MODELLING CHOICE OF AIRPORT AND ACCESS MODE

Madhav G, IIT Bombay, madhavence@gmail.com

Prof.K.V.Krishna Rao, IIT Bombay, kvkrao@civil.iitb.ac.in

ABSTRACT

As the economy of a region grows rapidly, it requires rapid modes of transport like air travel. This requires large infrastructural facilities like airports. These facilities involve huge construction cost and thus proper planning has to be done. Modelling Air travel demand at disaggregate level is a new concept in India as airport trips are not given much importance in traditional travel demand forecasting. This study focuses on development of disaggregate models for airport trip purpose, airport choice and access mode choice of airport travellers The prediction of air passenger and access mode choice decisions for travel to and from the airport forms a key analytical component of airport landside planning, as well as airport system planning. In view of the large demand of Mumbai Metropolitan Region (MMR) and the congestion at existing Mumbai airport, there has been a proposal for second airport in MMR. At this juncture the traveller would have an option to choose between two airports, assuming that similar airlines fly from both the airports. An airport choice model has been developed to study the behaviour of domestic air travellers, with regard to different attributes like access time to the airport, announced delay at the airport and new airport charges. Similarly, an Access mode choice model has been developed with emphasis on attributes like travel time, travel cost, level of comfort of the mode chosen to travel to the airport. For developing these models, a combined Revealed Preference (RP) and Stated Preference (SP) survey experiment was conducted in which the present airport trip details are enquired from the respondent and various hypothetical options were presented to him by varying the levels of attributes of his present trip. From the revealed preference data thus collected, an explanatory model which signifies the influencing attributes in airport access mode choice for various air travel purposes is proposed. The models developed indicated that travellers are willing to pay more money for modes with better access times and lesser delays at the airport.

Key Words: Airport Trip Purpose, Airport Choice, Access Mode Choice, Revealed Preference (RP), Stated Preference (SP).

1.0 INTRODUCTION

As the economy of a region grows rapidly, it requires rapid modes of transport like air travel. This requires large infrastructural facilities like airports. These facilities involve huge construction cost and thus proper planning has to be done. Air Traffic forecast forms the crux of any airport planning. It throws a light on the activity in the airport and the requirements to cater this activity. Various models have been developed to forecast air traffic demand. But, modelling Air travel demand at disaggregate level is a new concept in India as airport trips are not given much importance in traditional travel demand forecasting. Estimating airport trips is of much relevance in the present day context as it contributes to several other factors. The scale of air-related trip generation at metropolitan areas is of concern to regional transportation and environmental managers. For example, ground access traffic to the airport contributes to a number of problems; congestion, traffic noise, air pollution, etc. Empirically estimated choice model is of direct policy relevance, as it forms a key analytical component of economic models for the assessment of transport policies regarding parking charges, public transport fare, or the introduction of new modes (such as the extension of a light rail system to the airport), etc. However, there is currently no generally accepted and validated approach in India to modelling how airport users will change their access or egress mode in response to changes in the airport ground transportation system. The factors affecting airport travel are recognized as being significantly different from those affecting typical trips accounted for in regional transportation models.

Mumbai Metropolitan Region (MMR) is the largest industrially and technologically advanced region in India and is experiencing significant growth in terms of income and employment. The share of employment in manufacturing sector is declining whereas the share of tertiary sector is increasing. This trend clearly indicates that the region is emerging in trading and servicing activities. The ever-increasing trend in activities such as major trading, business and financial services will demand fastest modes of transport within the region as well as air linkage with the outside world. This requires large infrastructural facilities like airports. As it involves high cost it is very important for airport planners to develop reliable forecasting models for MMR and to understand possible limitations in the forecasting accuracy of these models. This study emphasizes on disaggregate airport related travel demand modelling of MMR. Passenger’s airport choice in multi-airport regions (MARs) is of great interests to transport researchers, local governments, airport authorities and airline companies. Airport choice depends upon various factors like air fare, access time, flight frequency and the number of airlines, airport access modes, access cost, airport shopping area and queue time at check-in counters etc. With a new airport originating in the Navi Mumbai region, it is important to assess the choice of people when this airport will be functional. The next important determinant of the study is the access mode which the people choose to make a trip to the airport. Airport access mode choice decisions by air passengers and airport employees affect a wide range of airport planning and operational management decisions, including the development of landside facilities, airport revenue from parking and other ground transportation services, and programs to reduce the growth in vehicle trips generated by the airport and the associated emissions. Potential uses of models that can predict the effect on access mode use of proposed changes to the system include sizing new planned facilities, evaluating the financial implications of proposed changes in parking rates or other ground transportation fees, determining the expected air quality impacts of planned new facilities or proposed mitigation measures, and assessing the feasibility of proposed projects to improve airport access. The access mode preferred by travellers can also be stratified by the purpose for which they are making air travel and the utility of an access mode for differ rent purposes has different significant variables in it. This study gives an insight into this.

Pels et al. (2001) made an initial attempt to jointly model the airport and airline choices by using the single-utility maximization framework. This framework assumes that every traveller's airport and airline choices result from the maximization of a single utility function, and therefore ensures that the observed choices, in combination, correspond to the maximized level of utility. Using this new framework, their study not only examined the major determinants of traveller's airport and airline choices, but also investigated how airport and airline choices are interrelated. Their results imply that while airport choices may represent unconditional choices, airline choices may represent conditional choices (on airport choices). This type of behavioural implication cannot be obtained if airport and airline choices are calibrated separately. **Basar and Bhatt (2004)** proposed the use of a probabilistic choice set multinomial logit (PCMNL) model for airport choice that generalizes the multinomial logit model used in all earlier airport choice studies. He discussed the properties of the PCMNL model, and applied it to examine airport choice of business travelers residing in the San Francisco Bay Area. The results indicate that it is important to analyze the choice consideration) set formation of travellers **Hess and Polak (2005)** presented an analysis of the choice of airport by air travellers departing from the San Francisco Bay (SF-B) area. The analysis uses the mixed multinomial logit model, which allows for a random distribution of tastes across decision makers. The results indicate that there is significant heterogeneity in tastes, especially with respect to the sensitivity to access time, characterised by deterministic variations between groups of travellers (business/leisure, residents/visitors) as well as random variations within groups of travellers. The analysis reinforces earlier findings showing that business travellers are far less sensitive to fare increases than leisure travellers, and are willing to pay a higher price for decreases in access time (and generally also increases in frequency) than is the case for leisure travellers. **Suzuki (2007)** developed a nested logit model of airport–airline choice that incorporates the "two-step" decision process of air travelers. The model assumes that a traveller first eliminates certain choice alternatives that do not satisfy his/her minimum acceptable standards (first step), and then chooses the utility-maximizing alternative from the set of screened choice alternatives (second step). The model is calibrated by using the survey data collected in the USA (central Iowa). The results imply that the "two-step" choice model may fit the observed data significantly better than the conventional "one-step" choice models.

Psaraki and Abacoumkin (2002) conducted studies on access mode choice to an airport. First access modal split at the existing airport is determined via passenger classification and discrete choice modeling. Both are conducted via a passenger survey study specifically designed for the purpose. The resulting models are then employed to forecast access modal splits for the relocated airport by proper adjustment of the attribute values. The method is applied to the new Athens International Airport. **Jun (2006)** estimated a mixed logit model to evaluate the factors valuing on airport ground access mode choice as well as airport choice using data from the 2001/2002 air passenger survey for San Francisco

Bay area Airports. Along with travel time and travel cost, the additional variables such as accessibility of public transit, the level of convenience, availability of cost reimbursement are introduced in the model to explain the access mode choice.

In the current study we tried to model the airport choice and access mode choice of present airport travellers of MMR region in light of a new airport proposed in the region. Models are proposed separately for airport choice and access mode choice. The next section will discuss about the characteristics of the study area, data set required for modelling purpose. Section 3 explains the methodology followed, and design of the experiment. Section 4 explains models developed and their results respectively.

2.0 STUDY AREA AND DATA SET

2.1 Air Transportation System of the Study Area

Basic structure of air travel in the country is greatly tilted towards the four major metropolitan cities namely, Mumbai, Delhi, Chennai and Kolkatta. Mumbai (30%) caters for the highest air passengers followed by Delhi (21%), Kolkatta (6.8%), Bangalore (5.4%), Chennai (9%), Hyderabad (3.6%) and Ahmedabad (2.0%). Mumbai and Delhi alone account for more than 50 percent of total, and more than 40% of the domestic air passengers in the country. Thus Mumbai airport is going to play a very important role in aviation sector of the country. Mumbai airport ranks 70th among the world's top 100 airports. It is the busiest airport in the country and handles approximately 30% of total passengers, 37% of cargo traffic and 25% of aircraft movements in country based on latest statistics. During the period 1972-1999, the international traffic at Mumbai Airport has increased from 1.04 million to 4.8 million whereas domestic traffic has increased from 1.34 million to 6.2 million recording an average growth rate of 6.10% for International and 6.06% for domestic traffic. In the past, air traffic growth in various studies adopted a telescopic growth rate ranging from 12.5 % to 4% in case of domestic and 8.5% to 4% for the international based on informed professional judgement with available past trend. A new airport in Navi Mumbai is under planning and is expected to be operational by 2015.

Netherlands Airport Consultants (*NACO*) has conducted studies for air travel demand fore casting of Mumbai International airport. They have carried out two parallel forecasts, one unconstrained and one constrained, which are explained below. The unconstrained forecast is the pure "demand forecast", describing the air traffic demand for the city of Mumbai that would be there if there were no physical constraints. It is based on a variety of economic parameters such as GDP growth, propensity to fly, the extrapolation of current traffic growth and envisaged market developments. However, the unconstrained situation would eventually require more than 100 air traffic movements (ATM's) per hour. The existing runway system at Mumbai can by no means support such a heavy demand. An improved runway system with a parallel runway at 380 m would be able to cater for a significant higher number of ATM's and would enable the airport to grow a number of years further, but will also not be able to handle the unconstrained forecast demand up to 2026.

Therefore there are two constrained forecasts. These relate to the following two runway configurations which are currently considered to be technically feasible at Mumbai Airport, each with its own constraints and maximum amount of air traffic movements (ATM's):

1. **Existing cross runway system.** After improvements to the taxiway system and ATC practice, it is determined that the maximum daily air traffic movements (ATM's) will be 44 ATM/hour.
2. **Close parallel runway at 380 m distance**. In this configuration it is determined that the maximum number of ATM's will be 60 in an hour. Figure1 depicts the forecasts for unconstrained and constrained forecasts.

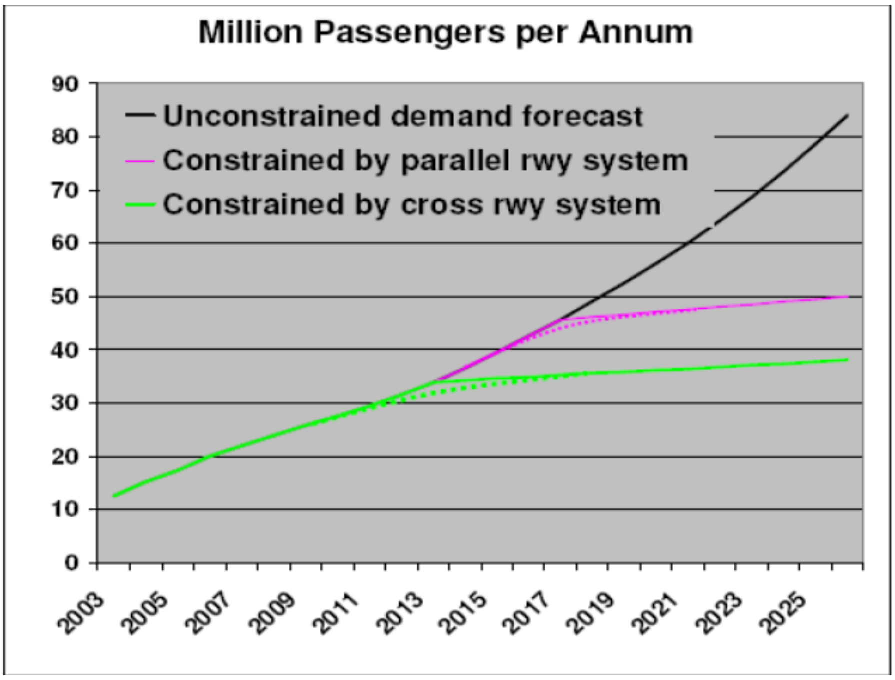

Figure 1 - Constrained and Unconstrained forecasts for Mumbai International Airport

(Source: NACO study for Mumbai International Airport)

2.2 Navi Mumbai Airport

Enhancement in aviation facilities in Mumbai is absolutely essential for sufficing the rapidly growing air travel demand of the region. Therefore a second airport in the Mumbai Region has become imperative, as the existing airport at Mumbai, is fast reaching saturation level. To meet the growing demand of air travel a new airport is getting structured in the Navi Mumbai region. The location of the proposed airport at Navi Mumbai has been considered on several parameters. Prominent among these is the fact that Navi Mumbai is expected to absorb the future growth in population, business and commercial activity of the region. The availability of physical and social infrastructure coupled with environmental friendly size with least resettlement and rehabilitation makes the Navi Mumbai airport project technically and financially viable. The airport would be one of world's few " Greenfield " international state-of-art airport offering world-class facilities to passengers cargo, aircrafts and airlines. The site of airport is located in an area of 950 hectares accommodating two parallel runways for simultaneous and segregated parallel operation with provision of full length taxi ways on either side of the runways. The airfield has been designed to accommodate the new large aircrafts compatible to aerodrome code 4-E. Navi Mumbai International Airport will support the rapidly growing air travel needs of MMR. It is expected to absorb annually 4.5 million passengers in its first operational year 2007, doubling to 8.2 million by 2010 to 13.7 million by 2020 and 30 million by 2030.

A project of such huge proportion needs careful forecasts to be done and the current study is a small contribution towards determining the choice of airport and choice of access mode of the present air travellers when Navi Mumbai airport is operational.

2.3 Data Set

Various data items are requires in the process of forecasting. The following data is collected in order to develop Airport and Access Mode Choice Models.

Access Time

The time that would take to travel to an airport depending on the traffic conditions and the availability of type of transport affects the choice of airport between two competing airports.

Access Mode

Type of access chosen to make a trip to the airport, gives us a picture of the preference of an individual to the access mode chosen depending on his socioeconomic characteristics and the availability of modes. This helps in providing public transport modes which would be more beneficial to both the operator and the user.

Access Cost

Access cost is an important factor for deciding the access mode. The cost here is the generalized cost which includes the travel cost, value of time, comfort level etc.

Level of Comfort

Level of comfort of the present mode by which the air traveller reached the airport is collected in order to present him with modes of better comfort levels and model his choice accordingly. The term “Level of comfort” is explained to the respondent in the form of figures given in the survey brochure.

Accessibility

A mode which has good accessibility is a mode which is available at your door step (Personal car, Auto, Call Cab etc.,) where as a mode which has moderate accessibility is a mode which is a little father from your doorstep. The respondent is asked regarding the accessibility of his present mode and is provided with better options during the survey.

Airport Tax

Since the respondents were not aware of the amount of airport tax that they were paying at the present airport, they were provided with that information and then presented with better options in the survey.

Announced Delay at the airport

This refers to the amount of delay that they have experienced on their last trip.

3.0 METHODOLOGY, EXPERIMENT DESIGN AND MODEL STRUCTURE

3.1 Methodology

Methodology as shown in Figure 2 has been proposed for Disaggregate Air Travel Demand Modelling of Airport Choice and Access mode.

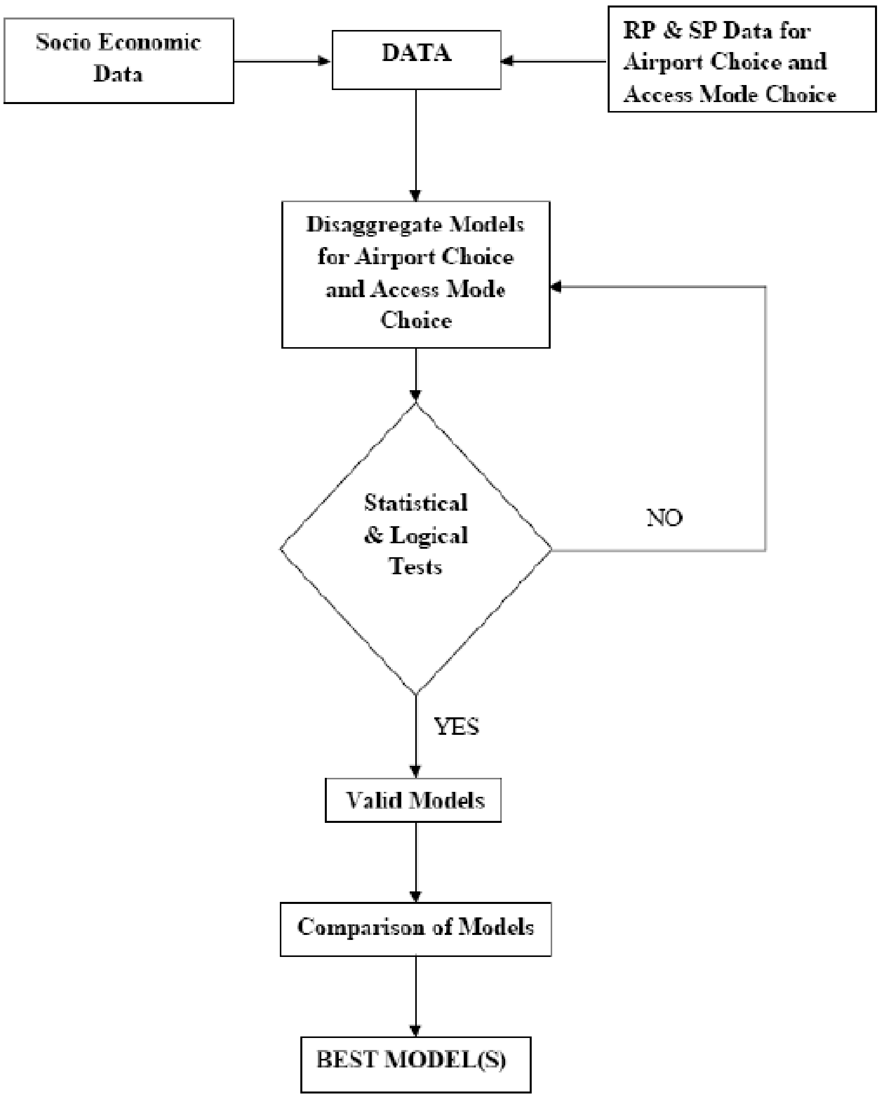

Figure 2. Methodological framework of the proposed work

The methodology involves development of various disaggregate models, for airport choice and access mode choice of an individual to an airport in a Multiple Airport Region (MAR). Variables like access time, airport access modes, access cost, airport tax and queue time at check-in counters etc are used to develop these disaggregate models. Various statistical & logical tests are performed on the models and their statistical & logical appropriateness is tested. The valid models are then compared the best model is suggested.

3.2 The Survey

A Survey was conducted at various localities in Mumbai and Navi Mumbai with passengers making air travel as respondents for the survey. SP survey of air travellers is required to model the generalized cost of airports and access modes as perceived by them along with their willingness to opt for better services. Without any doubt, the proposed new option will provide better quality service in terms of substantial reduction in access time, more comfort, and accessibility and on time performance. Therefore, in order to arrive at the realistic demand for the new airport/access mode, it is essential to calibrate the model using a generalized cost of airport/access mode. Income distribution of respondents of the survey are depicted graphically in Figure 3 and the sample size distribution by mode in Figure 4.

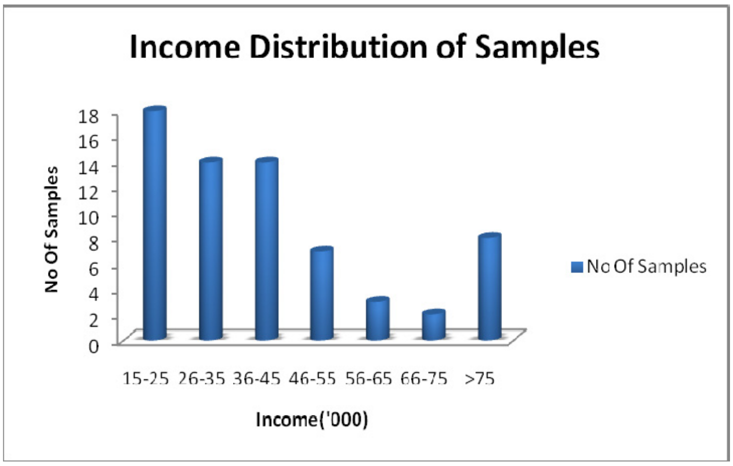

Figure 3. Monthly Income Distribution of the Respondents.

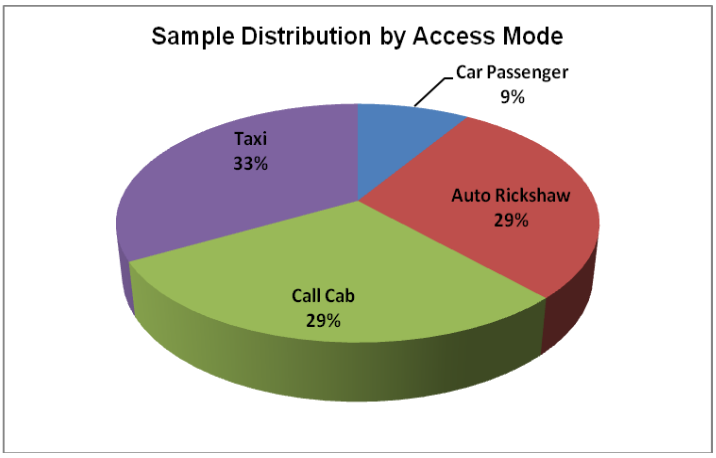

Figure 4. Sample Size Distribution by Mode

An auto rickshaw is a three-wheeler motor vehicle and a mode of transport for private use and as a vehicle for hire (*Refer Appendix 1 for Picture*). The difference between taxi and call cab passengers is, while taxi passengers may have to walk a small distance (to the taxi stand) to hire a taxi, call cab passengers will have the taxi service at their door step.

3.3 Development of Airport Choice and Access Mode Choice Models

As per the traffic forecast for MMR, the existing airport can cater to only a proportion of this demand in the future years. To support this huge demand a new airport is being proposed at Navi Mumbai. At this juncture MMR would become a Multi Airport Region and thus airport and access mode choice would be a matter of importance. Depending on the attributes of both the airports a traveller would make his choice of airport as well as the mode to access the airport. Thus to know the demand split between the airports, Airport and access mode choice models are proposed in the study.

3.3.1 Design of SP Experiment for Airport Choice

In the present context, attributes of Airport like access time, announced delay and new airport charges would play major role in attracting the travellers from the existing airport. The SP experiment is designed as a ranking and choice experiment by constructing several options with different attribute levels. To analyse the ranking data a procedure known as exploded logit has been applied. Exploded logit converts each ranking observation into a number of pseudo observations. The functional form of application of exploded logit to ranking data is as follows:

$$P(1>2>\ldots\ldots\ldots>J) = P(1 \mid \{1,2,\ldots,J\}).P(2 \mid \{2,\ldots,J\})\ldots\ldots\ldots\ldots P(J-1 \mid \{J-1,J\})$$

$$\text{Where } P(i \mid \{i,\ldots,J\}) = \frac{e^{v_i}}{\sum_{j=i}^{J} e^{v_j}} \quad [1]$$

The basic format of stated preference experiment used and the different levels of attributes used are shown in Table 1 and Table 2 respectively.

Table 1. Typical Stated Preference Experiment Design for Airport choice

Existing Airport		**New Airport**	
Access Time	Stated	Access Time	3 Levels
Announced Delay	Stated	Announced Delay	3 Levels
Airport Charges	0	Airport Charges	3 Levels

Table 2. Levels of Attributes in SP Experiment for Airport Choice

Attribute	**No. Of Levels**	**Values**	**Units**
Access Time	3	0.5,0.75,1 times	Minutes
Announced Delay	3	0,0.5,1 times	Minutes
Airport charge	3	0,350,500	Rupees

The attribute Access time is considered at three levels, being 0.5, 0.75 and 1 times of the access time of the existing airport. The attribute announced delay is considered at three levels, being 0, 0.5 and 1 times the delay of the existing airport. The attribute new airport charge is considered at three levels being Rs0, 350 and 500. Each respondent was asked to rate 8 options comparing each of the options with the existing option for hypothetical airports on a choice scale of 1-5. While doing so he was asked not to compare any 2 of the hypothetical modes mutually. And then he was asked to rank all the options including existing, 1 being the rank of best option and 9 being the rank of the worst option (Refer *Appendix I* for detailed SP format).

3.3.2 Airport Choice Model

A multinomial logit model has been developed based on the SP data and the parameters were estimated using ALOGIT software for ranking and choice experiments The specification of the utility function of the model is as follows.

$$U_{airport\ i} = \alpha AT_{airport\ i} + \beta AD_{airport\ i} + \gamma AC_{airport\ i} + \varepsilon \qquad [2]$$

Where,

$U_{airport\ i}$ is utility of airport i
AT = Access time,
AD = Announced delay,
AC = Airport charges,
ε is the random error in the determination of utility
α, β, γ =parameters to be estimated using SP data

3.3.3 Design of SP Experiment for Access Mode Choice

For modelling the Access Mode choice attributes like access time, access cost, level of comfort and accessibility are considered. The SP experiment is designed as a ranking and choice experiment by constructing several options with different attribute levels. To analyze the ranking data a procedure known as exploded logit has been applied. Exploded logit converts each ranking observation into a number of pseudo observations. The basic format of stated preference experiment used and the different levels of attributes used are shown in Table 3 and Table 4 respectively.

Table 3. Typical Stated Preference Experiment Design for Access Mode Choice

Existing Mode		**New Mode**	
Access Time	Stated	Access Time	3 Levels
Access Cost	Stated	Access Cost	3 Levels
Level of Comfort	3 levels	Level of Comfort	3 Levels
Accessibility	2 levels	Accessibility	2 Levels

Table 4. Levels of Attributes in SP Experiment for Access Mode Choice

Attribute	No.of Levels	Values	Units
Access Time	3	0.5,0.75,1 times	Minutes
Access Cost	3	0.5,1,1.5 times	Rupees
Level of Comfort	3	1,2,3	Constant
Accessibility	3	1,2	Constant

The attribute Access time is considered at three levels, being 0.5, 0.75 and 1 times of the access time of the existing mode. The attribute Access cost is considered at three levels, being 0.5,1 and 1.5 times the cost of the existing mode. The attribute Level of comfort is defined into 3 levels and Accessibility into 2 levles (1 = Good accessibility i.e., at the door step and 2 = moderate accessibility). The explanation for level of comfort was given by the help of figures to the respondents showing him the conditions for various levels of comfort (Refer *Appendix I* for detailed SP format).

Each respondent was asked to rate 9 options comparing each of the options with the existing option for hypothetical modes on a choice scale of 1-5 which were explained earlier. While doing so he was asked not to compare any 2 of the hypothetical modes mutually. And then he was asked to rank all the options including existing option, 1 being the rank of best option and 10 being the rank of the worst option (Refer *Appendix I* for detailed SP format).

3.3.4 Access Mode Choice Model

A multinomial logit model has been developed based on the SP data and the parameters were estimated using ALOGIT software for ranking and choice experiments. The specification of the utility function of this model is as follows

$$U_{mode\ i} = \alpha\, AT_{mode\ i} + \beta\, AC_{mode\ i} + \gamma LOC_{mode\ i} + back + \varepsilon \qquad [3]$$

Where,
$U_{mode\ i}$ is utility of mode i
AT = Access time,
AC = Access cost,
LOC = Level of comfort,
ACC = Accessibility
ε is the random error in the determination of utility
$\alpha, \beta, \gamma, \delta$ =parameters to be estimated using SP data

3.3.5 Explanatory Model for Travel Purpose and influencing attributes in Airport Access Mode Choice

People make air travel for various purposes like visiting a relative, official business or personal business etc. Therefore an airport trip may have various purposes and can be disaggregated accordingly. From the Revealed preference data collected during the survey three major purposes for making airport trip were found out as Social, Recreational and

Employers' Business. Access Mode Choice models were developed for these three trip purposes using various attributes collected during the survey. Numerous number of combinations were tried to define the utility of an access mode for airport trip makers with different travel purpose (social, recreational etc.,).Variable definitions used in the explanatory model are presented in Table 5 (Refer *Appendix I* for detailed SP format).

Table 5. Variable Definitions used in the development Explanatory Model

Variable Code	Description Of Variable
TT	Travel Time of that Trip in minutes
TC	Travel Cost of that Trip in Rupees
ACC	Accessibility of the mode chosen for the trip(1,2)
LOC	Comfort Level of the mode chosen for the trip(1,2 or 3)
IN	Income of the Respondent
AG	Age of the respondent
CO	Car Ownership of the Respondent

All the specifications use subsets of the variables defined in Table 5. A large set of variables that are likely to influence access mode choice were identified. The Trip Purposes considered are 1(Social), 2(Recreational) and 3(Employers' Business). Simple MNL model was estimated by proper specification. As a starting point socioeconomic variables were used along with the trip-specific constants in defining the utility of different trip purposes. The variables were eliminated if found insignificant or having illogical signs. The variables so eliminated were then used in the utility function of other trip purpose and again the same checks were made. It was observed that on reaching the most optimal model specification, the absence of insignificant variables did not alter the value of coefficient estimates of remaining variables.

3.3.6 Explanatory Model

The variables considered in this the explanatory models developed for airport access mode choice of Social, Recreational and Employers Business trip makers are as follows:

$$U_{Social} = \alpha TT + \beta TC + \gamma IN + \varepsilon \quad [4]$$

$$U_{Recr} = \alpha TT + \beta LOC + \gamma AG + \varepsilon \quad [5]$$

$$U_{EB} = \alpha TC + \beta LOC + \gamma ACC + \delta IN + \eta \quad [6]$$

Where
U_{Social} = Utility of an access mode for a Social Trip
U_{Recr} = Utility of an access mode for a Recreational Trip
U_{EB} = Utility of an access mode for an Employers' Business Trip
ε is the random error in the determination of utility
α,β,γ = Parameters to be estimated using RP data.

4.0 MODEL RESULTS AND DISCUSSION

4.1 General

Airport and Access Mode choice models are developed based on both Choice and Ranking Stated Preference (SP) experiments. Both the models are then compared against each other.

4.2 Results based on SP data for Airport Choice (Ranking) Model

The parameters of the multinomial logit model were calibrated by employing maximum likelihood method of estimation. The results of calibration of logit model for ranking experiment are provided in Table 6.The signs of all the parameters are found to be logical. All the variables entered the model are found to be statistically significant. The ρ^2 statistic (a robust goodness-of-fit statistic that varies between 0 and 1) for the model is found to be reasonably good at 0.1145. Subjective values of time obtained from SP survey results are presented in Table 7.

Table 6. Calibrated Parameters of Airport Choice (Ranking) Model

α (AT)	β (AD)	γ (AC)
-.0793 (-8.7)	-.0432 (-6.7)	-.0048 (-7.6)

Table 7. Subjective Values of Time from SP Survey Result of Airport Choice (Ranking) Model

Type of Traveller	Access Time (Rs/hr)	Delay (Rs/hr)
All Travellers	948	536

The subjective values indicate that the respondents are more sensitive to Access time to the airport than the Announced delay at the airport.

4.2.1 Prediction Success Table for Best option in Airport Choice

Though the model developed has a reasonable goodness-of-fit when measured by standard statistical tests, it is also desirable to test the performance of the models in predicting the observed choice behaviour. So, a prediction success table is written for the best option (option which is ranked 1 in a sample) to see how accurately can the model predict the observed values. The observed samples mostly had options 2, 3 and 7 ranked 1.

The Prediction Success for the best option in airport choice is shown in Table 8. Similarly, prediction success for the whole ranking data was observed and is found to be satisfactory.

Table 8. Prediction Success Table for Best option in Airport Ranking Data

Option No	**2**	**3**	**7**	**Observed Sum**	**Observed (%)**
2	4	4	6	14	21.21
3	1	11	1	13	19.70
7	2	6	31	39	59.09
Predicted Sum	7	21	38	**66**	100.00
Predicted (%)	31.82	31.82	57.58	100	
Correctly Predicted (%)	**57.14**	**52.38**	**81.58**		
Over all Prediction Success(%)	**69.70**				

The table above gives the number of samples observed in rows vs. the Number of samples predicted in columns viz. the value in cell 2, 3 represents the number of options with best rank observed as 2 but predicted by the model as 7. Thus the diagonal elements give the number of options observed from the sample and predicted by the model correctly. From the table Option 2 is predicted correctly 57 % of the times, Option 3, 53 % of times and Option 7 is predicted correctly 82% of the times. Overall prediction success rate of the sample is 70 % which is satisfactory.

4.3 Results based on SP data for Airport Choice (Choice) Model

The same SP experiment was conducted in which the respondent was asked to compare certain Hypothetical airports with the existing airport and state his choice on a scale of 1-5 which are explained in Table 9.

Table 9 Scales for Choice Experiment

Choice	**Meaning**	**Standard Probability**
1	Will definitely choose the proposed airport	0.9
2	May choose the proposed airport	0.7
3	Can't Say	0.5
4	Will definitely choose the existing airport	0.3
5	May choose the existing airport	0.1

The results of calibration of logit model for choice experiment are provided in Table 10. The signs of all the parameters are found to be logical. All the variables entered the model are found to be statistically significant. The ρ^2 statistic (a robust goodness-of-fit statistic that varies between 0 and 1) for the model is found to be satisfactory at .1120. Subjective value of time obtained from SP survey results are presented in Table 11.

Table 10. Calibrated Parameters of Airport Choice (Choice) Model

α (AT)	β (AD)	γ (AC)
-.030 (-3.6)	-.037 (-5.4)	-.0031 (-5.2)

Table 11. Subjective Values of Time from SP Survey Result of Airport Choice (Choice) Model

Type of Traveller	Access Time (Rs/hr)	Delay (Rs/hr)
All Travellers	967	1193

The results obtained from choice experiment are not same as the results from the ranking experiment because of the probabilities we have quoted for the options of choice (Table 9). The values stated are the standard values for any choice experiment, but values of confidence specific to this experiment are found comparing the Ranking and Choice models which is explained below.

4.3.1 Comparing the Ranking and Choice models for Airport choice

A study is made by taking the ranking model as standard, as ranking design is more robust and comparing the model with various trails for choice experiments in which the probabilities of responses are varied. For the model which has maximum resemblance with the ranking model the probabilities determined will be specific to this case only. The outputs for various probabilities are given in Table 12.

Table 12. Outputs for Various combinations of Probabilities for choice

Probability for Choice					**Coefficients In Utility Function**		
1	2	3	4	5	**TT**	**Delay**	**Airport Tax**
80	60	50	40	20	-0.0237	-0.0243	-0.0024
80	70	50	30	20	-0.0256	-0.0262	-0.0025
85	75	50	25	15	-0.0311	-0.0337	-0.0030
90	70	50	30	10	-0.0303	-0.0372	-0.0031
90	75	50	25	10	-0.0364	-0.0413	-0.0036
90	80	50	20	10	-0.0375	-0.0426	-0.0037
90	85	50	15	10	-0.0387	-0.0440	-0.0038
95	85	50	15	5	-0.0453	-0.0535	-0.0045
95	**90**	**50**	**10**	**5**	**-0.0467**	**-0.0553**	**-0.0046**
Ranking Model					-0.0793	-0.0432	-0.0048

From the above observations the optimum Probabilities for choice are found out as 95%, 90%, 50%, 10%, and 5% for choices 1, 2, 3, 4, 5 respectively, which are very much different from standard values for option 2, i.e., when a respondent specifies that he chose option 2, it is likely that he will stick to his opinion 90% of the times on contrary to 70% which is the standard value.

4.4 Results based on SP data for Access Mode Choice (Ranking) Model

The results of calibration of logit model for ranking experiment are provided in Table 13. The signs of all the parameters are found to be logical. All the variables entered the model are found to be statistically significant. The ρ^2 statistic (a robust goodness-of-fit statistic that varies between 0 and 1) for the model is found to be reasonably good at 0.282. Subjective values of time, comfort and accessibility obtained from SP survey results are presented in Table 14.

Table 13. Calibrated Parameters of Access Mode Choice (Ranking) Model

α (AT)	β (AC)	γ (LOC)	δ (ACC)
-.1129 (-14.3)	-.0036 (-3.9)	-.6273 (-4.7)	-1.611 (-9.7)

Table 14. Subjective Values of Time from SP Survey Result of Access Mode Choice (Ranking) Model

Type of Traveller	Access Time (Rs/hr)	Level of Comfort (Rs/unit)	Accessibility (Rs/unit)
All Travellers	1850	171	440

4.4.1 Prediction Success Table for Best option in Access Mode Choice

Though the model developed has a reasonable goodness-of-fit when measured by standard statistical tests, it is also desirable to test the performance of the models in predicting the observed choice behaviour. So, a prediction success table is written for the best option (option which is ranked 1 in a sample) to see how accurately can the model predict the observed values. The observed samples mostly had options 7, 8and 9 ranked 1. The Prediction Success for the best option in access mode ranking is shown in Table 15. Similarly, prediction success for the whole ranking data was observed and is found to be satisfactory.

Table 15. Prediction Success table for Best option in Access Mode Ranking Data

Option No	7	8	9	Observed Sum	Observed (%)
7	7	3	2	12	18.18
8	2	21	4	27	40.91
9	2	10	15	27	40.91
Predicted Sum	11	34	21	**66**	100
Predicted (%)	16.67	51.52	31.82	**100**	
Correctly Predicted (%)	**63.64**	**61.76**	**71.43**		
Over all Prediction Success(%)	**65.15**				

The table above gives the number of samples observed in rows vs. the Number of samples predicted in columns viz. the value in cell 7, 8 represents the number of options with best rank observed as 7 but predicted by the model as 8. Thus the diagonal elements give the number of options observed from the sample and predicted by the model correctly. From the table Option 7 is predicted correctly 64 % of the times, Option 8, 62% of times and Option 9 is predicted correctly 71% of the times. Overall prediction success rate of the sample is 65 % which is satisfactory.

4.5 Results based on SP data for Access Mode Choice (Choice) Model

The same SP experiment was conducted in which the respondent was asked to compare certain Hypothetical airports with the existing airport and state his choice on a scale of 1-5 which are explained in Table 9. The results of calibration of logit model for Choice experiment are provided in Table 16. The signs of all the parameters are found to be logical. All the variables entered the model are found to be statistically significant. The ρ^2 statistic (a robust goodness-of-fit statistic that varies between 0 and 1) for the model is found to be reasonably good at 0.110. Subjective values of time, comfort and accessibility obtained from SP survey results are presented in Table 17.

Table 16. Calibrated Parameters of Access Mode Choice (Ranking) Model

α (AT)	β (AC)	γ (LOC)	δ (ACC)
-.027 (-5.7)	-.001 (-1.3)	-.267 (-2.8)	-.707 (-4.7)

Table 17. Subjective Values of Time from SP Survey Result of Access Mode Choice (Ranking) Model

Type of Traveller	Access Time (Rs/hr)	Level of Comfort (Rs/unit)	Accessibility (Rs/unit)
All Travellers	1620	267	707

The results obtained from choice experiment are not same as the results from the ranking experiment because of the probabilities we have quoted for the options of choice (Table 9). The values stated are the standard values for any choice experiment, but values of confidence specific to this experiment are found comparing the Ranking and Choice models which is explained below.

4.5.1 Comparing the Ranking and Choice models for Access Mode Choice

A study is made by taking the ranking model as standard, as ranking design is more robust and comparing the model with various trails for choice experiments in which the probabilities of responses are varied. For the model which has maximum resemblance with the ranking model the probabilities determined will be specific to this case only. The outputs for various probabilities are given in Table 18.

Table 18. Outputs for Various combinations of Probabilities for choice.

Probability for Choice					Coefficients in Utility Function			
1	2	3	4	5	TT	TC	LOC	ACC
70	60	50	40	30	-0.01238	-0.0007919	-0.1535	-0.3208
80	60	50	40	20	-0.01818	-0.001292	-0.2375	-0.4725
90	70	50	30	10	-0.02768	-0.001042	-0.267	-0.7069
90	75	50	25	10	-2.97E-02	-1.83E-03	-0.3483	-0.7522
95	60	50	40	5	-2.89E-02	-2.25E-03	-0.3907	-0.746
95	80	50	20	5	-0.03601	-0.002186	-0.4137	-0.9062
95	85	50	15	5	-0.03798	-0.002174	-0.4201	-0.9504
95	**90**	**50**	**10**	**5**	**-0.08004**	**-0.002162**	**-0.4268**	**-0.9967**
Access Mode Ranking Model					-0.1129	-0.003661	-0.6273	-1.611

From the above observations the optimum Probabilities for choice are found out as 95%, 90%, 50%, 10%, and 5% for choices 1, 2, 3, 4, 5 respectively, which are very much different from standard values for option 2, i.e., when a respondent specifies that he chose option 2, it is likely that he will stick to his opinion 90% of the times on contrary to 70% which is the standard value. The value of this probability is specific for this SP experiment only.

4.6 Results for Explanatory Model

The software ALOGIT is used to estimate the models parameters. The statistics and coefficient estimates for the model are presented in Table 19 and Structural Parameter values are reported in Table 20. The mode choice models developed and calibrated in this study exhibit good results in terms of goodness-of-fit measures. The ρ-squared value was found to be 0.38, in many trials this value varied between 0.30 and 0.39, which could be considered as good fit.

Table 19. Statistics and coefficient estimates of Explanatory Model

Variable	Coefficient	Standard error	t-stat	Relevant to Trip Purposes
TT	-0.033	0.022	-1.5	Specific to Social Trip
TC	-0.007	0.004	-1.7	Specific to Social Trip
IN	0.0001	0.00007	1.8	Specific to Social Trip
Constant 1	0.289	2.60	0.1	Specific to Social Trip
TT	-0.051	-0.032	1.6	Specific to Recreational Trip
LOC	-0.722	0.604	-1.2	Specific to Recreational Trip
AG	0.01	0.1	0.1	Specific to Recreational Trip
Constant 2	4.008	3.360	1.2	Specific to Recreational Trip
TC	-0.004	0.004	-1	Specific to Employers' Business Trip
ACC	-2.338	0.942	-2.5	Specific to Employers' Business Trip
CO	-2.618	1.26	-2.1	Specific to Employers' Business Trip
IN	0.0002	0.00008	2.3	Specific to Employers' Business Trip
LOC	-0.144	0.632	-0.2	Specific to Employers' Business Trip

Table 20. Structural Parameters of Explanatory Model

Structural Parameter	Value
L (0)	-54.93
L (c)	-49.76
L (θ)	-33.79
ρ2 (0)	0.38
ρ2 (c)	0.32

4.6.1 Deductions from the Explanatory Model

The model developed for airport access mode choice of trip makers travelling for social purpose had travel time as the significant variable. Value of time for this particular purpose is observed as 282 Rs/hr which means the traveller is ready to pay Rs. 282 for a mode which makes him reach the airport an hour faster. Coefficient for income in this equation is also found to be significant owing to the high value of tstatistic. Value of the coefficient for income came out to be less due to the high levels of incomes observed in the samples. The income distribution of the respondents is reported in fig 2.2.

Airport access mode choice model for recreational purpose has travel time as the significant variable. Recreational travellers gave a higher level of importance to travel time as recreational trips are planned over a period of time and one would be extra cautious while making such travel. Level of comfort also has a very significant effect on the mode choice in this model. This is justified as these are planned trips and one would prefer a higher level of comfort during such trips. Also travel cost did not enter the utility for access mode for recreational travellers because on such occasions one would always spend higher amounts for better luxury. Age which was used as an explanatory variable has shown correct sign when checked with the cross section of the data collected.

In the Airport access mode choice model for business travellers value of accessibility came out as Rs.584 per unit increase of accessibility while Level of comfort had Rs.29 per unit increase. This clearly depicts that business travellers chose a mode which has better accessibility than a mode which has a higher level of comfort. The model is also less sensitive with respect to travel cost as the expenses of such trips are covered by the employer and one doesn't have to spend it directly from his/her pocket.

4.7 Application of Developed Models

The developed airport and access mode choice models will help in assigning the traffic predicted by airport trip generation model. The assignment of the predicted demand to the two airports in the study area can be then done using these models. Thus the study helps us in forecasting the demand for individual airports in MMR. The explanatory model developed gives an insight into the importance of various attributes for access mode utilities of various purposes.

4.8 Discussion

Airport trips are not given much importance till date in the traditional travel demand modelling practice in India. But due the fast growing demand for air travel in the country, it is now very necessary to model the airport trips separately. Modelling trips at disaggregate level helps in estimating trips at zonal level.

Similarly capturing the psychology of individual's decision process in airport choice is important particularly in regions where new airports will be getting commissioned competing with the old ones, because this will alter the travel demand structure of the region. Decision of air passengers in airport choice depends upon various parameters such as distance, accessibility, operating airlines, type of airport etc. Knowing the access mode which the air passengers choose to go to the airport will help in providing the necessary mass transit systems or any other infrastructural facilities for the most favourable mode by the passengers.

In line with the above mentioned objectives, this report has presented the various aspects of Disaggregate Air travel demand modelling .Models for airport choice and access mode choice were developed. The problem identification, objectives of the study, development of the various models and detailed methodology of the work were explained in the previous chapters. Some conclusions derived from the developed model are given below

- A total of 5 models were developed and all the models show reasonable statistical and logical significance for the attributes used.
- Airport choice ranking model shows that the airport travellers give a high level of importance to the access time to an airport which is quite practical in a congested city like Mumbai.
- Air travellers are ready to pay an additional charge of Rs.948 for every one hour reduction in access time to the airport.
- Similarly the trade off rate for delay was Rs.536 for every 1 hour reduction in delay.
- Given a better access time and better functioning of the airport (lesser flight delays), people are readily welcoming a new airport.
- Same is the case with the access mode. People are giving a very high level of importance to access time by the mode than the level of comfort or accessibility of the mode.
- Airport travellers are ready to pay an additional charge of Rs.1850 for the mode which saves an hour of their travel time.
- Both Airport and Access mode ranking models predicted the best option with a reasonably fair level of accuracy.
- Explanatory model developed from the reveled preference data signifies that different trip purposes have different importance levels in choosing an airport access mode.

REFERENCES

Basar, G., Bhatt, C., (2004). A Parameterized Consideration Set Model for airport choice: An Application to the San Francisco Bay Area. Transportation Research Part B 38 , 889–904.

Hess, S., John, W.Polak, (2005). Mixed Logit Modelling of Airport Choice in Multi - Airport Regions. Journal of Air Transport Management 11 , 59–68.

Jun, S., (2006). Access Mode and Departure Airport Choice in San Francisco Bay Area. [Accessed 1st July, 2007]. Avaialable from World Wide Web: http://www.economics.uci.edu/docs/colloqpapers/f06/grad/Jun.pdf

Pels, E., Nijkamp, P., Rietveld, P., (2001). Airport and Airline Choice in a Multi- Airport Region: An Empirical Analysis for the San Francisco Bay Area. Regional Studies 35 (1), 1–9.

Psaraki, V., Abacoumkin, C., (2002). Access Mode Choice for Relocated Airports: The New Athens International Airport. Journal of Air Transport Management,Vol 8, No. 2, March, pp. 89-98(10).

Suzuki, Y., Crum, M.R., Audino, M.J., (2003) Airport Choice, Leakage, and Experience in Single-Airport Regions. Journal of Transportation Engineering 129, 212–218.

Suzuki, Y., (2007) Modeling and Testing the ‘‘Two-Step’’ Decision Process of Travellers in Airport and Airline Choices. Transportation Research Part E 43, 1–20.

APPENDIX I

Socio Economic Background

1)	**Place of Origin**				
2)	**Sex**		**M/F**	**Age**	
3)	**Monthly Income (Rs.)**				
4)	**Purpose of Travel**				
5)	**Vehicle Ownership**			**Cars**	
				2/W	

Codes for Purpose of Travel (Q.No 4)	**Social = 1**
	Recreational = 2
	Employers Business = 3
	Personal Business = 4

How Did You Reach The Airport ???

	Mode of Travel	Travel Time(min)	Travel cost (Rs)	Level of comfort (1,2,3)	Accessibilty (1= Good, 2 = Moderate)	Announced Delay @ the Airport (Min)	Airport User Charge (Rs)
6)							

Codes For Mode (Q.No 6)	**Car driving =1**	**Auto =2**	**Taxi = 3**	**Call Cab =4**
	Bus =5	**Car Pool = 6**	**Company Car =7**	**Car passenger =8**

Codes For Accessibility (Q.No 6)	**1 = Mode @ your Door Step (Example: Own Car, Call Cab etc.,)**
	2 = Mode Away from Door Step (Example: Taxi, Auto etc.,)

Codes for levels of comfort

CALL CAB (OR)

Own Car (Chauffer Driven)

Level of Comfort = 1

OWN CAR (DRIVING)
LEVEL OF COMFORT = 2

TAXI or AUTO

LEVEL OF COMFORT = 3

Stated Preference Experiment for Airport Choice

	TT (Min)	Delay @ the Airport (Min)	Airport Tax (Rs)	Choice	Rank (1-9)
Existing	**0**	**0**	**0**	**NA**	
Option 1	0	0	500		
Option 2	0	0	350		
Option 3	0	0	500		
Option 4	0	0	350		
Option 5	0	0	350		
Option 6	0	0	0		
Option 7	0	0	0		
Option 8	0	0	500		

Option scale	**1 = Definitely Proposed**	**2 = May be Proposed**	**3 = Cant Say**	**4 = May be Existing**	**5 = Definetly Existing**

Stated Preference Experiment for Access Choice

	TT (Min)	TC (Rs)	Level of Comfort	Accessibility	Choice	Rank (1-10)
Existing	**0**	**0**	**0**	**0**	**NA**	
Option 1	0	0	2	1		
Option 2	0	0	3	1		
Option 3	0	0	1	2		
Option 4	0	0	2	1		
Option 5	0	0	3	2		
Option 6	0	0	1	2		
Option 7	0	0	2	1		
Option 8	0	0	3	1		
Option 9	0	0	3	2		

Option scale	**1 = Definitely Proposed**	**2 = May be Proposed**	**3 = Can't Say**	**4 = May be Existing**	**5 = Definetly Existing**