variables into smaller number. Factor analysis is performed in two steps, factor extraction, and factor rotation. Factor extraction involves choosing the number of factors to extract. Factor extraction adopted for this study is Principal component analysis. The principal component technique is an extraction method that captures the variance in a smaller number of variables while also evaluating the questionnaire's validity. Factor rotation comes after the factors are extracted, to achieve a simple structure to improve interpretability.

2.4 Confirmatory Factor Analysis

A multivariate statistical technique known as confirmatory factor analysis (CFA) is used to assess if the number of latent constructs is accurately represented by the measured variables. It is a model done after EFA, to find whether the variables are loaded properly and the construct is valid.

2.5 Structural Model

Structural Equation Modeling (SEM), it is a multivariate statistical technique for analyzing structural relationships. This method combines factor analysis and multiple regression analysis to investigate the structural link between variables of interest and latent constructs. This method is preferred because it estimates the multiple and interrelated dependence in a single analysis. There are two categories of variables employed in this study: endogenous and exogenous variables. A classification of a variable obtained by a statistical model that is explained by the interactions between functions within the model is known as an endogenous variable. Exogenous influences a model without being affected by it, and whose qualitative characteristics and generation process are not specified by the model designer. Exogenous variables are the same as dependent variables, while endogenous variables are the same as the independent variable. When

there is more than one dependent and independent variable, SEM is used. Structural model was developed in order to correlate endogenous variables (latent variables) with exogenous (explanatory variables). Between constructs, structural paths are drawn. A single-headed arrow is used to depict a hypothetical structural relationship between two constructs. To examine the structural model validity, model is considered a good fit if the value of the chi-square test is significant.

3. Results and Discussion

3.1 Exploratory Factor analysis

The response data of 19 indicator variables included in the questionnaire were subjected to EFA. These indicator variables are formulated in the sense that it can measure the unobserved latent variables. The rotated component matrix revealed that there is an existence of 4 factors, that means 4 latent variables with eigen

to be significant. That is out of 19 indicator variables, 16 have been identified with factor loading greater than 0.5 and these variables are grouped under 4 latent variables based on factor loadings.

The initial EFA had identified 5 components and showed lower loadings and cross loadings on 2 items and hence, the item with lower loading was removed. On the next iteration, 4 components were identified with no cross loadings and with all loadings greater than 0.5. [9] Each component represents each latent variable. The latent variables are named by identifying the loaded indicator variables. The significant latent variables revealed after EFA are;

i. Comfort and Convenience of the mode
ii. Concern about travel cost and travel time
iii. Life style of the commuter
iv. Habit of the commuter

3.2 Confirmatory Factor analysis

After completing EFA it was found that there are 16 significant indicator variables loaded under 4 latent variables. Confirmatory factor analysis is done to confirm whether the selected 16 variables are significant and correlated to the latent factors. That is, it forms a measurement model which correlates the indicator variables with latent variables. After completion of analysis, the indicator variables with loading greater than 0.5 is considered and the rest are eliminated. Hence after conducting CFA 16 variables are reduced to 13 variables. Table 2. summarizes the 13 indicator variables and Fig. 2, shows the path diagram of measurement model after model fit indices.

Table 2. Latent variables and indicator variables selected after CFA

Latent variables	Indicator variables	Labels
➢ **Comfort and Convenience of the mode**	• Bag and luggage	CC1
	• Comfortable and Cushioned seats	CC3
	• Neat and tidy &Dust and pollution	CC4
	• Single mode for travel	CC5
➢ **Habit of the commuter**	• Listen to music	HAB1
	• Check e-mails, whatsapp, news papers	HAB2
➢ **Life style of the commuter**	• Social status	LS1
	• Privacy	LS2
	• Prestige	LS3
➢ **Concern about travel cost and Travel time**	• Fuel economy/travel cost	TC1
	• Parking charge/toll charge	TC2
	• Monetary benefit	TT1
	• Prefer mode with less travel time	TT2

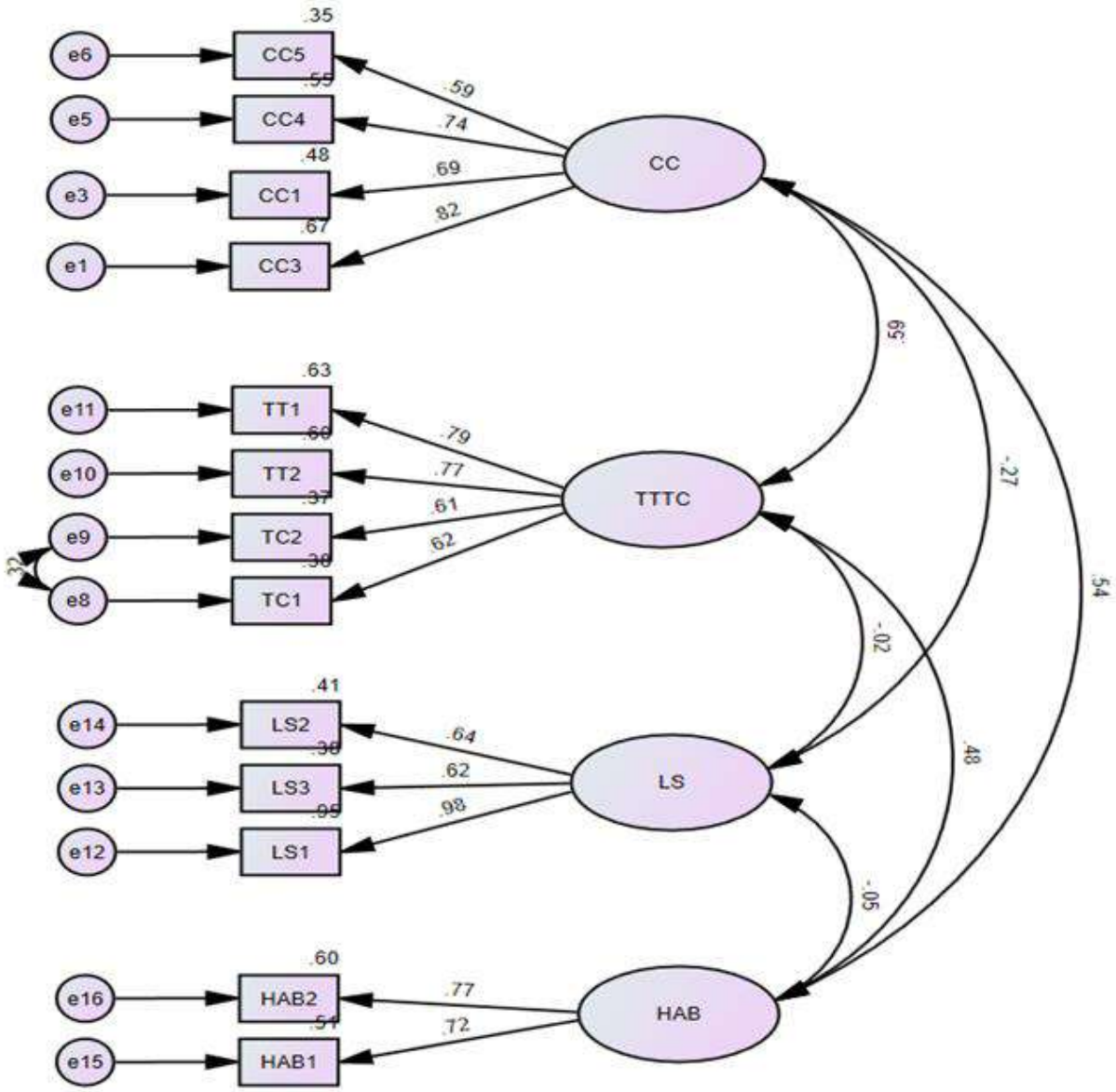

Fig. 2. Path Diagram of Measurement Model

The goodness of fit for CFA model was assessed using Root Mean Square Error of Approximation (RMSEA), Goodness of Fit (GFI), Adjusted Goodness of Fit (AGFI), Comparative Fit Index (CFI), Tucker Lewis Index (TLI), and Chi-squared test value. The results of final variables selected after EFA and CFA are reported in Table 1 and the final measurement model for study provides a good fit as per the fit statistics. Chi-squared test value ($\chi 2$ /df) = 3.821; GFI =0.922; AGFI = 0.878; RMSEA = 0.085; TLI = 0.822 and CFI = 0.912. RMSEA value obtained for the model was 0.085 and a value < 0.05 good; .05 – 0.10 moderate is considered as good fit. And also GFI is > 0.9, AGFI > 0.8 and CFI value obtained for this model was 0.912 which is > 0.9 indicates that the model fit is good. The Chi-squared test value obtained for the model was 3.821 which is within the acceptable value being less than 5. [11,12]

Model validation is done using Reliability -Convergent Validity and Discriminant Validity. Table. 3 shows validation of measurement model using Reliability and Convergent Validity. Convergent validity assesses the extent to which the measured variables accurately represent the latent variables. All standardized loadings exceed 0.5, and the average loadings per factor surpass 0.7, except for the construct 'Concern about travel cost and travel time,' where the value approaches 0.7. The composite reliability (CR) exceeds the desirable threshold of 0.6 for all constructs [13]. Additionally, the average variance extracted (AVE) was computed for all factors, demonstrating values greater than 0.50, except for 'Concern about

travel cost and travel time,' which, although close to 0.5, was considered acceptable. Consequently, our measurement model meets the criteria for convergent validity.

Cronbach's alpha is a metric that determines the data's reliability. Variables having an alpha value greater than 0.70 are regarded as reliable. [9] We can observe that the Cronbach's alpha value is larger than 0.70 for all latent constructs, which is acceptable and indicating that the measurement model is reliable. Composite reliability, Average variance extracted and Cronbach's alpha is calculated using stat tool package.

Table. 3. Validation of Measurement Model- Reliability and Convergent Validity

Latent variable	Avg. loading	CR	AVE	Cronbach's Alpha
Comfort and Convenience of the mode (CC)	0.710	0.806	0.513	0.795
Concern about travel cost and travel time (TTTC)	0.699	0.794	0.494	0.804
Life style of the commuter (LS)	0.747	0.799	0.581	0.777
Habit of the commuter (HAB)	0.745	0.714	0.556	0.713

The discriminant validity of the model is demonstrated in Table. 4. Discriminant validity is a method of demonstrating how one construct is measuring other latent constructs. From the estimates of the results, the correlation value of the factors is taken from standardized regression weights of these factors. The correlation matrix is shown in Table. 4. We can see from the correlation matrix that no pairs have a correlation greater than square root of AVE, i.e., all of these values are lower than the square roots of the AVE for the corresponding factors. [9]

Table 4. Validation of Measurement Model—Discriminant Validity.

	CC	TTTC	LS	HAB	Square root of AVE
CC	1				0.716
TTTC	0.595	1			0.703
LS	-0.274	-0.022	1		0.762
HAB	0.536	0.480	-0.047	1	0.746

4. Conclusion

Mode choice models play a crucial role in predicting commuters' decision-making processes when opting for a particular transportation mode. Beyond the conventional factors, the selection of a transportation mode is shaped by unobservable or latent variables. This research aims to discern the factors impacting mode choice behavior in the specified study area, specifically the commute between Vytilla Mobility Hub and Kakanad-Infopark in Ernakulam district. The ensuing conclusions from the study are outlined below:

- After reviewing the literature, it was discovered that, in addition to socio-demographic characteristics, activity characteristics, and trip characteristics, individual behaviour and perception play an important role in mode choice modelling.
- Six latent factors and 19 indicator factors were considered for studying the attitude and behavior of the commuters. Considering these factors, a factor analysis is done to find the significant factors.
- After the EFA, out of 19 indicator variables, 16 have been identified as significant and these variables are grouped under 4 latent variables based on factor loadings.

- The four Latent variables obtained as significant are: Comfort and Convenience of the mode (CC), Concern about travel cost and travel time (TTTC), Life style of the commuter (LS) and Habit of the commuter (HAB).
- After conducting EFA, Confirmatory Factor Analysis done by correlating these 16 indicator variables to 4 latent variables and found out that, out of 16 indicator variables only 13 variables are significant. The model is validated using reliability, convergent validity, and discriminant validity, and these constructs have a high level of internal consistency.

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