DISCRETE CHOICE MODEL FOR OPTIMIZATION OF URBAN TRANSIT SYSTEM : A CASE STUDY

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ABSTRACT

A revealed preference experiment was used using Discrete Choice theory for determination of optimum transit system for Hyderabad, India by considering two Public Transportation modes. The model for optimization of transit system is developed by relating the demand of a mode to the aggregate cost of travel, travel time and accessibility. Two competitive modes of public transportation are selected such as Multi Modal Transport System (MMTS) and Andhra Pradesh Road Transport Corporation (APSRTC) buses. The other modes are not considered for the study. The travel time, cost of travel for the same origin and destination by the two modes provides the base for the demand estimation of the both the systems of Public Transportation. The accessibility level for each mode is prioritized based on its frequency of service, time, cost and the distance. By considering the above mentioned variables, a revealed preference model developed for determination of demand for MMTS system in Hyderabad. This developed model is found to be statically significant in explaining the variation in the demand for travel. The model is also used for demand estimation for future requirement.

Keywords: **M**odel, Transit Systems, Optimization, Demand Estimation, revealed preference

1. INTRODUCTION

All the metropolitan cities in India are now witnessing a common scenario that public transport systems are inadequate in terms of both capacities, commuter facilities so huge investments are made for alternate Transit System solutions. Hyderabad, a major city, is one of the fastest growing urban agglomerations spread over 1905 square kilometers and with a population of 6.38 million (2001). Due to the spurt in road traffic after 1980, the State government commissioned several studies, starting with the Hyderabad Area Transportation Study (HATS) in 1984 to find ways and methods to deal with the problem of traffic congestion. The study, inter alias recommended (a) improvements to existing road network, (b) provision of light rail transit system (LRTS) and (c) development of rail based Mass Rapid Transportation System (MRTS). Meanwhile, the Andhra Pradesh High Court, on a Writ Petition (7755 of 1997), observed that the Government of Andhra Pradesh (GoAP) would be failing in the discharge of their duties if they did not endow sufficient consideration to pollution control. With this background, the GoAP decided to go in for a Multi Modal Transport system (MMTS) as a part of MRTS.

Accordingly, GoAP sent a proposal in year 2000 to the Ministry of Railways for the introduction of MMTS on the already existing two rail sections viz., Secunderabad /Hyderabad-Lingampalli and Secunderabad – Falaknuma sections. These sections were part of the zonal railway network on which mainline passenger trains as well as short distance services were plying to accommodate suburban traffic. The MMTS was thus, essentially an upgradation of the existing network and not a new system. This constituted Phase-I of the MMTS. The MMTS was introduced in the year 2003 initially started its service from Secunderabad - Hyderabad - Lingampally. (28 km) and Secunderabad - Falaknuma (14.54 km) at a cost of Rs. 178 crore. This project, as phase I for a length of 32.54 Km was completed in February 2004 in Fig 1.

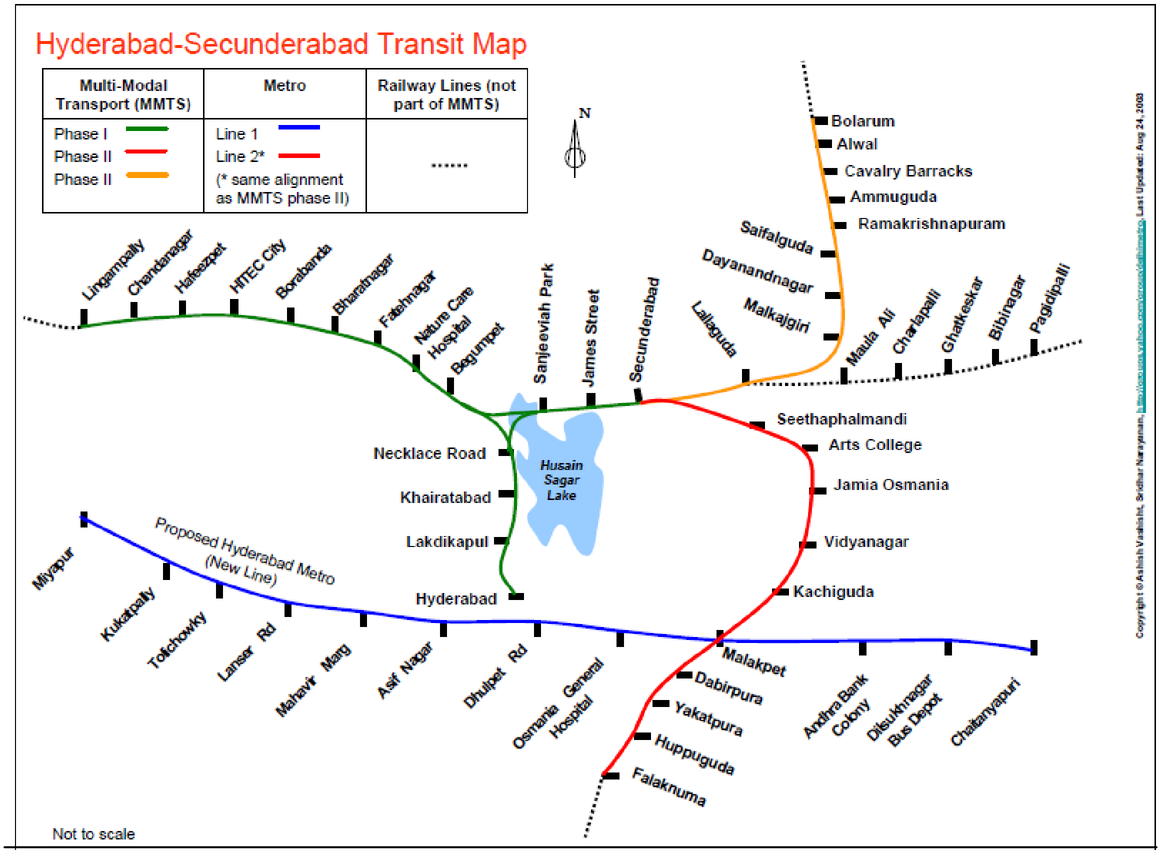

Figure 1 Map of MMTS Transit Map

The system was designed in such a way to carry 3.36 lakh passengers per day. The introduction of rail network will bring the changes in transportation system and travel pattern of the people (B R Marwah, Dr R Parti, 2004) but after introduction, the patronage is very nominal to the extent of 10.7 % against the projected traffic of 3.36 lakh per day which makes the system underutilized. The Demand modeling provides the frame work for forecasting the future traffic (Selvakumar and Tamilarasan, 2006), to achieve the required demand and to identify the proportion of shift the logit model was developed. Bruce. D. Spear *et al.*, discuses that the probability of an individual will choose a particular alternative is a function of characteristics of individual and the overall desirability of the chosen alternative relative to other modes. The opinion survey was conducted to find the real desire of the public about the MMTS system. Based on the Random Utility Theory, the utility coefficients of travel time, cost and accessibility are arrived to estimate the travel demand. Using Logit model and by sensitivity analysis various scenario’s are developed to optimize the utilization of Urban Transit System. In this paper an attempt is made to develop a model to forecast the demand for an existing system.

2. STUDY OF MMTS/ APSRTC AND PASSENGERS MOVEMENT AND CHARACTERS

The MMTS is designed to carry 3.36 lakhs passenger trips per day on its full capacity. In the beginning 14 cars of Electrical Multiple Units (MEMU) ran on this MMTS route, but at present only 8 cars of EMU are running at an interval of 20-30 minutes from Secunderabad - Kacheguda - Falaknuma and at an interval of 40 minutes from Secunderabad - Hyderabad - Lingampally. One EMU is of 110 seats capacity. At present (36 + 36) 72 services per day are operated on this MMTS route. Hence the present carrying capacity of MMTS system is 35,000 numbers per day. While comparing with the average demand of 17,500 per day, the system is only half used even for its reduced capacity.

To assess the total demand along the MMTS Corridor and to identify the nodes which generate more trips along MMTS Corridor, the existing bus passenger movement is studied. The total number of bus route services operated along MMTS Corridor is about 175 services with 2862 trips per day and carries about 60,000 passengers per day. The study was carried out during 28.10.2009 to 30.10.2007. The average number of ticket sales per day at different stations are, at Secunderabad is 3234, Lingampally is 938, Hitec City is 2793, Borabanda is 700, Fetahnagar is 553 and Nature cure Hospital & James Street is 1020. The maximum movement is at Hitec City where the station is located with proper accessibility and parking facilities. It is also found that the average demand on MMTS corridor is about 13,000 per day.

3. REVEALED PREFERENCE SURVEY

A commuter opinion survey is conducted at the different nodes among bus passengers along the MMTS Corridor mainly to understand (i) the reasons for not using MMTS for that trip and (ii) the conditions under which a commuter can switchover to MMTS (Train) from APSTRC(Bus).

The results of opinion survey are given in Figures-2 and 3. Figure-2 shows that the conditions under which a commuter can switchover to MMTS. The major conditions at which a commuter can switchover to MMTS are (i) Increase in frequency 32%, (ii) Inter-modal facility 35%, (iii). Single ticket for Bus and Train 15%, (iv) others 12% and (v) Parking facility 6%.

The Figure-3 shows that the reasons for not using MMTS are due to mainly (i) Not accessible 35%, (ii) Near bus stop 27%, (iv) More waiting time 22%, (v) More travel time 5% and others 11%. Hence the major reasons for not using MMTS are (i) Less accessibility, and (ii) More waiting time.

The analysis of opinion survey shows that nearly (35 + 22) 55% of people are not using the MMTS because of lack accessibility, less frequency and more waiting time. These problems can be easily sorted without any extra investment by operating shuttle trips between stations. The short trip makers will be attracted by the above action if there is no delay in the travel. The next major problem the MMTS face poor connectivity

(27%). If we provide proper inter-modal facility at all stations the patronage can be further increased by 35 %.

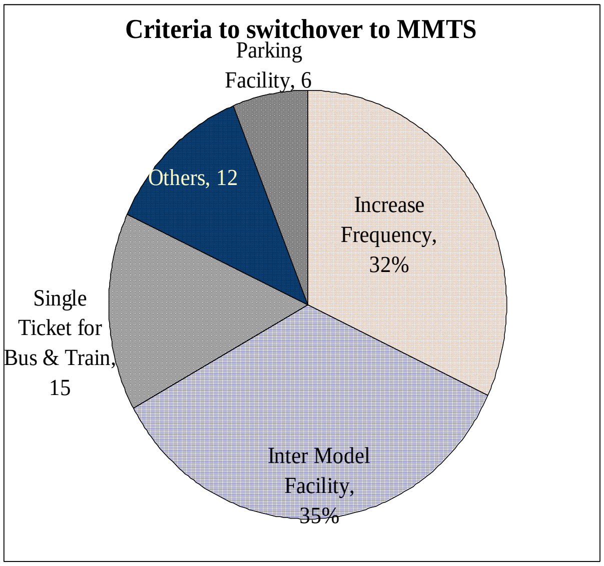

Figure 2 Criteria to Switchover to MMTS

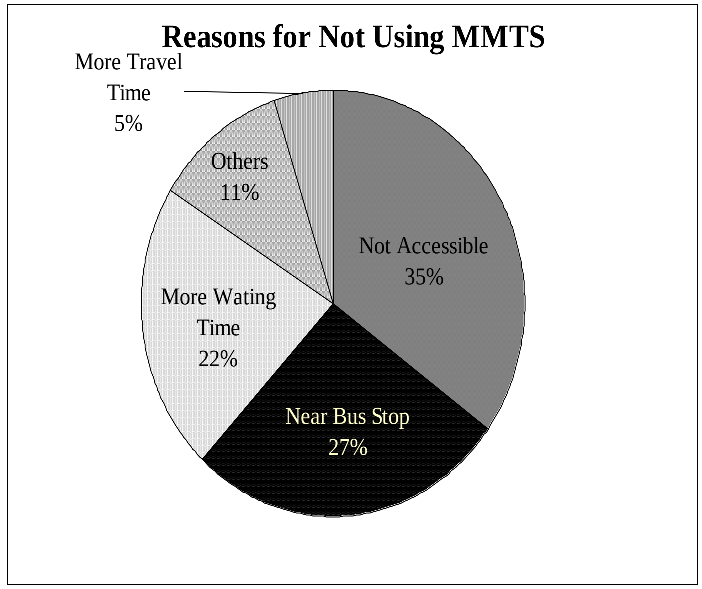

Figure 3 Reasons for not using MMTS

4. STUDY OF TRAVEL TIME IN MMTS/ APSRTC

By analyzing the bus routes, it is found that a total distance of 28 Km. from Secunderabad - Lingampally has an overlap on MMTS route. For determining the travel time between any two nodes the Inter Travel Time is estimated with (i) no transfer case (ii) one transfer case and (ii) two transfer cases for bus and MMTS. By comparing the Figures 4 and 5, the waiting time for MMTS is very high i.e. 30 minutes. This is the main reason for the poor patronage of the MMTS system. Even though the MMTS travel time between the same origin and destination is less than the APSRTC due to the less frequency the MMTS system is affected. On careful analysis of Figures 4 and 5 it is found that the travel time between Hitech City & Secunderabad in MMTS is less by 20 min compared with APSRTC. This is possible because the frequency of MMTS between these nodes is for every 30 Min. As it was stated in opinion survey if we increase the frequency itself will attract more passengers to MMTS.

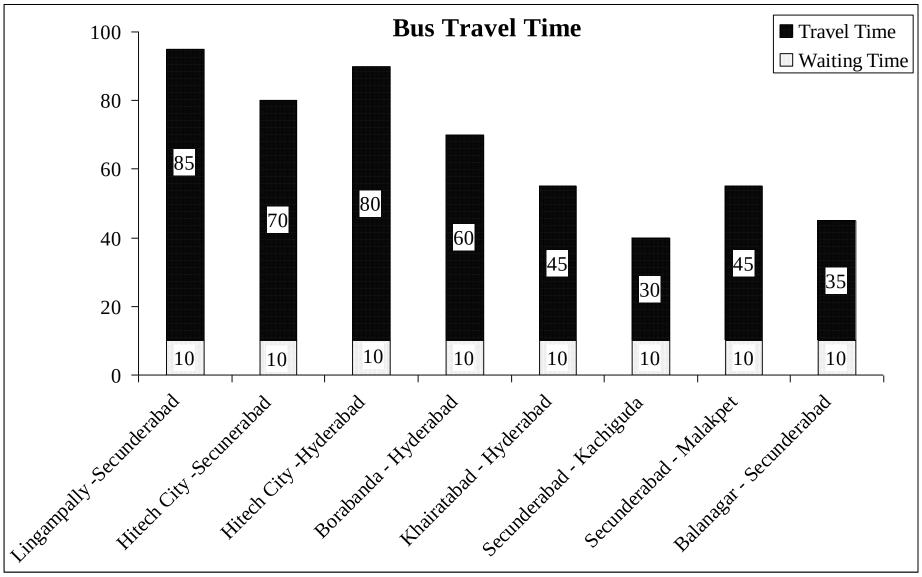

Figure 4 APSTRC Bus Travel Time

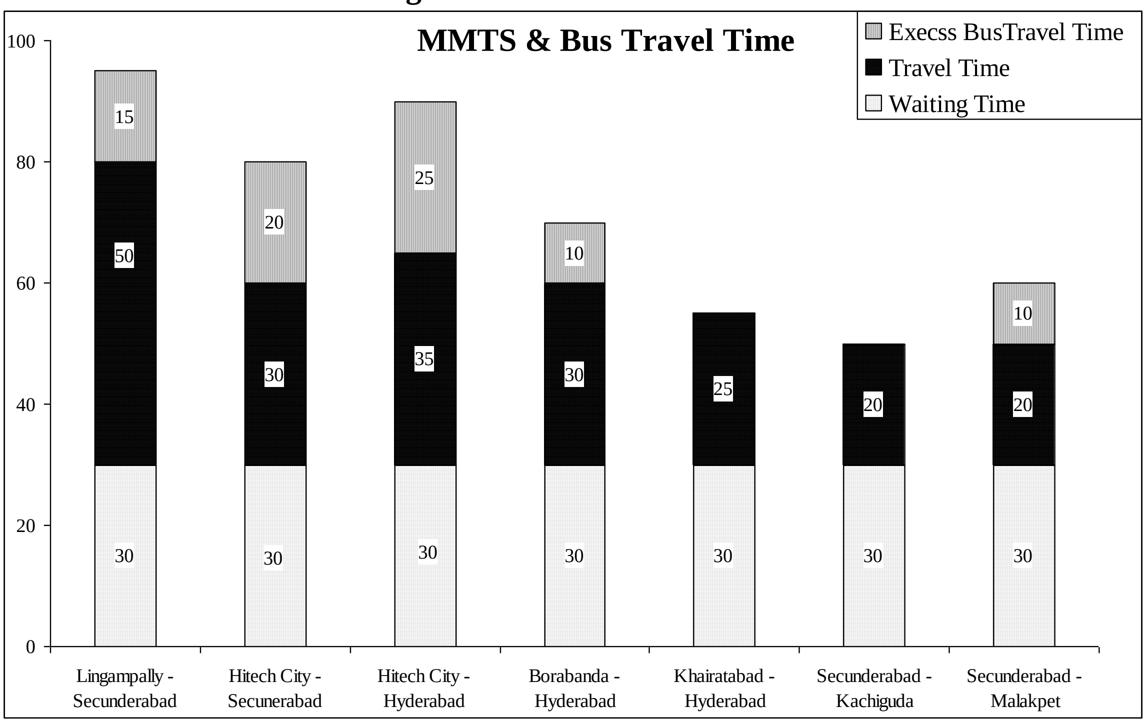

Figure 5 MMTS / Bus Travel Time

5. STUDY ON ACCESSIBILITY LEVEL

The effective function of MMTS is based on the frequency of feeder service availability. Accessibility index is developed by the following ranking method. If the frequency is available for $\leq$ 10 minutes it is awarded with 2 marks. Likewise for 10 – 20 minutes frequency is awarded 1 mark and the node with $\geq$ 20 minutes is awarded 0 mark and similarly for the proximity of bus stop i.e. if it is less than 200m it is awarded with 2 marks and if it is between 200 –500m it is awarded with 1 mark and if it is more than 500m then it is awarded with 0 mark. If the MMTS station approach is good on both sides and safety is ensured awarded 1 mark and if it is poor then it is awarded 0 marks. A maximum number of marks awarded to a node are 5 marks and to a pair are 10 marks.

6. THEORETICAL FRAME WORK AND MODEL DEVELOPMENT

Random Utility Theory is based on the hypothesis that every individual is a rational decision maker, maximizing utility relative to his/her choices. Random utility theory is the most common theoretical base for generating discrete choice models (Domencich and McFadden, 1975). The theory postulates that an individual 'q', belonging to homogenous population 'Q' and possessing complete information acts rationally and assigns a net utility 'U_{jq}' to each alternate option 'j' belonging to the set of available alternatives 'A'. The net utility comprises of two components, a measurable part and a random part. Measurable attractiveness (V_{jq}) is a function of the measured attribute 'X', itself a function of system and individual's characteristics and random part (**ϵ_{jq}**) reflects taste variation and errors committed during modelling. The utility ca be mathematically presented as,

$$\mathbf{U_{jq} = V_{jq} + \varepsilon_{jq}} \qquad \textbf{(1)}$$

$$\textbf{Where, } V_{jq} = \psi\ (X, \theta) = \sum \theta_{kj}\ X_{jkq} \qquad \textbf{(2)}$$

'θ' is a vector of parameter assumed to be constant for all individuals but nay vary across the alternatives. The individuals will select that alternative, which has maximum utility as given by,

$$U_{jq} \geq U_{iq},\ J \neq I,\ \forall\ A_i \in A\ (q) \qquad (3)$$

$$V_{jq} - V_{iq} \geq \varepsilon iq - \varepsilon_{jq} \qquad (4)$$

Thus the probability of choosing A_j can be given by,

$$P_{jq} = \text{Prob}\ \{(\varepsilon iq - \varepsilon_{jq}) \leq (V_{jq} - V_{iq}),\ \forall\ A_i \in A\ (q)\} \qquad (5)$$

The expression for this will depend on the distribution of random error term ε. In case the random residuals are Independently and Identically Distributed (IID) Gumbel distribution, the expression will reduce to well-known multinomial logit model (MNL),

$$P\ (j, i) = \frac{\exp(V_{jq})}{\sum_{j \in C} \exp(V_{jq})} \qquad (6)$$

or if it is normally distributed then it will reduce to probit model, or if the random residuals are separately IID Gumbel distributed then it will reduce to hierarchical (nested) logit (NL) model. The composite utility of the nest, comprising of alternatives similar in nature or having correlated utilities, is a function of expected value of the maximum utility of the members of the nest (EMU) and a common parameter to all the members of the nest (**θ_c).** A desirable condition is that the parameter value should always be greater than 0 and should be less than or equal to 1. The value close to one transforms it into MNL model. The probability of choosing an alternative $j \in C$ in the nest n_i

In the present study two alternatives A and B are in a choice set (Bus and MMTS) and if the alternatives have systematic utilities of say U_{BUS}, U_{MMTS}, the measure of utilities U_A, U_B is the function of travel time, travel art and accessibility.

(a) The generic decision maker “i” in making a choice considers “m”, mutually exclusive alternatives which make up his/her choice set ‘S’.
(b) The decision maker ‘i’ assigns to each alternative ‘j’ from his/her choice set a perceived utility or attractiveness ‘U j’ and selects the alternative maximizing the utility.

The following are the expressions of the utilities for Bus and MMTS

$$U_{Bus} = a_0 + a_1 \text{ x Tr. Time}_{Bus} + a_2\text{.Tr.cost}_{Bus} + a_3\text{. Access}_{Bus} \quad (7)$$

$$U_{MMTS} = b_{0+} b_1 \text{ x Tr. Time}_{MMTS} + b_2 \text{ x Tr.cost}_{MMTS} + b_3 \text{ x Access}_{MMTS} \quad (8)$$

Where, $a_0,a_1,a_2\ a_3$ and b_0,b_1,b_2,b_3 are calibrated coefficients.

Using the above theory, for the proportion of travel demand, the binomial logit model can be expressed as:

$$P(A) = \frac{\exp(U_A)}{\exp(U_A) + \exp(U_B)} \quad \mathbf{(9)}$$

$$P(A) = \frac{\exp(U_B/Ø)}{\exp(U_B) + \exp(U_A)} \quad \mathbf{(10)}$$

P (A) and P (B) = the proportion of demand of Bus Transit System and MMTS respectively,
U_{Bus} and U_{MMTS} = utility means of Bus transit and MMTS respectively,

In Hyderabad city along the MMTS Corridor about 65,000 passengers are using the bus system and about 16,000 passengers are using the MMTS systems. Knowing the present share of both systems, and the three logit parameters of utility measure i.e. travel time, accessibility and cost. For the purpose of the model development, the data retaining to a set of 100 pairs were used. Step wise linear regression analysis was used to calibrate the model. The value of t statistics for the intercept accessibility, travel time, and cost for MMTS/ APSRTC are -425,-2.345,-1.766/ -3.88,-2.28,-1.62 indicating that the independent variables are significant at 1% level. The co-efficient of determination (R^2) for the model is 0.989/0.995 implying that the independent variables together, explain about 98.9% of the variation of the dependent variable. The standard error of estimation of the regressed values of the dependent variable is 130.4/125.8 which is less than the standard deviation of observed value of the dependent variable 2388.14/2634.8 and this further corroborates the validity of the model.

7. MODEL VALIDATION

After ensuring the statistical significance of the model the same was validated by applying the model to predict proportion of shift. The details of the travel prediction are given in Table-1.

Table-1. Details of predicted demand.

Sl.No.	Pair of nodes	Demand per day	Predicted Demand per day	Error
1	Ligampally – Secunderabad	7678	7432	-0.23
2	Ligampally - Falakuma	6587	6455	-0.18
3	Ligampally – Hyderabad	7842	7951	+0.35

8. RESULTS

1) At present MMTS systems is utilized only 10.7 % for its initial capacity and 50% for its reduced capacity. This shows the system is under-utilized and need attention.

2) The reason for not using the MMTS is due to less accessibility (35%), near bus stop (27%), more waiting time (22%), and others (11%).

3) It was found from logit model for mode choice analysis that the demand can be increased by reducing the travel cost by 30% of the existing fare

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4) The MMTS passenger volume decreases to 7200 passengers per day as the total travel time increases by 20%. This is mainly because of higher waiting time, delay at stations, delay due to operational problems, etc. The increased waiting time makes MMTS less attractive. On other hand if further reduce the waiting time about 25 % the MMTS system will get additional patronage up to 12000.

5) Shuttle trips can be operated between two or three stations in order to attract the short trip makers. When the people start to use the MMTS slowly we can extend the length of shuttle trips service.

6) When the feeder service is available only at one end of the trip, the MMTS rider ship will be less compared to when service is availed at both ends. The feeder trips should be operated at all stations to increase the patronage.

9. CONCLUSIONS

The estimated MMTS demands for various scenarios in the sensitivity analysis indicate that the formulated mode choice appears to give realistic results. The estimated MMTS demand matrix obtained from mode choice analysis can be used for planning the feeder bus network. The cause for the less patronage like higher travel cost, more waiting time, poor feeder service, and physical accessibility has been identified and the solution is also suggested. The findings and solutions may be experimented to optimize the urban transit system utility and for the benefits of public.

REFERENCES

1. *M. Vijayalakshmi. 2003. Evaluvation of MMTS in Chennai With respect to its planning and performance. M. Tech Thesis (unpublished). Anna University, Chennai.*
2. *JuneB R Marwah, and R Parti. 2004. Modeling for Estimation of Demand to Generate Feeder Bus Routes of Mass Rapid Transit System. IE (I) Journal CV. 85: 169-174.*
3. *Selvakumar and Tamilarasan. 2006. Demand Forecasting For Long Haul Intercity Rail Travel. IE (I) Journal CV. pp. 77-82.*
4. *Bruce D. 1997. Spear, Application of New Travel Demand. A report.*
5. *Shimazaki, T. Kazunori, H. and Shihana, S. M. 1994. Comparative study of transportation modal choice in Asian countries. Transportation Research Record. 1441: 71-83.*
6. *Koppelman, F. S. Kuah, G., and Hirsh, M. 1984. Review of Intercity Passenger Travel Demand Modeling: Mid 60's to the Mid 80's, The Transportation Center, Department of Civil Engineering, Northwestern University.*
7. *McFadden, D. 1973. Conditional logit Analysis of Qualitative Choice Behavior, in P. Zarembka, Frontiers in Econometrics, Academic Press: New York. pp 105-142.*
8. *Schimek, P. 1996. Automobile and public transit use in the United States and Canada: comparison in the postwar trends. Transportation Research Record. Vol. 1521.*

9. *J.C. Yu. 1970. Demand Model for intercity Multimode Travel. Transportation Engineering Journal, ASCE. 96(2): 203.*
10. *Dr N.V. Ramamoorthy and S. Ragavachari. Planning and design of demand oriented Bus Route network. Indian Journal of Transport Management. pp 5-17.*
11. *Dr N.V. Ramamoorthy. Bus Scheduling-A marginal Ridership approch. Indian Journal of Trasport Management. pp 5-17.*
12. *Daniel A. Badoe and Bikram Wadhawan. Jointly Estimated Cross Sectional Mode Choice Models: Specification and forecast Performance. Journal of Trasportation Engineering. pp. 259-269.*
13. *Ahamed Hamdy Ghareib. Evaluvation of Logit and Probit Models in mode choice situation. Journal of Trasportation Engineering. pp. 282-290.*
14. *M. E. Ben-Akiva. 1973. Structure of passenger travel demand models. PhD Thesis. Department of Civil Engineering, MIT, Cambridge,*