Mode shift behaviour study of car users with respect to mass transit in a metropolitan context

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Abstract

The research article focus on development of behaviour prediction models to predict personalized car users' willingness to shift to public transport based on their responses collected through stated preference survey for various hypothetically designed mass transit improvement scenario. Research instrument developed and adopted for the present study was tested through pilot survey and corrected as per data compatibility requirement. The main survey is executed through carefully designed stratified random sampling technique. Comparative analysis between two separately developed models using binary logistic approach is presented in this paper to evaluate changes in personalized car users' behaviour and model performance with and without inclusion of latent classes. The study will provide user friendly statistically tested and validated model to evaluate probable mode shift from private transport to mass transit which can be further utilized by decision makers for development and design of demand oriented transport rather than supply oriented system.

Keywords : Travel mode shift, logistic models, personalized car users', mass transit, latent classes

1.0 Introduction

Increasing intensity of traffic in developing countries has resulted in number of problems such as traffic congestion, delay, accidents and pollution which poses a potential threat to the economic vitality and productive efficiency of these cities**. According to Vedagiri . P and Arasan V.T (2009)** statistics of Indian cities are also observing similar threat as other developing countries. One of the major reasons for such alarming situation is increased ownership and usage of personalized vehicles on Indian roads and declined share of public transport. Statistical summary presented in literature justifies findings of **Pucher et al, 2004** showing serious challenges in road –based urban transportation sector for Indian metro cities. **Badami and Haider, 2007** suggested need of urban public transport system reform to accommodate growing need of sustainable urban mobility as the current public transit services particularly bus based services are found to be unreliable, slow, unsafe, uncomfortable, overcrowded and poorly managed in most of the Indian cities. Compared to major cities of world, statistics of Indian cities are showing very less percentage share of public transport around 1.1% almost in all metro cities, except few, which is demanding special attention of researchers, planners and policy makers as stated by **Padam S & Singh, S. K., 2001**. Shifting of personal automobile users to other environmental friendly transport modes is a key transit planning strategy adopted worldwide for reducing traffic congestion, air pollution, road accidents and health hazards. It also provides better mobility, improved quality of life and other socio economic benefits however these studies pertaining to mode shift differ greatly in methodologies, data, units of measurement and explanatory variables. **Vengaraju and Krishna Rao K.V. (1997), Rastogi R and Krishna Rao K. V. (2000), (2002), (2003), Kumar & Krishna Rao K.V. (2006) , Geetam Tiwari (2008), Rastogi R and Krishna Rao K. V. (2009), Vedagiri P (2009) and Arasan V.T (2009)** have studied travellers' behaviour for cities like Mumbai, Chennai, Delhi, Calcutta and Bangalore. **Nipa Desai & Goshi G J (2013)** have thrown some light on geographical and cultural variations in factors affecting travel mode choice. Recent findings in the transport modelling field suggests that only socio-economic attributes and trip related attributes are not sufficient to characterize travellers' and make forecasts about their travel behaviour. Recently published studies have shown integration of latent variables representing attitudes, perceptions, behaviour and preferences into choice models and revealed suitability of psychometric scales for measurement of latent variables. **Ben-Akiva et al. (2002)** presented a behavioural framework and related logical formulations for modelling these latent variables. **Morikawa et al. (2002)** and **Chih-Wen Yang et al. (2002)** included modal comfort and convenience in their analyses of mode choice and modelled latent variables through attitudinal indicator. **Maria Vredin Johansson et al. (2005)** studied the problem of unobservable, or latent, preferences in mode choice models and identified that latent variables enriched discrete choice models. But, till today no attempts are made for integration of latent categories in mode choice and especially mode shift studies in Indian metropolitan context. Looking to the need of design and implementation of most desirable plans for long-term sustainability of Indian metro cities through diverting personalized car users to public transport the present study has been carried out. Empirical studies to understand travellers' mode choice and mode shift behaviour were carried out by many researchers worldwide and findings of these studies provided significant insight into travellers' behaviour in variety of situations. However, for countries like India where very limited attempts are documented, more inputs are needed due to diversity in travellers' characteristics and behaviour with reference to geographical, cultural and other variations.

2.0 Research Objectives and Study area delineation

Research on travel mode shift behaviour study is focusing on serious need of diverting personalized vehicle users to mass transit modes through improved mass transit facilities, curtailed usage of personalized modes with strict policy interventions and bringing behavioural changes especially in context of Indian metropolitan cities. In this paper specific attention is given to travel mode shift behaviour of personalized car users' with respect to improved mass transit services. For fulfilment of research agenda entire research area is divided into smaller number of targeted research objectives. Identification of the most influential variables associated with car users' mode shift behaviour, modeling of car users' preferences to predict their behavior for various hypothetically designed mass transit improvement scenarios and analysis of changes in model performance with inclusion and exclusion of latent classes are the major focus areas of this paper.

Area selected for travel mode shift behaviour study is Vadodara city which is the third largest and one of the most developing cities in the State of Gujarat, India with a population of 2.1 million as per census 2011. The reason behind selection is the observed decline in Vadodara city public bus transport share and increase in share of personalized automobiles on city roads during last two decades **Nipa Desai & Vashi, B.D (2007)**. Like other Metro cities of India, this decline in Vadodara urban area mass transit share also needs special attention. Study carried out by **Nipa Desai & Vashi, B.D (2007)** concluded that more than 85% of Vadodara city commuters are diverted to personalized vehicles or other intermediate transportation modes due to inefficient fleet size and poorly managed city bus services during last two decades. The research has been taken as an initiative to provide statistically tested and validated behaviour prediction of personalized car users' for probable mode shift from private car to mass transit which can be further utilized by decision makers for development and design of demand oriented transport rather than supply oriented system. Entire process of database development, design and calculation of sample size, construction of psychometric scale for measurement of latent variables, design and testing of research instrument and execution of field survey can be referred from earlier research article of authors titled "Database Development Approach and Survey Design for Travel Mode Shift Behavior Study with Respect to Mass Transit in a Metropolitan Context. **Desai, Nipa A., and G. J. Joshi (2016)**

3.0 Sample descriptive statistics of car users'

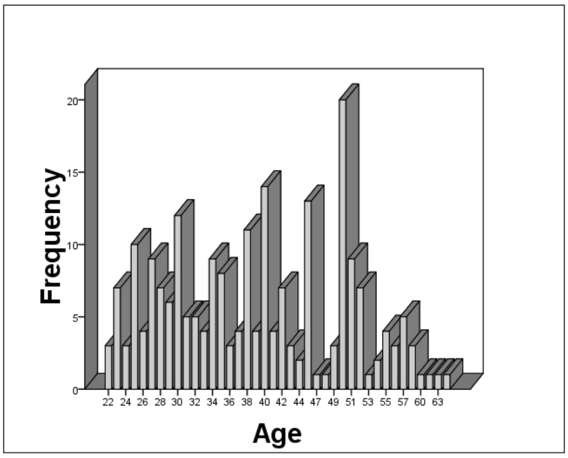
The city was divided into 10 household survey zones for execution of survey for better results and proper understanding of travel pattern. Based on ward population and formed strata, samples from each zones are collected. Total 1017 valid responses are collected out of which 220 responses of car users' are segregated and analysed separately to know sample distribution statistics. **Table 1** shows descriptive statistics of sample data. Average age of car user is observed as 39 years and the average household size is around 4 persons per household out of which around 2 persons are found working. Most of the households are found with ownership of two or more motorised 2-wheelers and one car. Average trip length of car users' for their work trips is observed around 7 k.m. with an average travel time of 21 minutes and average spending of around 102 INR/Day for their daily work trips.

Table 1 Sample descriptive statistics of car users'

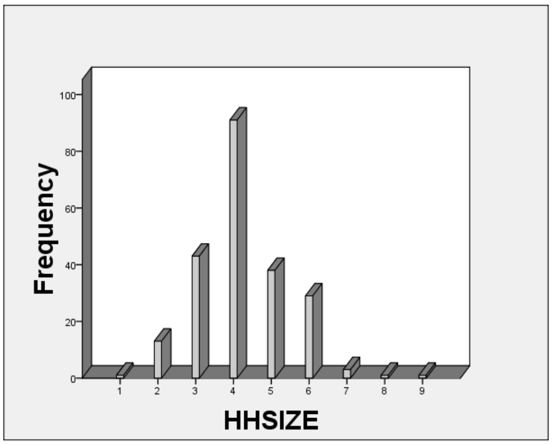
Variables	AGE	HH SIZE	HH WORK	HH MINC	NO_2W	NO_CARS	DIST WP	TIME ONEWAY	COST DAY
N	220 0	220 0	220 0	220 0	220 0	220 0	220 0	220 0	220 0
Mean	39	4	2	52107	2	1	7	21	102
Median	39	4	2	42500	2	1	7	20	100
Mode	50	4	2	42500	2	1	10	20	100
Std. Deviation	11	1	1	20490	1	0	3	9	54
Minimum	22	1	0	12000	0	0	1	5	20
Maximum	66	9	5	75000	4	2	13	45	250
Percentiles	3	1	42500	1	1	5	15	50	30
	4	2	42500	2	1	7	20	100	40
	5	2	75000	2	1	10	30	150	50

Note : AGE-Age , HHSIZE- Household size, HHWORK- Number of working persons per household, HHMIC – Household monthly income , NO_2W- Ownership of 2-wheelers per household, NO_CAR – Ownership of car per household, DISTWP – Distance to workplace, TIONEWAY- Time of one way trip, COSTDAY – Daily cost of travel for one way work trip

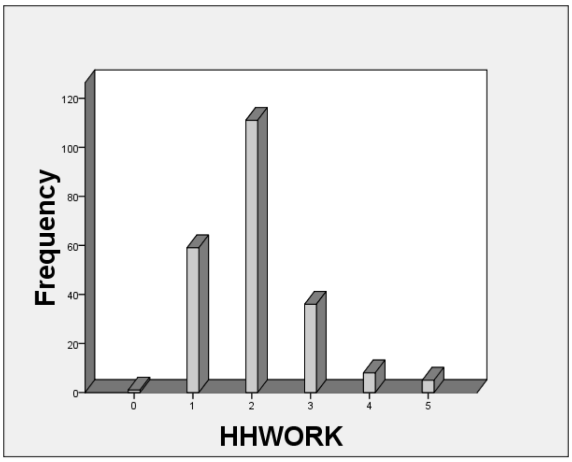
Graphical representation of sample descriptive statistics is given in **Figure 1.** It is observed from Figure 1(a) that samples of car users are found between age group from 22 years to 66 years and the maximum number of commuters who are using personalized car as their main mode of travel during their work trips are between 40 to 50 years of age. Highest frequency of car users' age is observed as 50 years. Maximum number of households is observed with a family size of 4 members per family as shown in Figure 1 (b) out of which two people are found working in majority of the households and more than 50% of car users are identified with two or more 2-wheelers' in a household as shown in Figure 1 (c) and (d). In case of car users' the maximum frequency of family monthly income is observed as shown in Figure 1 (e) as 42,500 Indian rupee (INR) followed by 75,000 INR where the observed values are mid of income range 30,000 INR-60,000 INR and 60,000 INR – 90,000 INR respectively. It is observed that in case of car user the time of travel for one way work trip varies from 5 minutes to 45 minutes however around 75% of car trips are observed within a reach of 35 minutes as shown in Figure 1 (g) and (h). Higher travel time by car in comparison with 2-wheeler is observed which may be due to the manoeuvrability restrictions of four wheelers' in comparison with compact two wheel vehicles.



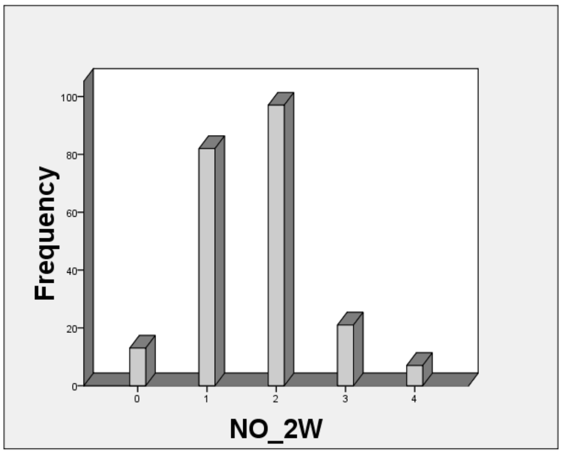
(a)
Sampling distribution of respondents' age



(b)
Sampling distribution of household size



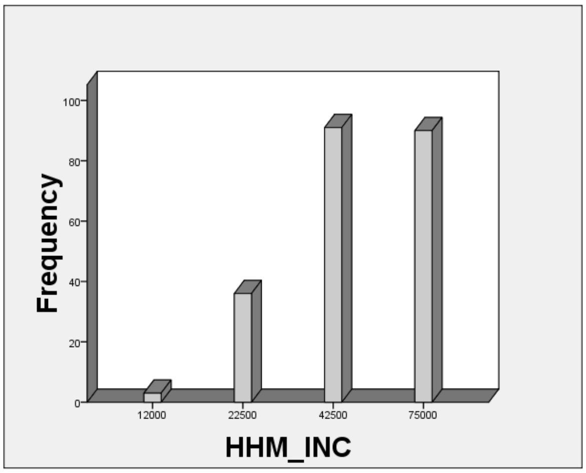
(c)

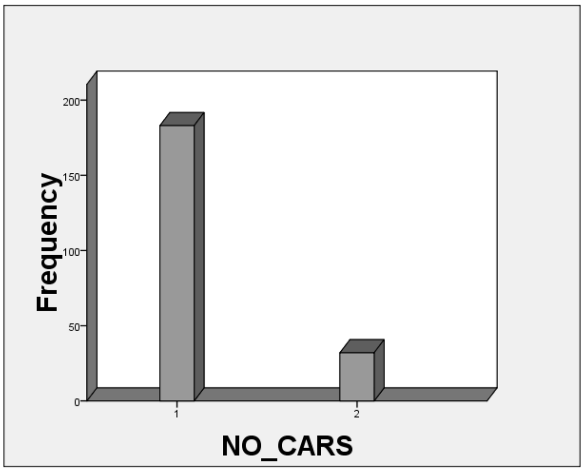


(d)

Sampling distribution of number of working persons per household

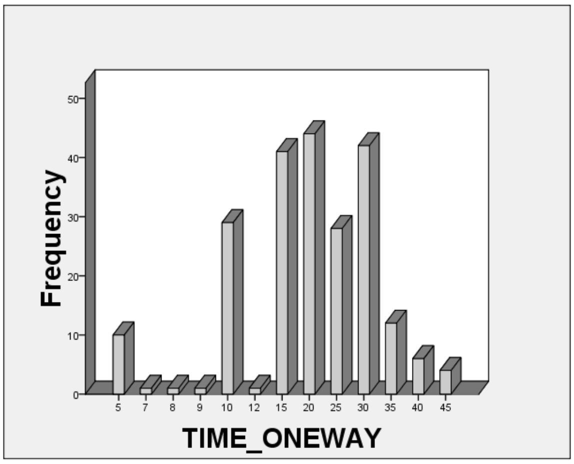
Sampling distribution of number of 2-wheelers per household

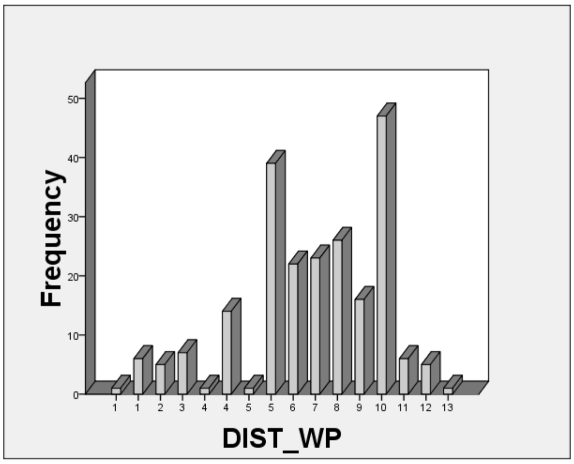




(e)
Sampling distribution of household monthly income

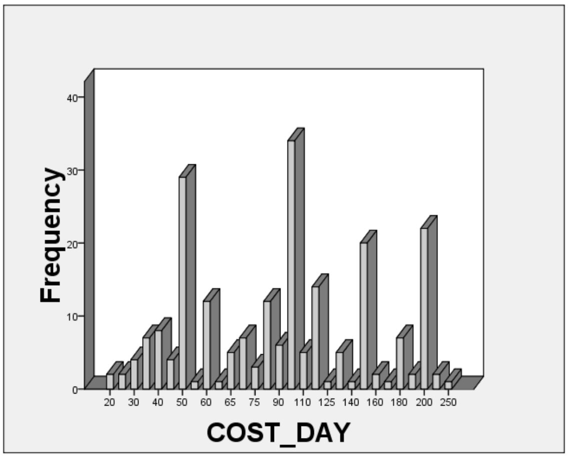
(f)
Sampling distribution of number of cars per household





(g)
Sampling distribution of respondents' time for one way trip

(h)
Sampling distribution of respondents' work place distance



(i) Sampling distribution for cost of one day work trip

Figure 1 Graphical representations of sample descriptive statistics of car users'

Cost of one day work trip for car users' have also been analysed and found as between 20 INR to 250 INR with an average daily expenditure of 102 INR for their daily work trips however more than 60% of car users are spending less than 100 INR for their one day work trips as shown in Figure 1 (h) and (i).

4.0 Comparative mode shift behaviour modelling of personalized car user with and without inclusion of latent classes.

The binary logistic regression approach is adopted for development of mode shift probability prediction models of personalized car users'. Preferences given by car users' for various hypothetical cases towards shifting to mass transit from their personalized modes are analysed and modelled to obtain statistically tested and validated mode shift behaviour models. The model is constructed using an iterative maximum likelihood method in SPSS software. In SPSS, calibration of model starts with an initial model known as constant only model for prediction of observed data. The initial model also known as base model is presented as Model-1 in Table 2. The variables are added one by one into the model using forward likelihood method until the model converges. The finally converged model with all the significant variables are compared with constant only model and various statistical tests are performed to check whether adding various variables have increased prediction capacity of models in comparison with constant only model or not.

Table 2 Model-1 (Constant only model) Beginning block of personalized car users' Binary Logit mode shift model of

(a) Variable coefficient for constant only model

	B	S.E.	Wald	df	Sig.	Exp(B)
Step 0	Constant	.818	.179	20.909	1	.000

(b) Observed and predicted probability summary for constant only model

		Predicted					
		Selected Cases			Unselected Cases		
		WILLING SHIFT			WILLING SHIFT		
Observed		0	1	% Correct	0	1	%Correct
WILLINGSHIFT	0	0	45	.0	0	18	.0
	1	0	102	100.0	0	55	100.0
Overall Percentage				69.4			75.3

(c) Test statistics

Hosmer and Lemeshow Test results					
Chi-square	df	Sig.	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
0.000	0	.105	140.00	.243	0.343

Model-2 and Model-3 as represented in Table 3 are developed by adding different variables to the constant only model. Model-3 is developed excluding latent classes while model-3 is with inclusion of latent classes of comfort & convenience and safety & security to check the effect on model output without and with inclusion of latent classes. Probable changes in model performances due to inclusion of latent classes are observed through detailed study of both the models. Table 3 (a) and (b) shows significant variables extracted for Model -2 and Model-3 after model calibration and validation by forward log likelihood method. Variables with significance value < 0.05 are included for development of final prediction model. In both the models sign of significant variables are analyzed and found logical. Significant variables responsible for car users' mode shift decisions in Model-3 are age (AGE), household size (HHSIZE), number of working in a household (HHWORK), lowest bus stop waiting time (WAITT_3) up to 5 minutes, more than 15 INR reduction in daily work trip travel cost (TC_3) and transit access time (ACCTIME_2) between 6- 9 minute as shown in Table 3 (a).

Table 3 Comparative analysis of binary Logit mode shift model of personalized car users' with and without inclusion of latent classes

Model-3 Excluding latent classes

(a) Significant variables in the model

	B	S.E.	Wald	df	Sig.	Exp(B)
AGE	.064	.027	5.650	1	.017	1.066
HHSIZE	.624	.258	5.839	1	.016	1.866
HHWORK	-1.052	.315	11.195	1	.001	.349
WAITT_3	1.895	.644	8.644	1	.003	6.651
RTC_3	1.971	.600	10.805	1	.001	7.178
ACCTIME_2	1.077	.523	4.231	1	.040	2.935
Constant	-5.018	1.801	7.762	1	.005	.007

(c) Test statistics

Hosmer and Lemeshow Test results					
Chi-square	df	Sig.	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
11.921	8	.155	116.622	.355	0.501

Model-4 Including latent classes

(b) Significant variables in the model

Variable	B	S.E.	Wald	df	Sig.	Exp(B)
AGE	.061	.025	5.848	1	.016	1.063
HHWORK	-.693	.262	6.997	1	.008	.500
RTC_3	2.086	.559	13.918	1	.000	8.049
COMLVL_3	2.552	.669	14.536	1	.000	12.831
Constant	-3.278	1.423	5.307	1	.021	.038

(d) Test statistics

Hosmer and Lemeshow Test results					
Chi-square	df	Sig.	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
4.828	8	.776	79.222	.500	.706

(e) Observed and predicted probability summary

Observed		Selected Cases WILLING SHIFT 0	Selected Cases WILLING SHIFT 1	Selected Cases % Correct	Unselected Cases WILLING SHIFT 0	Unselected Cases WILLING SHIFT 1	Unselected Cases %Correct
WILLINGSHIFT	0	36	9	80.0	13	5	72.2
	1	7	95	93.1	11	44	80.0
Overall Percentage				84.0			79.1

(f) Observed and predicted probability summary

Observed		Selected Cases WILLING SHIFT 0	Selected Cases WILLING SHIFT 1	Selected Cases % Correct	Unselected Cases WILLING SHIFT 0	Unselected Cases WILLING SHIFT 1	Unselected Cases %Correct
WILLINGSHIFT	0	34	11	75.6	14	4	77.8
	1	8	94	92.2	11	44	80.0
Overall Percentage				87.1			79.5

(g) Omnibus Tests of Model Coefficients

	Chi-square	df	Sig.
Step	6.260	1	.012
Block	75.316	6	.000
Model	75.316	6	.000

(h) Omnibus Tests of Model Coefficients

	Chi-square	df	Sig.
Step	6.376	1	.012
Block	70.152	4	.000
Model	70.152	4	.000

Positive value of variable coefficient AGE and HHSIZE reflects that if age of car user is more and larger is the household size than their desire towards willingness to shift is more. However the relationship between number of working persons in a family and their desire for willingness to shift is observed negative. The negative relationship shows, more is the number of working persons per household less is their desire to shift to public transport. In case of observed negative willingness to shift, it might be possible that when number of working persons in a family is more, few of them may prefer to share their vehicle for daily work trip rather than shifting to public transport. The positive sign of variables WAITT_3, RTC_3 as shown Table 3 (a) are found logical stating positive impact of these coefficients on willingness to shift. It shows that with increase into the reduction in bus stop wait time, reduction in travel cost compared to existing mode, commuters' willingness to shift towards public transport services increases. Positive sign of variable (ACCTIME_1) also shows positive relationship between reduced transit access time and subsequent increase in percentage willingness to shift.

When similar Model is developed once again for car users' with inclusion of latent classes notable differences are observed in model form in comparison with earlier Model-3 the positive sign of newly identified significant variable (CCLVL_3) sounds logical. It shows that with increase in level of offered comfort & convenience, increase in the car users' desire for willingness to shift is observed. Car users' age (AGE), number of working people per household (HHWORK), more than 15 INR reduction in daily work trip travel cost (TC_3) and highest level of comfort & convenience (CCLVL_3) are identified as the most significant variables for Model-4 with logical signs of parameters as shown in Table 3 (b). Out of all significant variables HHWORK, TC_3 and WAITT_3 in Model-2 and CCLVL_3 and TC_3 in Model-3 are having high values of odds ratio (Wald statistics) which shows its higher influence in models while making mode shift decisions as described in Table 3 (a) and (b).

Various statistical tests are performed to check model accuracy and difference in performance of both the models, here H&L statistics values for Model-2 is observed as 0.155 less than 0.5 describes poor fit of model to data, however with inclusion of latent classes in Model-3 the value of H&L statistics is increased to 0.776 which shows good fit of data to the model as well as improvement in model performance with inclusion of latent classes as shown in Table 3 (c) and (d). Under Model Summary as represented in Table 1 (c) and Table 2 (c) and (d), we see that the -2 Log Likelihood statistics for constant only model (Modle-1) is 140.00, for model without latent classes (Model-2) is 116.622 and for model with latent classes (Model-3) is 79.222. The -2 Log Likelihood statistic measures how poorly the model predicts the decisions, the smaller the statistic, better the model. Here, Model-3 developed with inclusion of latent classes shows the minimum value of -2 Log Likelihood representing the best fit model amongst all three models. Improved values of Cox & Snell R^2, Nagelkerke R^2 in both the models (Model 2 & 3) with respect to constant only model (Model-1) justifies improvement in model performance with addition of different variables in constant only model. Similar improvement in the values of Cox & Snell R^2, Nagelkerke R^2 are also observed for Model-3 in comparison with Model-2 which justifies significant improvements in model performance with inclusion of latent classes.

Table -2 (b) and Table-3 (e) and (f) shows comparison between model prediction success rates. Percentage correct prediction for selected cases of Model-3 is 84% which has improved to 87.1% with inclusion of latent classes however no specific improvement is observed in prediction success rate of unselected classes. Table 3 (g) and (h) represents test results for omnibus test carried out for both the models. Omnibus test is a test of null hypothesis which gives the result of Likelihood Ratio (LR) test which indicates whether the inclusion of this block of variables contributes significantly to model fit. A p-value (sig) of less than 0.05 for block means that the block 1 model is a significant improvement to the block 0 model. Here for both the models 3 & 4 values of omnibus tests observed with significant value less than 0.5 which shows improvement in models with respect to constant only model. The utility function developed using significant variables and variable co-efficient obtained during calibration are presented in equation 1 and equation 2 for Model-2 (Including latent classes) and Models- 3 (Excluding latent classes) respectively.

Z = 0.265+0891*GEN–0.756*MULTI_DES+1*WS_WAITT_3+0.811*WS_TC_3 + 0.801*WS_INTCHG_3 + 0.836*WS_ACCTIME_1 .... (1)

Z = -1.003-0.588*MULTI_DES + 0.808*WS_WAITT_3 + 0.793*WS_ACCTIME_1 + 1.504*WS_COM_3 + 1.501*WS_SAF_3 .... (2)

These utility values obtained from utility functions presented in equation 1 and equation 2 are further used to calculate the probability of personalized car users' towards shifting to public transport when substituted into binary Logit equation. Figure 1 and 2 shows predicted probability value plot for Model -2 and Model-3 respectively.

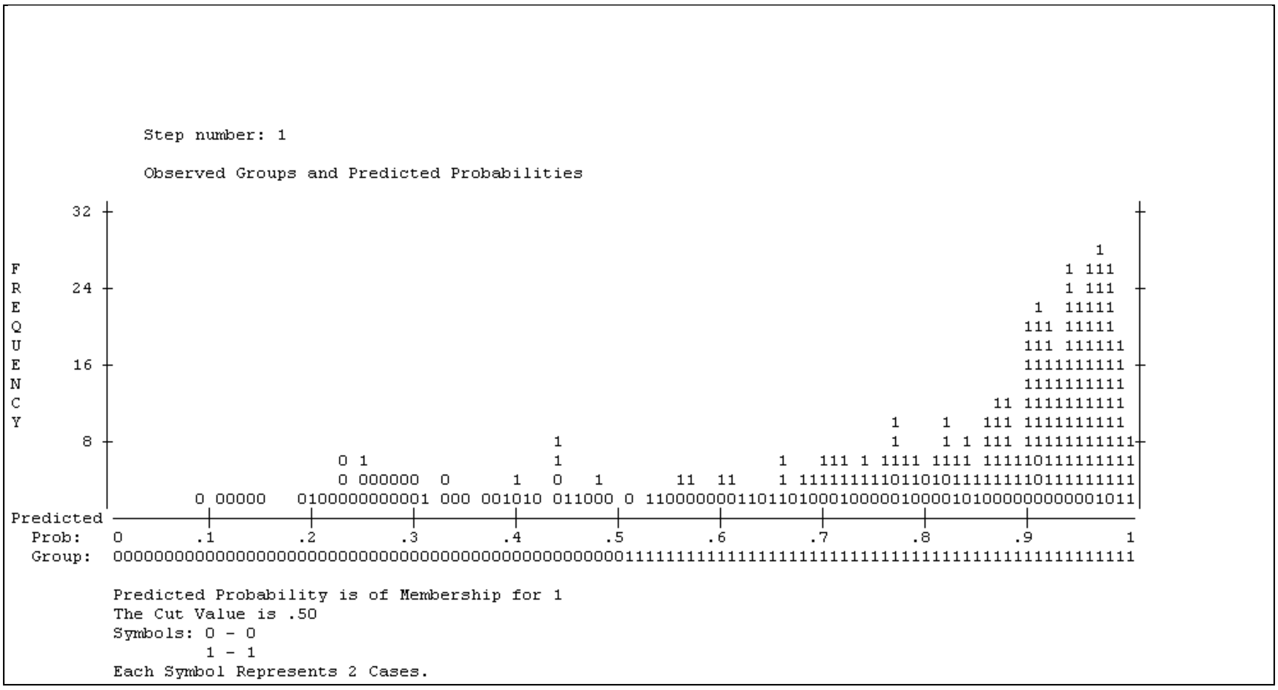


Figure 1 Graphical representation of predicted probabilities showing willingness to shift from personalized car to mass transit excluding latent classes (Model-3)

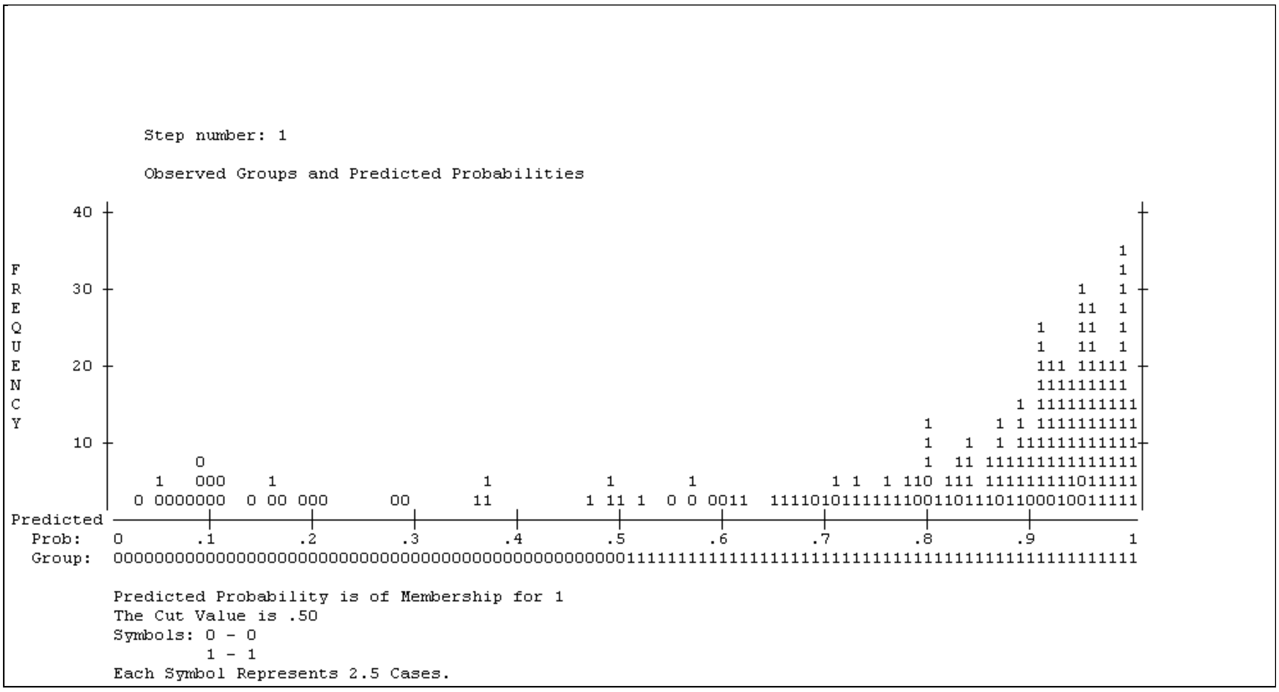


Figure 2 Graphical representation of predicted probabilities showing willingness to shift from personalized car to mass transit including latent classes (Model-4)

Further analysis to evaluate comparative performances of both the models is also carried out by plotting curves developed using Receiver Operating Characteristic (ROC) technique as shown in figure 3. The ROC curves plotted with blue and green colours are for Model-2 and Model-3 respectively. Visually the curve with green colour (Excluding latent) covers more area in comparison with blue (Including Latent) describes that prediction success rates for Model-3 is higher than Model-2.

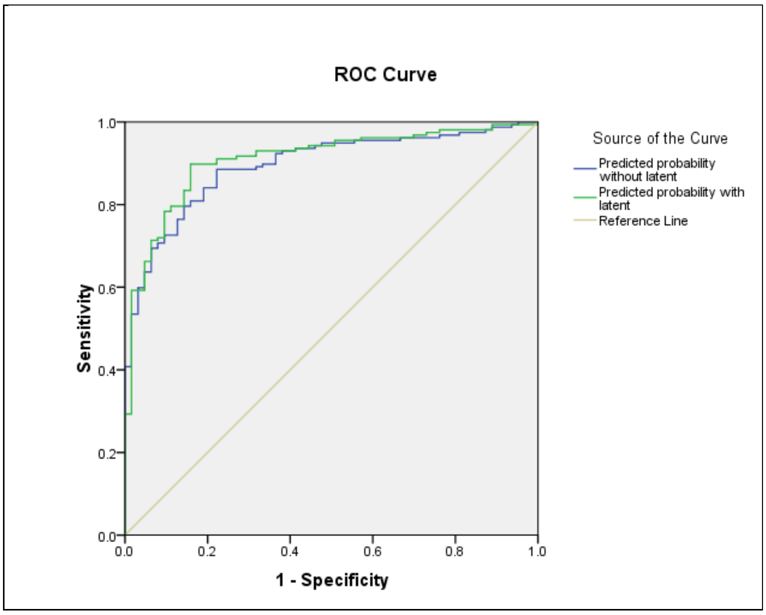


Figure 3 Comparative analysis for probability Prediction models with and without latent classes by Receiver Operating Characteristic (ROC) technique

Area under ROC curve is calculated and represented in Table 4. Increased area under curve for Model-3 in comparison with Model-2 shows improvement in performance of Model-3 with inclusion of latent classes.

Table 4 Area Under ROC curves for comparison of Model -2 and Model-3

Test Result Variable(s)	Line colour	Area	Std. Error	Asymptotic Sig.	Asymptotic 95% Confidence Interval	
					Lower Bound	Upper Bound
Predicted probability excluding latent classes	Blue	0.895	0.022	0.000	0.852	0.937
Predicted probability including latent classes	Green	0.909	0.021	0.000	0.868	0.950

5.0 Conclusion (Editing pending)

Significant variables found responsible for car users' mode shift decisions for the model developed without inclusion of latent classes are age (AGE), household size (HHSIZE), number of working in a household (HHWORK), lowest bus stop waiting time (WAITT_3) up to 5 minutes, more than 15 INR reduction in daily work trip travel cost (TC_3) and transit access time (ACCTIME_2) between 6- 9 minute. When similar Model is developed once again for car users' with inclusion of latent classes notable differences are observed in model form in comparison with earlier Model. Car users' age (AGE), number of working people per household (HHWORK), more than 15 INR reduction in daily work trip travel cost (TC_3) and highest level of comfort & convenience (CCLVL_3) are identified as the most significant variables. The positive sign of newly identified significant variable (CCLVL_3) sounds logical. It shows that with increase in level of offered comfort & convenience, increase in the car users' desire for willingness to shift is observed. It was found that both the models are satisfying statistical significance tests during model calibration and validation stages, however with inclusion of latent classes improvement in model performance is observed. Results of research findings complements potential of shifting personalized car users to mass transit through implementation of various corrective measures .Overall outputs of probability prediction models in variety of situation can be further utilized to design Vadodara city public transport services which can bring optimum shift from personalized travel modes to public transport.

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