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Modeling of Intercity Mode Choice Behaviour of Passengers

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Abstract—Mode choice behavior study is crucial to explain travelers' mode preferences under different scenarios and for the infrastructure development for new modes. And which has as a crucial part in transport planning process. Different mode choice generation, modeling the mode choice behaviour of different mode alternatives and heterogeneity across travelers are non-trivial challenges in intercity mode choice studies. This paper tackles these challenges by focusing on the revealed preferences of public transport users in the Thrissur, Cochi and Calicut cities. For a transport modeling process, adequate data is required. The data were bagged using the questionnaire survey. This work compares the predictive performance of train and bus public transport systems for travel mode choice analysis for intercity travel and makes recommendations for model selection. In addition, the model addresses the importance of different variables and how they relate to different travel modes. The trip distance and purpose are found in affecting the mode choice passengers. Travel time and cost are the most important variables in the binary logistic model development; the importance of the other variables varies with classifiers and travel modes.

Index Terms—Binary logistic model,Intercity Travel, Mode choice behavior,Mode Preferences, Model, Public Transport, Transport Planning, Travel Demand.

1 Introduction

CONGESTION in intercity corridors has been increasing steadily, which has raised serious impacts on regional economic development, environmental issues, national productivity and competitiveness (Bhat, 1995). To alleviate congestion, many major investment projects, such as high-speed and Maglev rail projects were proposed by different agencies. The quality of decisions of project selection is impacted by the accuracy of the travel demand prediction and the sensitivity of this demand to travel cost and enhancement of levels of service. Meanwhile, intercity passenger carriers welcome reliable forecasts of intercity demand so that they can be more responsive to their patronage and to remain competitive. Therefore, intercity travel behavior research is needed to estimate and evaluate expected policy impacts prior to implementation. Intercity travel behavior analysis can be used for demand forecasting, service pricing and improvement impact studies. Research is needed to understand the travelers' preferences and willingness to choose among many existing or potential alternatives, such as intercity bus, automobile, conventional rail, highspeed rail, Maglev, and any other convenient travel modes. The outcomes of the research can assist the policy makers in solving the issues of transit planning, with an efficient transit access mode network. Large numbers of people are travelling from Thrissur to Ernakulam and Kozhikode for the work, educational, recreational and also for some other purposes. Since the transportation needs are increasing day by day it is necessary to find the feasibility of public transit vehicles. Increased use of private vehicles creates problems like environmental impacts, traffic congestion, accident rates etc. This situation becomes harsher when the distance of travel is more. Various needs and objectives of the study are:

- To test the feasibility of developing disaggregate passenger mode choice models in a multi-modal environment of the study area, for different cities and trip purpose.
- To determine the influence of various modal parameters, in order to identify their relative influence on the travel behaviour
- To forecast the mode choice behaviour of passengers of the three cities for different trip lengths and trip purposes.

The outcomes of the research can assist the policy makers in solving the strategic issues of transit planning, including the future development of a busway corridor, implementation of high speed rail system or any other efficient systems with an efficient transit access mode network. The research findings can also be utilised in evaluating the feasibility of developing metros and bus rapid transit systems between the Thrissur, Ernakulam and Calicut cities.

2 Literature Review

2.1 History of Intercity Travel Demand Model

As early as 1961, Lansing et al. applied simple gravity models for New York and Chicago. The initial gravity model described the relationship between the total traffic between each of these two cities and the demographic and socioeconomic characteristics of the city pairs. In this model, only population, per capita income, and distance were included as independent variables. In 1969, Quandt and Young improved the initial model. Later, it was employed in the Northeast Corridor Project to forecast the ridership on potential and existing modes of intercity travel along the Washington DC - New York - Boston corridor (U.S. DOT, 1970).

2.2 Heteroscedastic Extreme Value Model

Chandra R. Bhat (1995) developed a Heteroscedastic

Extreme Value Model, The random utility of alternative *i*, v_i for an individual in random utility models takes the form

$$U_i = V_i + \varepsilon_i$$

Where V_i is the systematic component of the utility of alternative *i* which is a function of observed attributes of alternative *i* and observed characteristics of the individual, and ε_i is the random component of the utility function. Let C be the set of alternatives available to the individual. We assume that the random components in the utilities of the different alternatives have a type I extreme value distribution and are independent, but non identically distributed. We also assume that the random components have a location parameter equal to zero and a scale parameter equal to θ_i for the *i*th alternative. Based on the heteroscedastic extreme value model, the probability of choosing alternative i can be written, as follows;

$$P_i = \int_{w=-\infty}^{w=+\infty} \Pi_{j\varepsilon C, j\neq i} \mathrm{A}\left[\frac{V_i - V_j + \theta_i w}{\theta_j}\right]\lambda(w)dw$$

A number of different variable specifications were examined to determine the preferred utility function specification. We arrived at the final specification based on a systematic process of eliminating variables found to be insignificant in previous specifications and based on considerations of parsimony in representation. Among the specifications examined and rejected because they did not provide significantly better results were:

- Out-of-vehicle travel time segmentation into access time (to airport or railway station) and terminal time (at airport or railway station)
- Travel cost deflated by income to reflect a smaller marginal cost effect on high income travelers than low income travelers
- Differential sensitivities of high income and low income groups to changes in in-vehicle and out-of-vehicle travel times and travel cost and
- Alternative transformations of the frequency variable

The heteroscedastic extreme value model, however, is found to be superior to the multinomial logit model. The heteroscedastic model predicts smaller increases in rail shares and smaller decreases in non-rail shares than the multinomial logit in response to rail-service improvements. It also suggests a larger percentage decrease in air share and a smaller percentage decrease in auto share than the multinomial logit. Thus, the multinomial logit model is likely to provide overly optimistic projections of rail ridership and revenue, and of alleviation in inter-city travel congestion in general, and highway traffic congestion in particular. These findings point to the limitations of the multinomial logit and nested logit models in studying intercity mode choice behaviour.

2.3 Disaggregate Modeling

The disaggregate approach (H. M. Al-Ahmadi , 2007) was the second generation in model building after the aggregate approach in mode choice modeling . The development of disaggregate models provided a more effective tool for predicting an individual's behavior in selecting one mode from among different modes available. The decrease in explanatory power of the aggregate models due to data aggregation was avoided with the disaggregate models. The use of disaggregate models is supported by their representation of the individual tripmaker's decision, data efficiency, and superior estimation results. Most disaggregate models are based on the theory of "utility maximization." They assume that a person makes a particular choice from a set of different alternatives depending on the maximum benefit he receives. For example, a person may wish to minimize travel time and cost of the trip, and maximize comfort and convenience in selecting a mode from the available modes.

The primary model form for intercity mode choice utilizing disaggregates data is in a probabilistic form, as seen in the following example:

$$P_k^i = \frac{e^{V_{ki}}}{\sum_j e^{V_{ki}}}$$

Where

P_k^i = probability of tripmaker i choosing mode k out of j alternatives

V_k^i= the utility of alternative mode k to trip maker i = (Xk, Si)

X_k= a row vector of characteristics of alternative mode k

S_i = a row vector of socioeconomic characteristics of a tripmaker i

From this equation, it is clear that the probability of a tripmaker choosing a particular mode is a function of the characteristics of the tripmaker; such as, income, age, and sex and of the characteristics of the mode relative to alternative modes.

In summary, the logic employed to move from one specification to another can be described as follows:

- variables with insignificant coefficients were dropped;
- variables that had the "wrong" signs were dropped;

- variables that were related to level-of-service (i.e., those that might be considered supply variables) were considered in both straightforward ways (e.g., the cost variable was added) and in ratio forms (e.g., cost divided by income);
- sets of variables with high correlations were considered and selected variables were dropped;
- different versions of several variables with "wrong" signs were considered (e.g., out-of-vehicle time was examined as a mode-specific variable); and finally,
- Several intuitively important variables which had been dropped were reconsidered (in the original form and/or, for example, in mode specific form).

Miskeen.M.A.A.B. etal., (2013) developed a binary logit model for intercity business trips was developed for two alternatives, namely, intercity bus and car, to compare the utility of these travel modes and identify the factors that would influence car users to move from traveling by car to choosing intercity buses. In this model, the dependent variable was "1" if the commuters' traveled by intercity bus and "0" for car use After the variables with insignificant coefficients were dropped from the model, the explanatory variables were age, gender, nationality, household monthly income, out-of-vehicle travel time, total travel cost, duration of stay at destination, car ownership, convenience, comfort, and weather conditions. Some of the explanatory variables such as age, household monthly income, and gender were categorized. For instance, the income was categorized as, < LYD 300, LYD 301–400, LYD 401–500, LYD 501–600, LYD 601–700, and >701 (1 US Dollar = LYD 1.27), and gender was categorized as 0 for male and 1 for female. Age was categorized as, < 20, 21–30, 31–40, 41–50, 51–60, and > 60.

The coefficients are estimated by fitting the data to the model(s). The maximum likelihood estimation method is a commonly used fitting technique. This method involves choosing values for the coefficients to maximize the likelihood (or probability) that the model will predict the same choices made by the observed individuals. The method yields highly accurate estimates.

After the calibration process was completed, the validity of the succeeding models was tested. Using 75 observers, this test was conducted by using the calibrated models to predict model-split for data other than that used for model calibration. The collected survey data was divided into two parts. The first part was for model calibration whereas the other was used for model validation. The validity of models was tested by comparing observed choices and the predicted choice by using the calibrated models.

2.4 Multidimensional Choice Model

If the travelers' cabin class and transport mode choices are correlated, it can use a joint choice model to investigate their multidimensional choice behavior. Because the purpose of this paper is to investigate the effects of HSR cabin strategies on the joint choice behavior of cabin class and transport mode, a joint choice model with two dimensions should be constructed. Joint choice issues are usually analyzed using nested logit models. The main requirement of nested logit models is that the correlated alternatives be placed in the same nest within a multinest framework. An individual's choice procedure begins with a nest and that the alternatives and error terms within the same nest are i.i.d. (independent and identical distribution). The alternatives from different nests are integrated using an inclusive value (IV). The probability of a joint choice model (pt(ij)) can be represented by the product of the conditional probability of class choice (pt(i|j)) and the marginal probability of mode choice (pt(j)) (Yang c. etal., 2015).

First, the conditional choice model focuses on the service class choice for HSR offering two classes of cabins: the reserved seat cabin (R-cabin) and non-reserved seat cabin (U-cabin). On a given cabin choice for HSR, the utility function of class i for traveler t is as follows, consisting of the observed (V_{it}) and unobserved (ε_{it}).

$$U_{it} = V_{it} + \varepsilon_{it} = a_i + bTC_i + cY_i + dZ_t + \varepsilon_{it}$$

The joint probability of traveler t choosing cabin class i and transport mode j can be expressed as

$$p_t(ij) = p_t\left(i/j\right) \times p_t(j) = \frac{\exp\left(\mu_j.V_{it}\right)}{\sum_{i' \in I} \exp\left(\mu_j.V_{i't}\right)} \times \frac{\left[\exp\left(\mu_j.IV_{jt} + V_{jt}\right)\right]^{\frac{1}{\mu_j}}}{\left[\sum_{j' \in J} \exp\left(\mu_j.IV_{j't} + V_{j't}\right)\right]^{\frac{1}{\mu_{j'}}}}$$

The IV_{jt} for the HSR mode can be defined as follows. Its corresponding parameter ($0 < \mu j \le 1$) is also called the index of dissimilarity. Considering the subjects and nest structure, this *IV* exists only in the utility function of HSR within the mode choice nest.

$$IV_{jt} = In \sum_{i'} \exp\left(V_{i't}\right)$$

The empirical result of the joint choice model shows that the cabin nest significantly correlates with other transport modes. The inclusive-value coefficient (0.194) reveals that cabin strategy effects have more influence on cabin alternatives than on mode alternatives. This study used the interaction terms of travel cost and travel time, with an income variable, to capture the response heterogeneity of individual travelers, while other socioeconomic characteristics were specified to present the preference heterogeneity of mode/cabin alternatives. In addition, the significance of overlapped random individual effects in the ECL model can be used to detect the correlation across mode and cabin alternatives. This would help identify the nest structure of the joint choice model more efficiently.

2.5 Auto Regressive Distributed Lag Approach

It is proved that the test results derived from ARDL are robust even with a small sample size. Using the ARDL method, we can estimate both short- and long-run relationships simultaneously (Ghosh 2010). In addition, the model can capture the data-generating process in a general-to-specific modeling framework due to a sufficient number of lags (Laurenceson and Chai 2003). This approach is appropriate for evaluating the dynamic competition relationship between intercity transport modes as it can completely describe the long-run relationship and short-run dynamics without losing longrun information among the variables.

The first step is to formulate an unrestricted ARDL model and then to test for the existence of any long-run relationships using the cointegration test. Once a cointegration relationship has been found, our ARDL model will be constructed according to suitable lagged orders and restricted conditions. We can analyze the model's coefficients in order to understand the long-run relationships among variables. Secondly, the error correction model (ECM) is used to uncover the short-run dynamics, and the coefficients of short-run relationships are also estimated. Finally, the stability of the model is examined by employing the cumulative sum of recursive residuals (CUSUM) and the cumulative sum of squares of recursive residuals (CUSUMSQ) tests.

The form of the unrestricted ARDL model is defined by

$$\Delta y_t = \alpha_0 + \alpha_1 T + \sum_{i=1}^{p} \psi_i \Delta y_{t-i} + \sum_{i=1}^{q} \beta_i \Delta x_{t-i} + \delta_i y_{t-1} + \theta_i x_{t-1} + e_t$$

Suppose that there are two kinds of transport modes, Modes A and B. We would like to estimate the impact of Mode B on Mode A through their passenger volume. In the modeling process, the variables of passenger volume in Modes A and B do not need pre-testing with regard to whether the underlying regressors are purely I(0), purely I(1), or a mixture of both. Therefore, it is not necessary to use residual-based and maximum likelihoodbased approaches when adopting the ARDL approach for the cointegration test. In addition, the passenger volume of Mode A can be explained by its own lagged values plus the current and lagged values of the independent variables. The lagged values in these two modes are not limited to being the same.

3 INTERCITY TRAVEL SURVEYS

3.1 Study Area

The three major cities in Kerala were selected as the study area for this research. Thrissur, Ernakulam, and Kozikode are the three cities which are considered for the study. Thrissur and Ernakulam are located at a distance of 75kms. On a daily basis, 17 trains run between Kochi and Thrissur. On a weekly basis, the count shoots up to 78. 218 KSRTC buses are running between these cities. And also very few private buses are there. Thrissur and Kozikode cities are located at a distance of 119kms. On a daily basis, 7 trains run between Kozhikode and Thrissur. On a weekly basis, the count shoots up to 30. 142 KSRTC buses are running between Kozhikode and Thrissur cities. And also a number of private buses are there for travel between these cities.

3.2 Survey Data

The data in this study were obtained through intercity travel survey and the methodology conducted was based on study conducted by. Total of about 500 respondents were questioned. The questionnaire survey was designed to satisfy the requirements for the development of an intercity mode choice behavior model and to investigate the major factors that influence the choice of intercity travel mode.

The study was conducted in these three major cities in kerala because of the high car ownership, availability of intercity public transport, and the adequate representation of travelers. Specifically, this study randomly selected respondents from Thrissur, Ernakulam, and Kozikode city centres based on a stratified sampling approach to achieve` a representative sample that reflects demographic and socioeconomic profiles.The questionnaire covered all the relevant information which influences the mode choice behavior of passengers. It was composed of three parts. First part is the characteristics of traveler like age, gender, monthly income etc. second part is transit information like comfort, safety, convenience etc. and third part is the journey information.

4 STATISTICAL ANALYSIS

Various statistical analyses performed on the survey sample by doing analysis on the basis of different Distance from home to transit station, In vehicle travel time from home to transit station, Access time, Waiting time for the transit, Transit fare, Total fare, Gender, trip purposes etc. The main aim is to ascertain the percentage of passengers in the study area for each characteristic in order to surmise the influence on travel behaviour. In estimating the model, this study is, particularly, interested in the impact of all possible variables on mode

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choice decisions for long-distance travel. In case of public transportation modes, both travel time and costs include access time and costs to the closest intercity terminal. Then, this study attempts to test the impacts of travelers' characteristics on mode choice decisions by adding individual characteristics such as age related attributes, purpose of trips and income group etc. to explanatory variables.Among the range of variables that have been examined in the previous studies, both travel time and cost comprise the key variables that are expected to have negative signs. As travel time and cost increase, traveler's utility from a choice of the alternative decreases.Trip purposes such as work related trips and social and recreational trips are employed in the models as dummy variables that present the reasons why people travel. As explained above, this study intends to test the impacts of alternative-specific characteristics on the probability of choosing a specific mode. At the same time, this study aims to examine the potential impacts of an individual attributes on the mode choice decisions for long-distance travel.In this regards, this study estimates different models that include alternative-specific characteristics, individual attributes etc. for Thrissur - Ernakulam and Thrissur – Calicut cities.

A preliminary analysis has conducted in the data collected. Preliminary analysis of train passengers travelling from Thrissur to Ernakulam and to Calicut is conducted and the analysis results are presented in the graphical representation. Analysis has conducted based on the factors such as age, gender, purpose of trip.

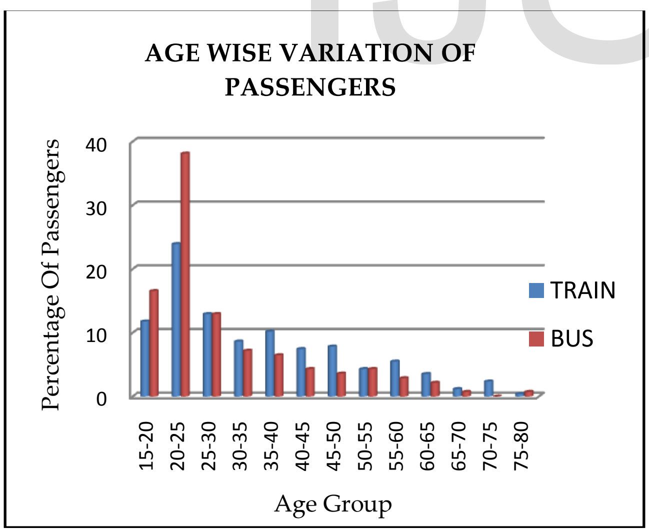

Fig.1 Age wise Train Usage Graph

4.1 Age Wise Transit Usage

Age is one of the demographic factors which influence the mode choice and travel behaviour of passengers. Survey is conducted on weekdays and most of the passengers were regular passengers. Mainly the people aging 18 to 75 are travelling in train between study cities. From Fig.1 it is clear that youngsters are major train users and they are going for education and work purposes. Among the passengers, aging between 20 and 25 are the major category and 15 to 20 coming as the second highest category using train or bus for their intercity travel. Elder people, aging above 75 are the least coming category of travelers.

4.2 Gender Wise Transit Usage

There is no rationality between men and women in the working environment. But percentages of males are more than that of females using train as a travelling mode for intercity travel and vice versa in bus passengers. Female passengers are giving more importance to safety and convenience that's why the female population is high in bus passengers. Frequency of buses and train timings are also affecting the mode choice behaviour of male and female passengers. Gender wise transit usage variation is clear from Fig.2 and Fig.3

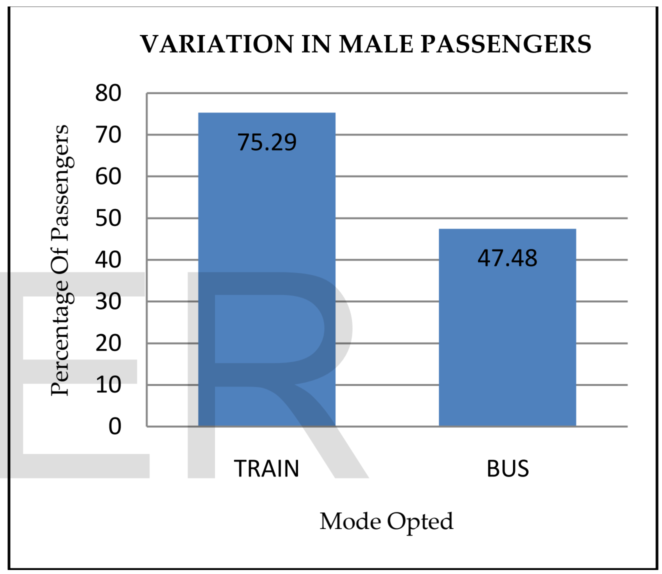

Fig.2 Gender wise Train Usage Graph

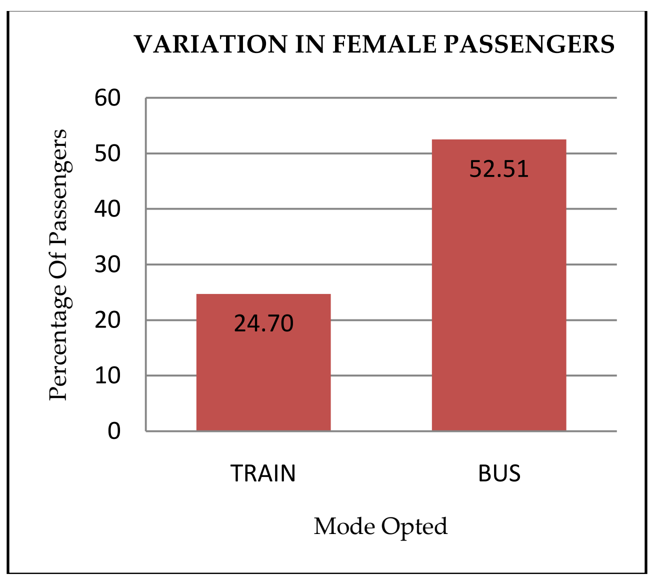

Fig.3 Gender wise Train Usage Graph

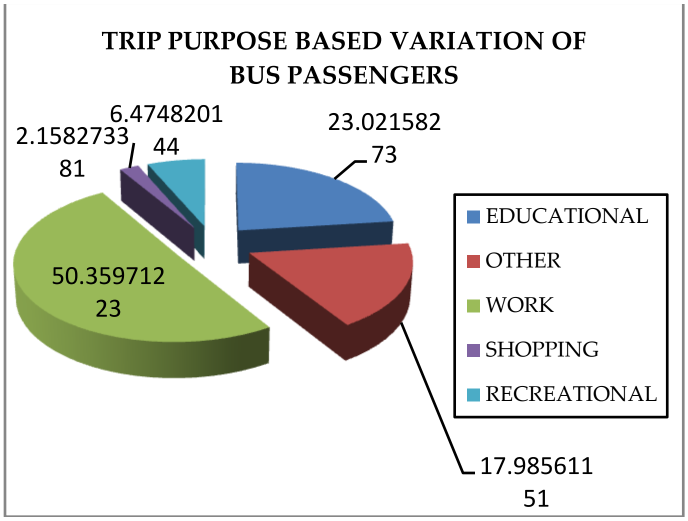

Fig.4 Trip purpose wise bus Usage Graph

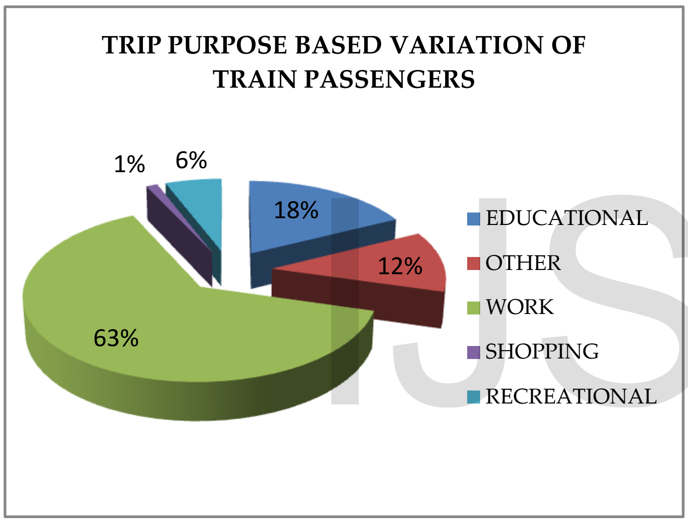

Fig.5 Trip purpose wise Train Usage Graph

4.3 Trip Purpose Based Transit Usage

Cochi is one of the metro cities in Kerala and it offers huge job opportunities and leading colleges are also present. Hence most of the travelers from Thrissur to Ernakulam are students and workers. Recreational centers also present in Cochi and it attracts tourists. But the percentage of travelers using train as their travelling medium for the recreational purposes is very few. The condition is almost same in the case of Calicut city. Trip purpose for both train and bus passengers are same. Most of the people are going for their work purposes. From the Fig.4 and Fig.5, it is clear that, more than half; about 63% people travelling in train and 51% in bus are going for their work purpose. And second most categories are students.

5 MODE CHOICE MODELING

From the range of variables that have been considered in the previous studies, it is found that, both travel time and cost comprise the key variables and are expected to have negative signs. As travel time and cost increase, traveler's utility from a choice decreases. Travel time is often split into in-vehicle time and out-of vehicle time of which the latter includes access/egress time, waiting time and in vehicle travel time for the transit and also for all other modes used. Meanwhile, travel cost commonly means fare level of public modes such as train or bus and for all modes used. Travel costs also can be split into two subcategories such as fare and access/egress costs. All these subcategories of travel time and costs are also expected to have negative sign in the estimated models. In addition to the attributes like socio economic characteristics, transit characteristics and journey of the alternatives, travelers' characteristics are also frequently employed in many mode choice models. In specific, this study includes gender, travel time and fare related attributes in the model and it is shown in Table.1 and Table 2. As explained above, this study intends to test the impacts of alternative-specific characteristics on the probability of choosing a specific mode. At the same time, this study aims to examine the potential impacts of an individual attributes on the mode choice decisions for these intercity travel. It was expected to obtain a negative correlation between time and mode choice and also between fare and mode choice. But in the current scenario the condition is vice versa. Waiting time shows a positive relationship with mode choice behavior. This is the clear evidence of travel behavior of people in the study cities. Most of them are not looking for their convenience only for the trip. That is the reason why these variables showing a positive relationship. Among the Thrissur and Calicut passengers as in Table 2, men are the major category of selecting a public transport vehicle than women. In both of the models, total fare is a major variable and which shows a positive relationship with mode choice. Passengers opting either a train or bus, the transit fare is low, but the reason for positive relationship between this variable and the dependant variable is, when other fares like home to transit station fare, transit station to destination fare, parking fee etc. are added to the transit fare, the total fare become slightly high. But the people are opting a mode based on their comfort and convenience only.

Table.1 Variables in Thrissur Ernakulam Model

Variables in the Equation							
		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	WAITING TIME2	-.173	.041	17.898	1	.000	.841
	TOTAL FARE	.030	.006	27.590	1	.000	1.030

a. Variable(s) entered on step 1: WAITING TIME2, TOTAL FARE.

Table.2 Variables in Thrissur Calicut Model

Variables in the Equation							
		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	GENDER	2.017	.602	11.220	1	.001	7.514
	IN VEHICLE TRAVEL TIME	-.037	.007	26.610	1	.000	.964
	TOTAL FARE	.034	.008	18.229	1	.000	1.034
a. Variable(s) entered on step 1: GENDER, IN VEHICLE TRAVEL TIME, TOTAL FARE.							

Table.3 Mode Choice Models

Thrissur Ernakulam Model	Y=-0.173*Waiting time for the transit+0.030*Total fare	R^2=0.699
Thrissur Calicut Model	Y=2.017*Gender-0.037*In vehicle travel time+0.034*Total Fare	R^2=0.644

R^2 value of a model tells us about how much variation is explained by a model. And its value ranges between zero and one. Here for both of the models as shown in Table.3, the R^2 value is in the moderate range and it is acceptable. All the independent variables in the model has the significance less than 0.05 and least correlation among them.

CONCLUSION

Major conclusions obtained are;

- Waiting time for the transit, Transit fare, Total fare, Gender, and In vehicle travel time in the transit are found as the major mode choice determining variables .
- Most of the daily passengers are choosing a public transport other than a private transport vehicle.
- People going for the working purpose are the major part of the passengers. Second most passengers are students going for their education purposes.
- Number of private buses running between the study cities is very few. Passengers opting buses for their intercity travel are choosing a KSRTC bus other than private buses. That is the reason why private bus owners reduced their number of runs between these cities.
- As the distance between cities increasing, number of passengers decreases. Number of passengers traveling between Thrissur and Ernakulam are more than that of between Thrisuur and Calicut.

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