

Integrated Mass Rapid Transit System for Smart City Project in Western India

Debasis Sarkar, Jatan Talati

Abstract—This paper is an attempt to develop an Integrated Mass Rapid Transit System (MRTS) for a smart city project in Western India. Integrated transportation is one of the enablers of smart transportation for providing a seamless intercity as well as regional level transportation experience. The success of a smart city project at the city level for transportation is providing proper integration to different mass rapid transit modes by way of integrating information, physical, network of routes fares, etc. The methodology adopted for this study was primary data research through questionnaire survey. The respondents of the questionnaire survey have responded on the issues about their perceptions on the ways and means to improve public transport services in urban cities. The respondents were also required to identify the factors and attributes which might motivate more people to shift towards the public mode. Also, the respondents were questioned about the factors which they feel might restrain the integration of various modes of MRTS. Furthermore, this study also focuses on developing a utility equation for respondents with the help of multiple linear regression analysis and its probability to shift to public transport for certain factors listed in the questionnaire. It has been observed that for shifting to public transport, the most important factors that need to be considered were travel time saving and comfort rating. Also, an Integrated MRTS can be obtained by combining metro rail with BRTS, metro rail with monorail, monorail with BRTS and metro rail with Indian railways. Providing a common smart card to transport users for accessing all the different available modes would be a pragmatic solution towards integration of the available modes of MRTS.

Keywords—Mass rapid transit systems, smart city, metro rail, bus rapid transit system, multiple linear regression, smart card, automated fare collection system.

I. INTRODUCTION

THE concept of MRTS in the transportation sector is developing in nature in terms of implementation in India. In terms of research, different areas are being explored for developing new transit modes, modal options for public transport, integrating different transit modes in India and all over the world, especially developing countries.

National Urban Transport Policy (NUTP), 2014 [1] has mentioned about the different categories of technologies available for MRTS. Underground metro rail has been considered as high cost technology while the low capacity para-transit may be considered as low cost technology. Other options of MRTS like Bus Rapid Transit System (BRTS), monorail, electric trolley buses, and water taxi fall in between. [1].

Each one of the above mentioned technologies has its

unique characteristics and is best suited to a specific situation; hence, city requirements, demand, and many other factors affect the selection of mode of transport. Given different conditions and constraints, each city would have to make a choice according to land use plans, generic policy and urban transport plans. There would be needed to provide a seamless journey to the commuter by integrating all the modes of MRT. Integration of MRT not only connects BRT with Metro, but also with para-transit services like autos, motorcycles, bikes, feeder buses etc., which would only be possible by developing city level urban mobility plans. The main challenge in multimodal integration is to make the interchange convenient and to reduce the time penalty. It becomes necessary to limit the maximum number of interchanges to one for most of the commuters. Therefore, it is encouraged to make transit hubs inside the city at locations where possible as part of hard core infrastructure along with intelligent transport services to link various passenger information, fares, ticketing and operations. The idea of integration at the city level focuses more on efficient transfers and integrated fares with integrated tickets. But at the regional or district level, when more than two or three mass rapid transit modes are operative, then planning of multimodal hubs with shopping, recreational facilities is generally required. As distance increases for a trip, the need for good transfers also arises and therefore must be considered and addressed while planning multimodal transport at the regional level. This study aims to identify the parameters and control variables affecting the development of an Integrated MRTS for a smart city and finally to develop an Integrated MRTS Model for a Smart City Project in Western India.

II. LITERATURE REVIEW

Shrivastava and Mahony [2] have mentioned in their work that a large number of the urban metropolitan cities are facing problems due to the inadequate co-ordination of different modes of public transport. The model developed by them considers real life problems faced by commuters, and hence, this modelling exercise would help in coordinated operations for passenger trips. Shrivastava and Dhingra [3] have carried out research in the same area of route and schedule coordination by adopting a Heuristic feeder route generation algorithm for generation of feeder routes. Most of the studies are limited to analytical modeling. Monterio et al. [4] carried out research and developed a framework for a multimodal transportation network with the help of an agent-based model approach. The four step model (FSM) is the key model to analyze a transportation network. Here the authors have tried to combine all four models into one single model called the

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Agent Based Model (ABM). It could be used as a tool for simulation and to integrate the FSM into one model. Traffic simulation represents a prominent application for modelling and simulation. Yu et al. [5] in their research regarding locating urban transit hubs have tried to find out a model using multi-criteria decision making theory of AHP (analytical hierarchy process) and integrating it with fuzzy logic to offer the strengths to effectively determine the weights for multiple

evaluation criteria and to synthesize the final score of each candidate plan for comparison. In contending with this critical issue, Rosenberg and Esnard [6] applied a hybrid scoring method to evaluate six candidate transfer station sites, and a recent study developed a hybrid AHP-data envelopment analysis (DEA) method to conduct comparative location studies for the joint development station of a MRTS.

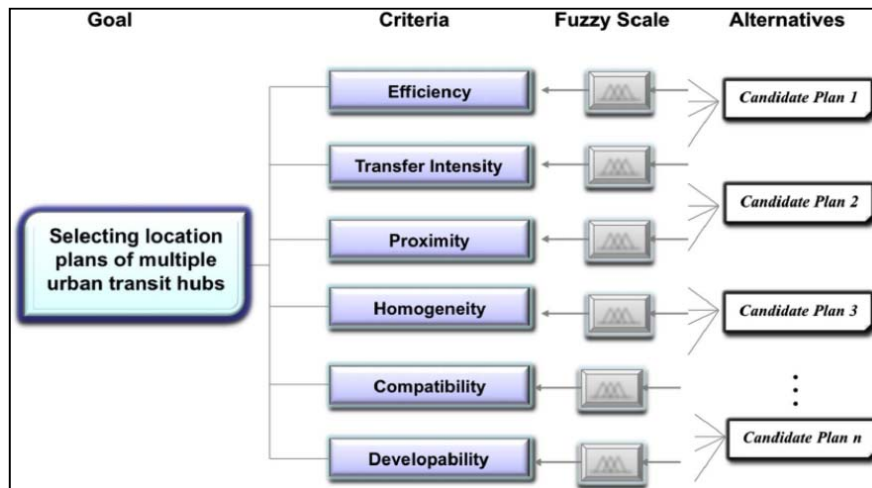


Fig. 1 Proposed hierarchical AHP structure [5]

Johanna Camargo-Perez et al. [7] have carried out research regarding locating Multi-Modal Transfer Nodes (MMTN) in passenger transport systems using AHP by considering the problem of locating passenger transfer nodes for an Integrated Public Passenger Transport System (IPPTS) that is mainly based on the use of a Bus Rapid Transit (BRT) network.

Wang et al. [8] carried out research in the development of a planning method for coordinating a public transport network with the location of transfer terminals by considering a multi-hierarchy PT network and transfer terminals location. Wu et al. [9] conducted research on evaluating the coordination for a multi-modal public transport system. Data Envelopment Analysis (DEA) was used to evaluate the degree of coordination for multi-modal public transport. Kumar et al. [10] focussed on development of a fuzzy logic based mode choice model considering various public transport policy options. Minaland Shekhar [11] has carried out research and survey on different types of models for the mode choice modelling purpose of transportation planning. They have given comprehensive understanding on statistical mode choice models such as Multinomial Logit and Probit Models as well as on various soft computing techniques such as Artificial Neural Network (ANN) models and fuzzy approach model that are employed for modal split analysis. The paper also explains the difference between discriminant analysis to mode choice by Multinomial Logit (MNL) and Decision Tree (DT) models. Sarkar and Kamdar [12] carried out a detailed simulation analysis to study the travel time performance of the BRTS of Ahmedabad City, India. Sarkar et al. [13] have

carried out a study of modal shift to BRTS in a developing country by considering the case study of India. Here, the authors have studied the impact of BRT services on modal shift before and after the introduction of cars in an exclusive BRT lane. The case study was done in the cities of Indore and Madhya Pradesh, India.

III. CASE STUDY AND ANALYSIS

The primary data was collected from questionnaire survey, as mentioned above about the respondents whose sample size was 45. The area was selected in such a manner that best possible routes for all mass transit systems would merge, and finally, an integrated route can be planned. The area selected was the lower portion of the west zone of Ahmedabad. The selected stretch was the Paldi to Panjrapole areas for work-based commuters only.

The secondary data which could help in integration was Ahmedabad Municipal Transport Service (AMTS), BRTS from their respective administrative offices in Ahmedabad. The data contained the basic route details, timings, fare matrix etc., of the existing system in the city. The data obtained from the questionnaire administered to the respondents was analysed for fitting the straight line equation for multiple variables, called as multiple linear regression. Through this analysis, we come to know the importance of various factors in mode shifting behaviour. The factors more important to mode shifting are assigned a positive coefficient, and those with low significance are assigned a negative coefficient.

The utility function $f(x)$ is obtained from these coefficients

and the probability of shifting of all sample passengers are found out. From these values of probability, average probability of modal shift is calculated. From the average probability of shifting is found, we can approximately judge the usage of smart cards for mass transit systems for which various assumptions are taken into consideration. From the number of users, the financial model for a private bidder is calculated at different rates of income sharing with a Municipal Corporation.

With an intention and objective to integrate the city-wide level transport systems by way of smart mobility measures including seamless transfer of passengers physically as well as operationally, data collection of existing bus transport systems was done. The data pertaining to existing city bus services are AMTS (Ahmedabad Municipal Transport Service), BRTS and proposed Metro Rail Service collected from AMTS house, BRTS Cell, Ahmedabad Janmarg Limited (AJL) and Metro details from Detailed Project Report (DPR), Metro Express-Link Gandhinagar Ahmedabad (MEGA). Ahmedabad city is one of the proposed hundred smart cities list in the Government of India initiative. The city has grown over the years tremendously and now to make it more livable, some smart features have to be adopted and implemented in terms of projects in the public transport sector. The proposal for a smart city has been prepared and the following existing transport facilities are available. AMTS has coverage of around 88% in municipal areas which has around 750 operational buses for 150-160 routes. Average daily ridership in AMTS is around 7 lakhs.

BRTS which runs under Ahmedabad Janmarg Limited

(AJL) has a peak hour speed of 25-30 km/h against average traffic speeds of 9-17 km/h. Daily ridership of 1.2 lakhs passengers and fleet of 235 buses. While AMTS has 780 kilometres of network, BRTS has around 130 kilometres of network in the city.

Two Pan City Proposals:

Components of Smart Transit – Seamless Urban Mobility would be:

- (i) Integrated Transit Management Platform
 - Web portal and mobile based application – Trip/journey planning & tracking app
 - GPS Module and Automatic Vehicle Location System (AVLS)
 - Public Information System (PIS)
- (ii) Common Card Payment System
 - Smart cards with application and card data format and card reading terminals
 - Smart card-based automatic fare collection system
 - Ticket vending machines and ticket value machines
 - Central clearance house management & central smart card host management

The city is at a mature level of ICT integration with applications such as GPS in public transport, commencement of a Common Card Payment System (CCPS) along with smart traffic management. So from above, smart city plans have been given to a pan city base (Integrated transit platform) and development of intermodal hubs (transfer stations or transit hubs) under an area-based proposal.



Fig. 2 Various integration points of Metro with BRTS, AMTS, GSRTC & IR

TABLE I
VARIOUS INTEGRATION JUNCTIONS WITH METRO RAIL ROUTE

Interchange Type	Metro To Metro	Metro To Indian Railways	Metro To GSRTC To BRT	Metro To BRT
North-South corridor	Old High Court	Gandhigram, AEC, Sabarmati Stations	Ranip Junction	APMC, Jivraj, Sabarmati, New Vadaj
East-West corridor	Old High Court	Kalupur Railway Station	Vastrapur Gam	Gujarat University, Rabari Colony

The study zone or area, i.e. the west zone of Ahmedabad, has a mixed land-use development of residential, commercial, recreational, as well as educational. The west zone of Ahmedabad has the following wards in municipality jurisdiction: Vasna, Paldi, Navrangpura, Naranpura, S. P. Stadium, Nava Vadaj, Ranip, Sabarmati and Chandkheda-Motera. The actual study area being researched would be only half of west zone of Ahmedabad, that is three wards, namely Vasna, Paldi, and Navrangpura are only to be included. These wards are covered by the oldest transport system known as the "AMTS". A part of BRTS also passes through the west zone from Vasna to L.D. College and along Nehrunagar, Shivranjani, etc., are well connected through different routes of BRTS.

IV. RESULTS AND DISCUSSIONS

The main purpose of the questionnaire data collection was to understand the human perception towards improving urban transport services and to know the factors which enable or inspire the people who travel to work for modal shift towards public transport. Also, the factors which restrain the integration of multimodal transport services are also taken care by way of human perceptions. The respondent were asked to rank their responses on a Likert scale from 1 to 5 i.e. 1 = Least Important to 5 = Most Important.

Percentage of Respondents with Respect to Male or Female:

Out of the sample size of 45, 70% are male and 30% are female respondents.

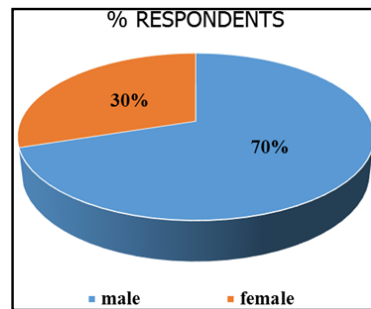


Fig. 3 Percentage distribution of respondents for the survey work

Age Group Distribution Corresponding To Respondents:

Out of sample size of 45, 30% are in age group of 20-30 years, 13% in 30-40 years, 22% in 40-50 years, and 35% are in the 50-60 year age group.

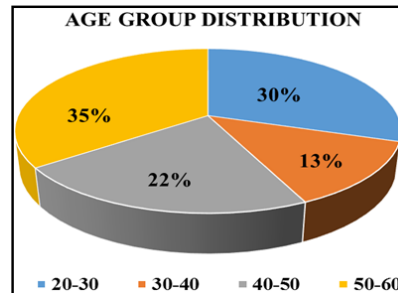


Fig. 4 Age Group Distribution of survey respondents

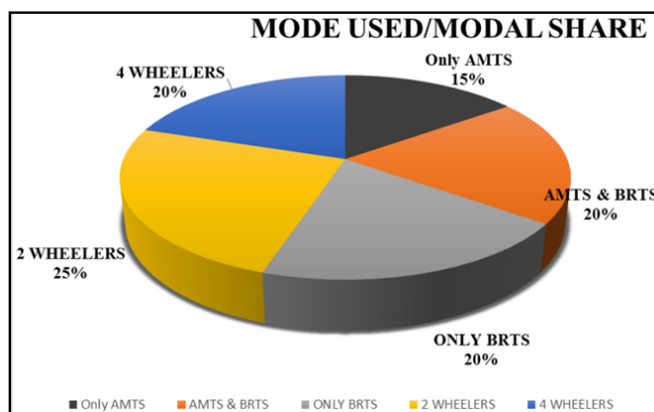


Fig. 5 Percentage modal share used by respondents on survey stretch

Percentage Mode Used by Respondents:

Factors motivating the public to use public transit over private and their priorities or ranking were safety, comfort, accessibility, travel cost and travel time.

Factors and their rankings in terms of using integrating

public transit system and help in efficient multimodal travel were (1) Smart applications with real time information, (2) Efficient and attractive multimodal transfer stations, (3) Cycle renting with GPS enabled system, (4) Park and ride facility at important metro stations, (5) Feeder service to the metro, (6)

Electric vehicles for intermediate transport, (7) Single ticketing system with integrated fares with help of a smart card, (8) Proper accessibility to metro/ BRTS stations, and (9) Proper street walking facilities.

The data in the proposed model has been fed into statistical software named 'R' for performing Multiple Linear Regression Analysis. The various tests conducted from the available data of the questionnaire survey were to be analysed for validation at the zonal level modal choice selection or modal shifting behaviour and subsequently finding its probability of shifting to public transport. The dependent variable taken here is mode choice selection for public transport in terms of Integrated Mass Rapid Transport System (IMRTS), and values for mode choice to public transport were input in form of 0 or 1 i.e. 0 as not shifting to public, 1 as shifting to public transport. The independent variable considered in the model are: (1) Travel time saving, (2) Age group or age, (3) Travel cost saving, (4) Income group/ Occupation, (4) Comfort rating, and (5) Accessibility. The sample size for analysis regarding sample zonal area was taken as 45. The values inserted for "Travel time saving" were in minutes, "Cost saving" in Indian Rupees (INR).

The values inserted for variables like accessibility and comfort rating were in the form of comparative rating with respect to private transport. The values were, 1 for less comfort or less accessibility in public transport with respect to private transport, 0 for the same level of comfort or accessibility in public transport with respect to private transport and +1 for more comfort or accessibility in public transport with respect to private transport. The Multiple Linear Regression Model executed in R is shown in the following paragraphs. It executes various tests required for fitting the straight line curve in the form of:

$$Y = \alpha + A_1X_1 + C_1 + A_2X_2 + C_2 + A_3X_3 + C_3 \dots\dots\dots + A_nX_n + C_n \quad (1)$$

The regression analysis developed here was for dependent variables such as Mode Choice shifting behaviour, along with multiple independent variables as mentioned earlier. Then, the function used for running multiple linear regression analysis used was:

$$\text{Model} \leftarrow \ln(\text{formula} = \text{Mode.Choice} \sim \text{Age.group.Age} + \text{Gender} + \text{Occupation} + \text{Travel.Time.Saving} + \text{Cost.Saving} + \text{Comfort.Rating} + \text{Accessibility}) \quad (2)$$

According to the analysis, Residual standard error was 0.207 on 37 degrees of freedom. The Multiple R-squared value was 0.835 and the Adjusted R-squared value was 0.804. Also according to the analysis, the average probability of work-based commuters shifting to public transport from private transport is 0.666. Therefore, the probability of zonal mode shifting behaviour is approximately around 66%. The proposed routes along the survey area consist of an elevated metro corridor, BRTS & AMTS routes act as feeder to the metro rail. The elevated metro corridor consists of two routes consisting of North – South along Old High Court to APMC

in Vasna area and East-West corridor route goes from S.P. stadium to the Old High Court.

V.CONCLUSION

After analyzing various factors through which integration of MRTS would become possible via questionnaire survey, multiple linear regression analyses was done to find out the following results. The multiple linear regression analysis showed that most important factors for shifting to public transport were travel time, saving and comfort rating. The cost saving factor and accessibility were not that important in terms of people shifting to using public transport systems. Maximum coefficients were of the comfort rating followed by the travel time saving, while cost saving and accessibility had a negligible effect on mode shifting behaviour. Also, it is important to note that, age, gender and occupation factors were not statistically significant compared to other more significant factors like comfort and travel time saving. By proposing different modes of transit on different routes, appropriate locations for developing multimodal hubs are found by integrating different modes like metro rail with BRTS, metro rail with Indian railways, metro rail with monorail and BRTS with monorail.

REFERENCES

- [1] National urban transport policy document, 2014www.itdp.in/wp-content/uploads/2014/11/NUTP-2014.pdf. (Accessed on 1st September, 2017).
- [2] P. Shrivastava and M. Mahony "Modelling An Integrated Public Transportation System- A Case Study In Dublin, Ireland" *Journal of European Transport*, vol. 41, pp 1-19, 2009.
- [3] P. Shrivastava and Dhingra L. "Operational Integration Of Suburban Railway And Public Buses- Case Study Of Mumbai" *Journal Of Transportation Engineering*, vol. 132, no. 6, pp 518-522, 2006.
- [4] N. Monteiro, R. J. F. Rosseti, P. Campos and Z. Kokkinogenis "A Framework For a Multimodal Transportation Network: An Agent Based Model Approach", *Elsevier, Transportation Research Procedia*, vol. 4, pp 213-227, 2014.
- [5] J. Yu; G.L. Chang, W. Ma and X. Yang "Locating Urban Transit Hubs: Multicriteria Model and Case Study in China" *Journal of Transportation Engineering*, ASCE, vol. 137, pp 944-952, 2011.
- [6] J. L. Rosenberg and A. M. Esnard "Applying a Hybrid Scoring Methodology to Transit Site Selection" *Journal of Urban Planning and Development*, vol. 134, no. 4, pp. 180-186, 2008.
- [7] J. Camargo-Perez; R. Jairo, M. Torres, H. Martha, C. Ramlrez "Multicriteria Decision Making For Locating Multimodal Transfer Nodes In Passenger Transport Systems" *International Conference on Systems, Man, and Cybernetics*, IEEE, pp 718-723, 2013.
- [8] Z. Wang, Y. Chen, and Y.Y. Mao "Development of a Planning Method for Coordinating a Public Transport Network with the Location of Transfer Terminals" *Journal of Integrated Transportation Systems*, ICCTP, ASCE, pp 2530-2539, 2010.
- [9] P. Wu, Y. Chen, G. Zhang, W. Wu "The Coordination Evaluation Research For Multimodal Public Transport System" *Journal of Integrated Transportation Systems*, ICCTP, ASCE, pp 2515-2521, 2010.
- [10] M. Kumar, P. Sarkar, and M. Errampalli "Development of Fuzzy Logic Based Mode Choice Model Considering Various Public Transport Policy Options" *International Journal for Traffic and Transportation Engineering*, vol. 3, no. 4, pp 408-425, 2013.
- [11] C. Minal, and R. Shekhar, "Mode Choice Analysis: The Data, Models and Future Ahead" *International Journal for Traffic and Transport Engineering*, vol. 4, no. 3, pp 269-285, 2014.
- [12] D. Sarkar, and P. Kamdar "Application of Simulation in Evaluation of Travel Time Performance of Bus Rapid Transit System, Ahmedabad" *Journal of Institution of Engineers*, vol. 92, pp. 9-13, 2011.
- [13] A. Sarkar, A. Mane, and S. Arkatkar "Study of Modal Shift to Bus

Rapid Transit (BRT) In Developing Country: A Case Study In India”
*Int. 94th Annual Transportation Research Board Meeting, Washington
D.C, 2014.*

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