ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

MODELING FOR OPTIMIZATION OF URBAN TRANSIT SYSTEM UTILITY: A CASE STUDY

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ABSTRACT

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 are selected such as mass rapid transit system (MRTS) and Metropolitan transport corporation (MTC) leaving other modes since they do not affect the systems performance. The travel time cost of travel for the same origin and destination by the two modes provides the base for the demand estimation. The accessibility level for each mode ranked based on its frequency of service and distance. This study deals with the development of demand model for MRTS system in Chennai. 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.

Keywords: model, transit systems, optimization, demand estimation.

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. To feed the increasing demand of the urban commuters in public transport system, the MRTS was introduced in 1995 at Chennai city. Initially the service was started between Beach to Chepauk and the extension affected in 1997 to Thirumailai, This project, as phase I for a length of 7.88 Km was completed with an investment of 89.8 crores. Subsequently the II phase of MRTS at a cost of Rs. 609 crores was completed in 2004. The system became operational from 26.1.2004. The system was designed in such a way to carry 6.03 lakh passenger trips daily. 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 2.7 % and made 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 MRTS 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 MRTS/ BUS AND PASSENGERS MOVEMENT AND CHARACTERS

The MRTS is designed to carry 6.03 lakhs passenger trips per day on its full capacity, when MRTS line becomes operational after completion of all phases. In the beginning 9 cars of EMU ran on this MRTS route, but at present only 3 cars of EMU are running at an interval of 20-30 minutes from Beach to Thirumailai and at an interval of 40 minutes from beach to Thiruvanmiyur. One EMU is of 110 seats capacity. At present (36 + 36) 72 services per day are operated on this MRTS route. Hence the present carrying capacity of MRTS system is 33,000 numbers per day. While comparing with the average demand of 16,200 per day, the system is only half used even for its reduced capacity.

To assess the total demand along the MRTS Corridor and to identify the nodes which generate more trips along MRTS Corridor, the existing bus passenger movement is studied. The total number of bus route services operated along MRTS Corridor is about 195 services with 2882 trips per day and carries about 65,000 passengers per day.

The study was carried out during 26.1.2007 to 31.7.2007. The average number of ticket sales per day at different stations are, at Beach is 1434, Thirumailai is 3838, Chepuk is 593, Indiranagar is 700, Park is 553 and Thiruvanmiyur is 2920. The maximum movement is at Thirumailai where the station is located with proper accessibility and parking facilities. It is also found that the average demand on MRTS corridor is about 16,261 per day.

3. REVEALED PREFERENCE SURVEY

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

 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

The results of opinion survey are given in Figures-1 and 2. Figure-1 shows that the conditions under which a commuter can switchover to MRTS. The major conditions at which a commuter can switchover to MRTS are (i) Reduction in fare 27%, (ii) Increase in frequency 22%, (iii) Inter-modal facility 25%, (iv). Single ticket for Bus and Train 11%, (v) others 12% and (vi) Parking facility 3%.

The Figure-2 shows that the reasons for not using MRTS are due to mainly (i) Not accessible 30%, (ii) Difference in fare 24%, (iii) Near bus stop 17%, (iv) More waiting time 12%, (v) More travel time 6% and others 11%. Hence the major reasons for not using MRTS are (i) Less accessibility, (ii) More cost and (iii) More travel and waiting time.

The analysis of opinion survey shows that nearly (22 + 27) 50% of people are not using the MRTS because of high fare and more travel time due to less frequency and lack of accesibility. These problems can be easily sorted without any extra investment by operating shuttle trips between at least three stations. The short trip makers will be attracted by the above action if there is no delay in the travel. On the other hand the cost of travel is very high in MRTS since the minimum ticket is Rs. 6. The short trip makers will prefer MTC since it is relatively cheaper i.e. minimum Rs. 2. If we reduce the cost of ticket for MRTS it will certainly have a great impact on MRTS patronage. The next major problem the MRTS face is the poor accessibility (30%) and connectivity. If we provide proper inter-modal facility at all stations the patronage can be further increased by 25 %.

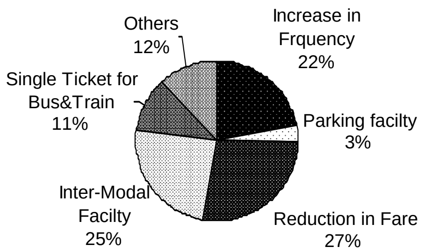

Figure-1. Criteria to switchover to MRTS.

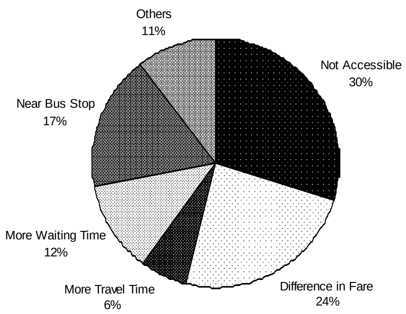

Figure-2. Reasons For Not Using MRTS.

4. STUDY OF TRAVEL TIME IN MRTS/ MTC

By analyzing the bus routes, it is found that a total distance of 20 Km. from Velachery- Thiruvanmiyur-Parrys has an overlap on MRTS 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 MRTS. By comparing the Figures 3 and 4, the waiting time for MRTS is very high i.e. 40 minutes. This is the main reason for the poor patronage of the MRTS system. Even though the MRTS travel time between the same origin and destination is less than the MTC due to the less frequency the MRTS system is affected. On careful analysis of Figures 3 and 4 it is found that the travel time between Mylapore and Parrys in MRTS is very less (25 min) compared with MTC (35 Min). This is possible because the frequency of MRTS between these nodes is for every 15 Min. As it was stated in opinion survey if we increase the frequency itself will attract more passengers to MRTS.

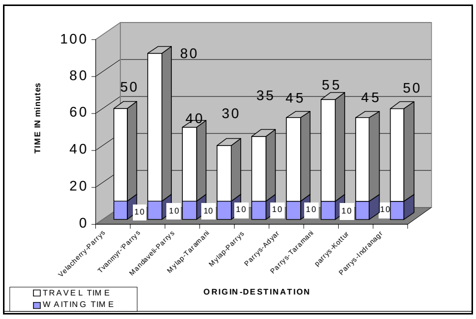

Figure-3. MTC Bus Travel Time.

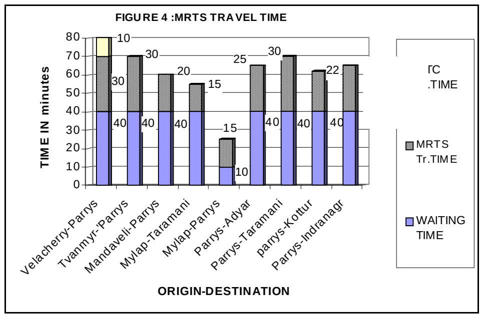

Figure-4. MRTS/ Bus Travel Time.

5. STUDY ON COST OF TRAVEL MRTS/ MTC

The costs of travel through the bus transit system and MRTS for the above referred nodes are shown in Figure-5. It is clear that the cost of travel in bus (MTC) is less than the travel cost of MRTS for all node pair. As it is stated earlier, the minimum cost of ticket in MRTS is Rs. 6 whereas the minimum cost of ticket in MTC is Rs. 2 only. A person who is 1-2 Km away from the origin or destination have to spend Rs. (6 + 2) 8 to reach his destination. The same person if selects MTC will need to pay only Rs. 3-4 to reach his destination. Since due to this fact there is less attraction to MRTS facility. The cost of ticket in MRTS needs to be revised as to achieve the estimated demand.

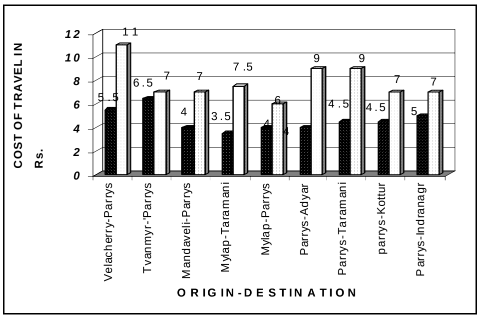

Figure-5. MRTS / Bus Travel Cost.

6. STUDY ON ACCESSIBILITY LEVEL

The effective function of MRTS 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 MRTS 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.

7. MODEL CONSTRUCTION

Mathematical models derived from Random Utility Theory is the richest and tried extensively for the simulation of transport related choices and choices among discrete alternatives. Random Utility Theory is based on the hypothesis that every individual is a rational decision maker, maximizing utility relative to his/her choices. The underlying important assumptions are:

(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.

In the case of only two alternatives A and B are in a choice set (like Bus and MRTS) and if the alternatives have systematic utilities of say U_{BUS}, U_{MRTS}, the measure of utilities U_A, U_B is the function of travel time, travel art and accessibility which may be expressed as:

$U_{Bus} = a_0 + a_l \times \text{Tr. Time}_{Bus} + a_2.\text{Tr.cost}_{Bus} + a_3.\ \text{Access}_{Bus}$

$U_{MRTS} = b_0 + b_1 \times \text{Tr. Time}_{MRTS} + b_2 \times \text{Tr.cost}_{MRTS} + b_3 \times \text{Access}_{MRTS}$

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

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

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

$$P(B) = \frac{\exp(U_B/\theta)}{\exp(U_B) + \exp(U_A)}$$

P (A) and P (B) = the proportion of demand of Bus Transit System and MRTS respectively,

U_{Bus} and U_{MRTS} = utility means of Bus transit and MRTS respectively,

In Chennai city along the MRTS Corridor about 65,000 passengers are using the bus system and about 16,000 passengers are using the MRTS systems. Knowing the present share of both systems, and the three logit parameters of utility measure i.e. travel time, accessibility and cost. The analysis was done by using SPSS software. 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 MRTS/ MTC 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.

8. 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.

Pair of nodes	Demand per day	Predicted demand	Error %
Velacherry-Parrys	8460	8396	-0.76
Thiruvanmiyur-Parrys	6420	6440	+0.31
Adayar-Mylapore	4200	4210	-0.23
Tollgate-Velacherry	5042	5028	-0.28

9. FINDINGS

1) At present MRTS systems is utilized only 2.7 % for its initial capacity and 50% for its reduced capacity. This shows the system is underutilized and need attention.

2) The reason for not using the MRTS is due to less accessibility (30%), difference in fare (24%), near bus stop (17%), more waiting time (12%), and others (11%).
3) To achieve the maximum demand, by the LOGIT model based on mode choice analysis it is found that the cost has to be reduced by 30%.
4) The MRTS 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 MRTS less attractive. On other hand if we further reduce the waiting time about 25 % the MRTS system will get additional patronage up to 17000.
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 MRTS 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 MRTS 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.
7) To achieve the estimated patronage in MRTS the optimum cost of ticket should be 23% less than the existing cost of ticket and the optimum travel time in MRTS should be 25 % less than the existing travel time.

10. CONCLUSIONS

The estimated MRTS demands for various scenarios in the sensitivity analysis indicate that the formulated mode choice appears to give realistic results. The estimated MRTS 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.

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