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A Performance Analysis Of Modelling Route Choice Behavior On Urban Bus And Multi Mode Transit Route

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ABSTRACT

The main objective of this work is to measure the performance of direct route and multimodal route in terms travel time, travel cost, transfer time, waiting time and line haul time. For this analysis, data was collected as commuter travel survey and traffic data. Delhi has been taken as study area to measure the performance analysis of the bus and multimodal transit route.

From the modal split models some performance measures were used to analyse the performance of bus and metro transit system. Such measures as Relative Travel Time (RTT), Relative Travel Cost (RTC), Relative Travel Service (RTS), Inter Connectivity Ratio, Passenger Waiting Index (PWI), and Running Index (RI).

In this study VISSIM (simulation modal) software were used simulate the bus and metro travel times, pedestrian transfer times and waiting times at varies transit stops for selected network, and analyse the travel times and delays at various segments in the network. From the commuter travel survey questionnaires and simulated travel time elements, some (OVTT, IVTT, cost, reliability, comfort age and gender) variables were used to define the utility of the two alternative route choices and construct the discrete choice (multinomial logit) model, and the choice probability of the alternative routes were analyzed for both equations.

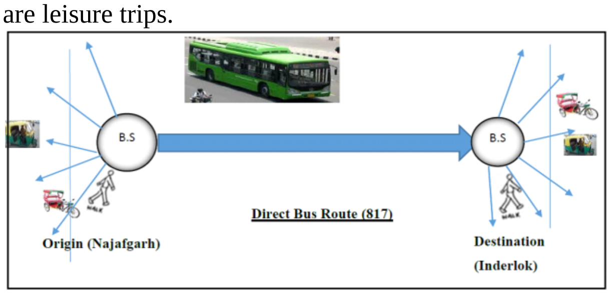
Research Review

Shaaban and Khalil (2013) investigated the quality of service and passenger's perception regarding various factors such as comfort, convenience, safety, and cleanliness. They collected data through questionnaires to observe the quality of the prevailing bus service. They have also tried to predict the future of bus service in Qatar by developing structural equation modelling (SEM) approach. They have made few recommendations to improve the usage of bus service as public transportation.

Kumar et al. (2013) evaluated the performance of multimodal transportation system (MMTS) in New Delhi. They examined the influence of access and egress times on the total travel time. They further evaluated the performance measures such as Travel Time Ratio, Level of Service, Interconnectivity Ratio, Passenger Waiting Index, and Running Index. Interconnectivity ratio i.e. proportion of access and egress timew.r.t total travel time for various combinations such as Mixed-Metro-Mixed, Walk-Metro-Walk, Walk-Metro-Bus and Walk- Bus-Walk was observed. Travel Time Ration i.e. the time differential between private transport and public transport showed much variation with trip direction, time of day, mode used, and distance travelled, etc. Level of Service Indicator Ratio (Out of- vehicle Travel Time/In-Vehicle Travel Time) inferred that people spends More time out-of-vehicle as compared to that of in-vehicle.

Brief Overview of Study Area

Apart the commuter travel survey to get an overlook of the study area, the study of two lines are considered from same origin to destination. One is the direct bus route (817) and other multimodal transit route from the same origin to destination (Najafgarh to Inderlok), in both routes most of the trips patterns observed are work-based trips. Some of them are leisure trips.



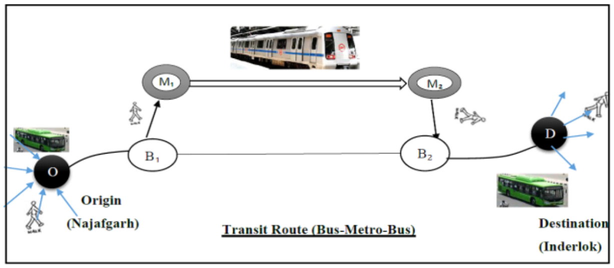


Fig. 1.0

Commuter Survey: For this analysis required large and extensive commuter travel data

i). Personal Information of the passenger: Gender, Age, Income, and Purpose of Trip.

ii). Travel Information of the passenger: Origin, Destination, Access mode and Access time, Egress mode and Egress time, Transfer Time and Wait time at each switch point, In-vehicle time.

iii). Passenger Satisfaction Measures in terms of speed, cost, comfort, reliability and transfer.

Traffic Data Collection

Data of heterogeneous traffic flow such as traffic volume, composition, speed, and signal timing at the study sections of the chosen road along with geometric data were collected. In this, study data was collected at Najafgarh road (from Najafgarh to Inderlok) in Delhi, both for bus and metro routes. Table 1.0 shows the volume of traffic flow at various sections in Najafgarh route from Najafgarh to inderlok observed by dividing the survey into 15 min time periods.

Spot Speed Surveys

Cumulative frequency distribution for each class of the vehicle is plotted and an example of bus as shown in Figure3.6. From these distributions important parameters namely 15th Percentile Speed (V_{15}), 50th Percentile Speed (V_{50}), 85th Percentile Speed (V_{85}) and 95th Percentile Speed (V_{95}) were calculated and values are listed in Table 2.0. These data are used as input in simulation program.

Table 1.0 Composition of Different Class Vehicle at Varies Section from

Vehicle class Section No	Car	Two-Wheeler	Bus	Trucks	Auto Rickshaw	Cycle Rickshaw	Cycle	Total Volume
1	0.207	0.542	0.036	0.056	0.051	0.049	0.061	1780
2	0.185	0.552	0.028	0.006	0.139	0.044	0.046	4040
3	0.274	0.572	0.016	0.003	0.046	0.015	0.074	4314
4	0.284	0.568	0.016	0.002	0.056	0.028	0.045	4119
5	0.283	0.562	0.019	0.001	0.068	0.035	0.033	3762
6	0.324	0.449	0.025	0.001	0.116	0.044	0.041	2971

Najafgarh to Inderlok

Table 2.0 Speed Statistics of Different Vehicle on Selected Section

Vehicle Type	V_{15}	V_{50}	V_{85}	V_{95}	Min. Speed	Max. Speed	SD
Car	27	33	39	44	21	51	6
Two-wheeler	28	35	41	47	19	56	6.5
Bus	23	27	31	33	19	36	4
HCV	22	27	31	35	19	37	4.5
Auto	19	23	29	31	16	34	5

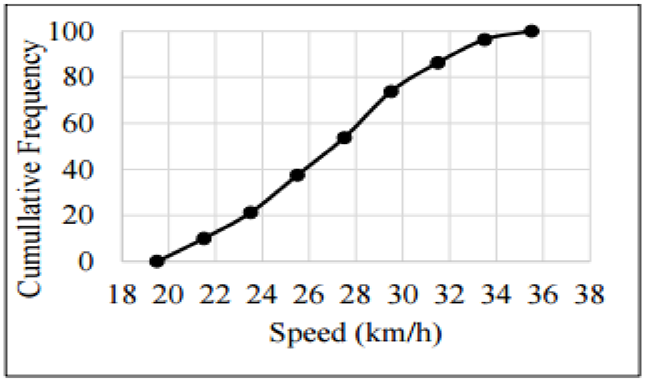


Fig. 2.0

METHODOLOGY

Performance Measures

Relative Travel Time (RTT) = --------- (1)

Relative Travel Cost (RTC) = ------ (2)

Relative Travel Service (RTS) = --------- (3)

Where

$W_{1,2,3,4}$ = Walking Time from Home to bus stop, Bus stop to destination, home to nearest bus stop, bus stop to destination

$Wt_1t_2t_3t_4$ = Waiting Time for Bus at Origin, Metro at Transfer Location-1 (M_1) Bus at Transfer Location, -2 (B_2), Bus at Origin (Direct Bus Route)

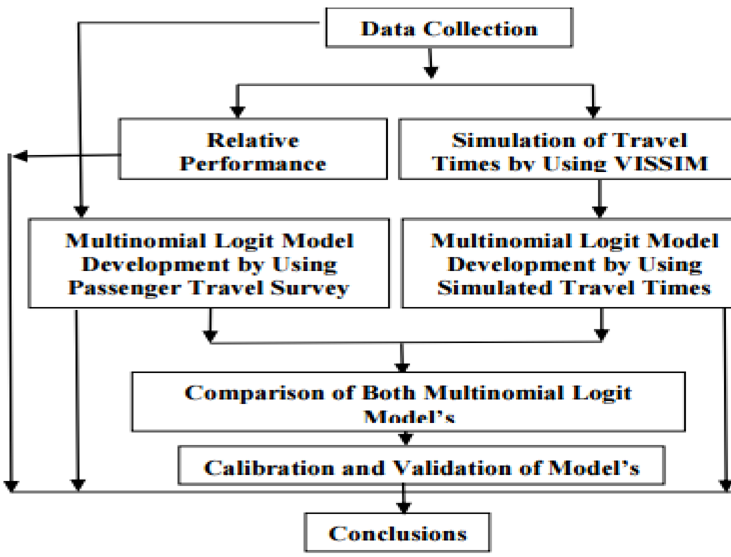


Figure.3.0 – Flow Chart of Methodology for Performance Analysis of Bus and Multimodal Transit Route

$X_{1,2,3,4}$ = Travel Time From Origin to Transfer Location -1 (B_1), Transfer Location,-1 (M_1) to Transfer Location -2(M_2) , Transfer Location-2 (M_2) to Destination, Origin to Destination

$C_{1,2,3,4}$ = Travel Cost of Bus from Origin to B_1, M_1 to M_2, B_2 to Destination Origin To Destination

Interconnectivity Ratio (IR) The interconnectivity ratio is defined as the ratio of the combination of access and egress time to the total trip time. It ranges between 0 and 1.

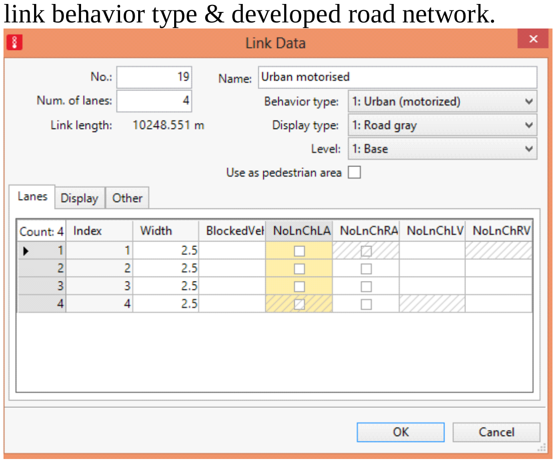
Passenger Waiting Index (PWI) The passenger waiting index (PWI) is the ratio of mean passenger waiting time to the frequency of the transport service. The value of PWI ranges between 0 and 1.

Running Index (RI) Running index (RI) is defined as the ratio of total service time to the total travel time. Running Index is inversely proportional to the efficiency of the system. As RI increases, efficiency of the system decreases. Its value can be fixed between 0 and 1. In general, its value is taken in between 0.15 and 0.75 depending upon the number of passengers boarding and alighting at different hours of the day. However, the total service time and total travel time depends upon number of stops and lanes as well as passenger boarding and alighting under prevailing traffic conditions.

VISSIM: It is used for simulating the travelling time of pedestrian's and vehicles. VISSIM is a Microscopic simulation model. It can analyze public and private transport operations and makes it useful for evaluation of various alternatives for transportation planning. This VISSIM software is used in this study to simulate the vehicle travel times from origin to destination, pedestrian transfer times, travel times and waiting times at various bust stops and transfer points. It can be valid for all the vehicles (i.e. buses, Bikes, HCV's, LCV's, Autos, Cars, Rickshaws and Cycles). Traffic signs (warning signs, prohibited signs, cautionary signs, speed indicators etc.,) are to be placed at necessary locations.

Link Generation

In the present work as a side unidirectional, along the considered road network no of lanes varies, (origin (Najafgarh) to Dwaraka Mor '2' lanes Dwaraka Mor to Uttam Nagar '3' lanes and Uttam Nagar to destination (inderlok) '4' lane road network)) is considered for simulation. The road geometry is plain and lane link data are shown in Figure 4.0. It is required to input the link data such as number of lanes, lane width, and link behavior type & developed road network.



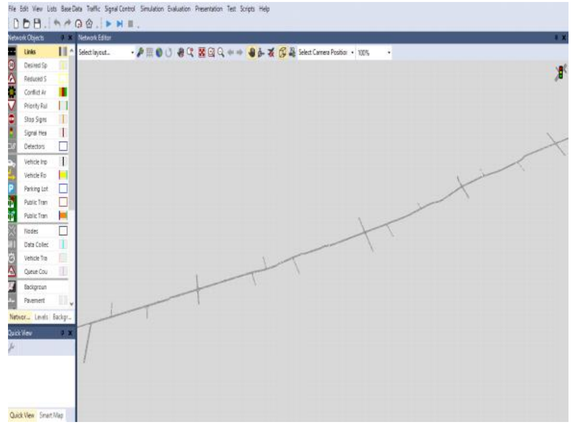


Figure 4.0 Link Input Data in VISSIM, Developed Road Network

Running of Simulation Model VISSIM

After giving all input parameter to VISSIM, a travel time section of 100 meter was selected on the link at an appropriate distance away from the point of vehicle input. Desired traffic composition and input traffic volume (vehicle/hr) are assigned. For this study, simulation run time was kept 7200 second and simulation data from 900 second to 3600 second was filtered for each volume input. Fig. 5.0 show running of vehicle on a link generated in VISSIM.

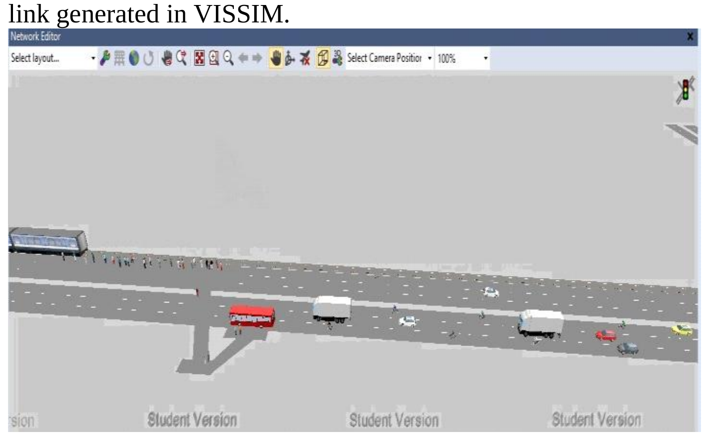


Figure 5.0 A snapshot of simulation run in VISSIM

Utility Function

$U_i = a_i + a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4$

------------ (4)

ji -------------(5)

x_1 = Waiting Time for mode in minutes

x_2 = Travel time (in vehicle time) in minutes

x_3 = Travel Cost in Rupees

x_4 = Access and Egress Time in minutes

Where U_i and U_j is the utility alternatives, a_i and $_j$ is calibrated mode-specific constant for the same model which represents advantages or disadvantages of mode. a_1 to a_4, coefficients are related to variables.

Multinomial Logit Model of Transit Route Choice

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The basic model estimated for predicting transit choice, the discrete choice (multinomial logit) model calculate the probability of choosing mode i if disaggregate, or the proportion of travelers in aggregate case that will select a specific mode according to following relationship.

General expression for the probability of choosing an alternative '*i*' (*i = 1, 2 - - - - J*) from a set of *J* alternatives is given as

----------- (6)

Where, *Pr (i)* is the probability of the decision-maker choosing alternative *i* and j

RESEARCH OUTCOMES

Purpose of Trip

Four activity categories were observed in this survey, as plotted below for selected sections.

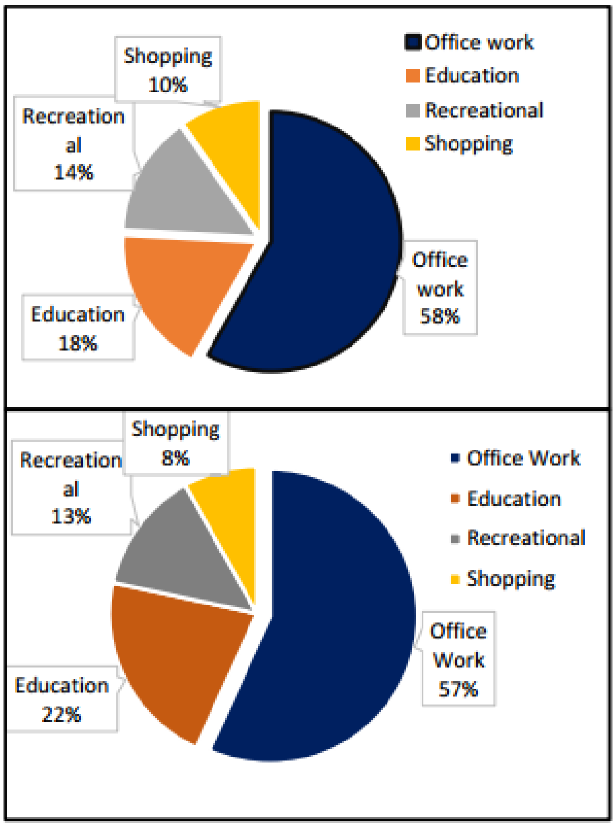


Fig. 6.0

Access and Egress Travel Times

Access and egress travel times mainly depend on distance from home to transit stop and transit station to destination. In present study observed access plus egress time vary from 7 to 20 minutes, there is no much variation in both route access and egress travel times.

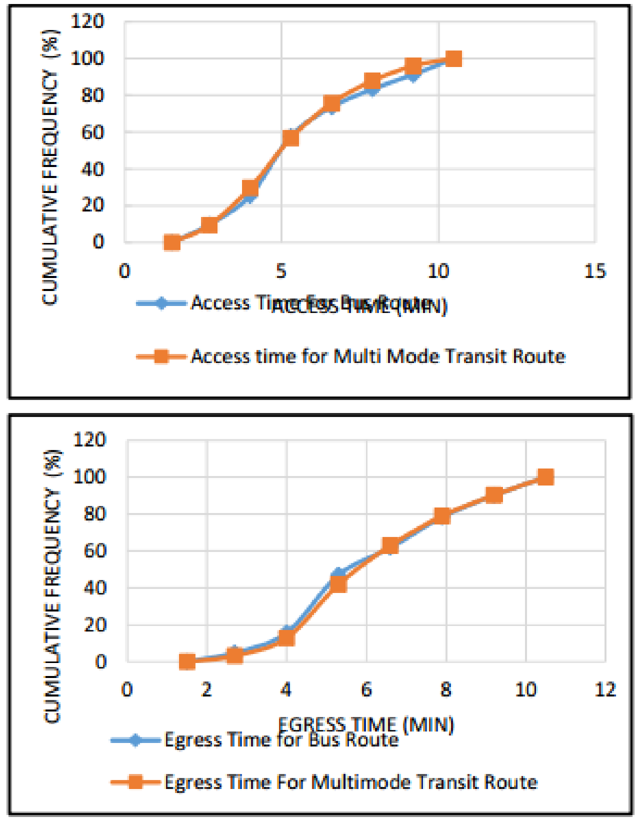
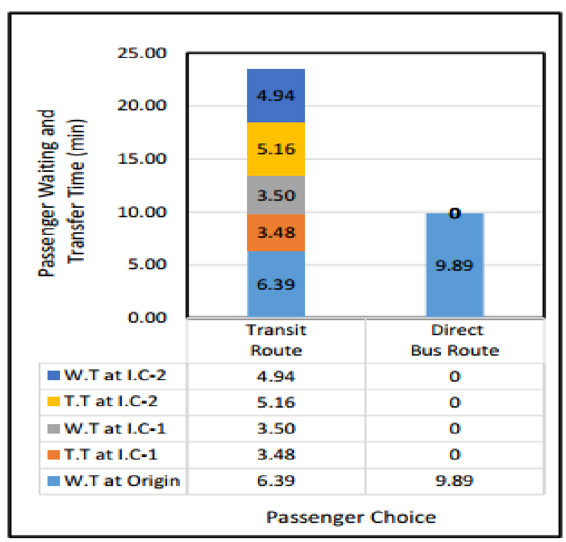


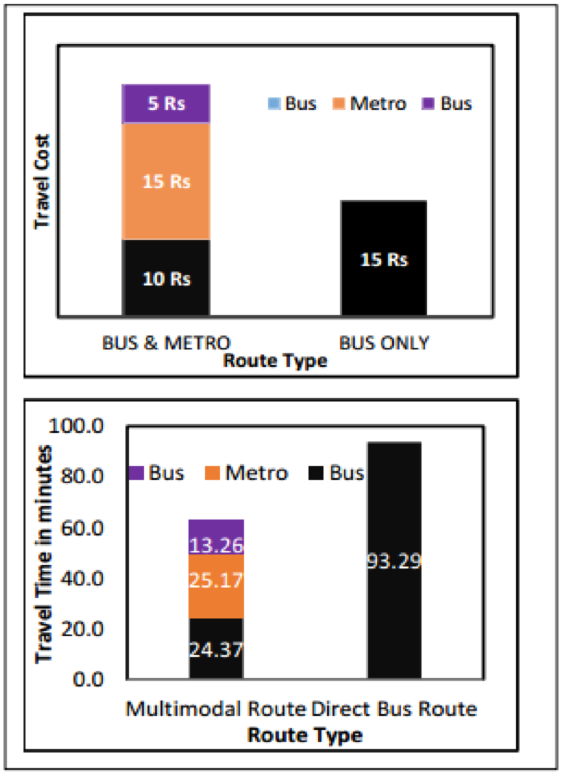
Fig. 7.0

Transfers and Waiting Time, Travel Cost and Travel Time

In passenger trips, transfer time, waiting time, Travel cost and travel times effects the total travel time of passenger and performance of transportation system as plotted below. Lower the transfer and waiting time, higher will be the performance of the transport system.

B.R: Bus route M.R: Multimodal route





B.R: Bus route M.R: Multimodal route

Fig. 8.0

Commuter Satisfaction

In the study between direct bus route and interchangeable (Bus-Metro-Bus) route, it is required to realize to what degree the overall quality of metro and bus services facilitate the commuters. Commuter travel survey questionnaire asked passengers for their view on their satisfaction in terms of Speed, Cost, Comfort, Time Reliability, and Ease of Transfer. From Fig.9.0 , it can noticed that in multimodal transit route as higher percentage of passengers are satisfied in terms of speed, comfort and reliability than the direct bus route, but in direct bus route passengers are satisfied in terms of cost than the multimodal transit route.

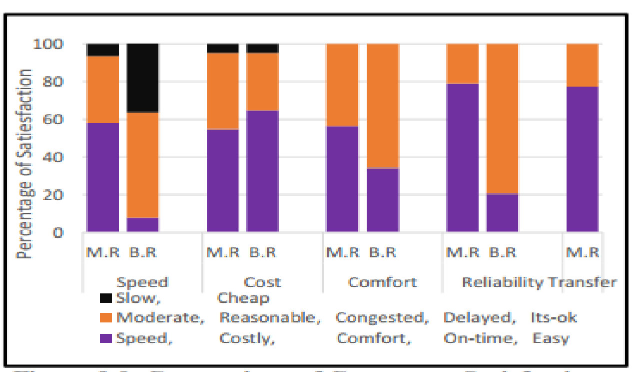


Figure 9.0 Comparison of Commuter Satisfaction

Performance Measures

Table 3.0 Performance Measures

Indices	Min Value	Max Value	Mean Value
Relative Travel time	0.622	0.0.974	0.861
Relative Travel Services	2.156	5.800	3.528
Relative Travel Cost	2	2	2

Interconnectivity Ratio

For Mixed–Metro–Mixed mode trips, the complete value range of interconnectivity ratio falls within the 0.785–0.810 range and the spread in values for chains involving different modes ((Walk+bus) - Metro - (Bus+Walk)) as access/egress modes shown below.

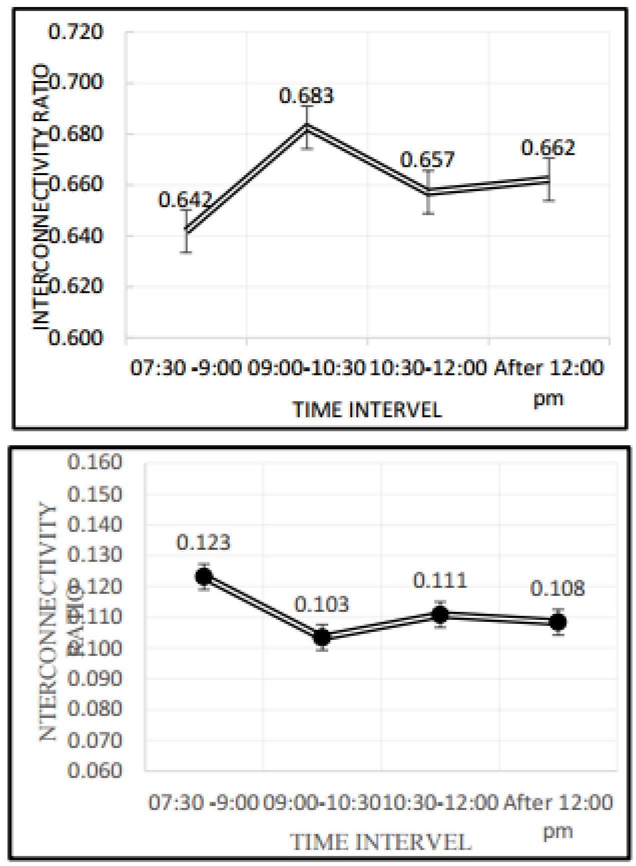


Fig. 10.0

Passenger Waiting Index (PWI)

The PWI is the ratio of mean passenger waiting time to the frequency of the transport service. PWI can be used to compare the performance of two routes have the same frequency of service. The PWI value can be fixed between 0 and 1. Table.4.0 shows PWI value for varies transit modes at transfer locations in multimodal transit route.

Table 4.0 PWI value for varies transit modes

Transit service	Mean passenger waiting time (min)	Frequency of the transport service (min)	PWI
Feeder bus and DTC (at Origin access service)	6.39	10	0.639
Metro (DMRC) (at Transfer Location-1 Main Mode)	3.0	4	0.75
DTC (at Transfer Location-2 egress service)	4.94	8	0.617
DTC (Direct Bus service from Origin to Destination)	0.618	15	0.642

Running Index (RI)

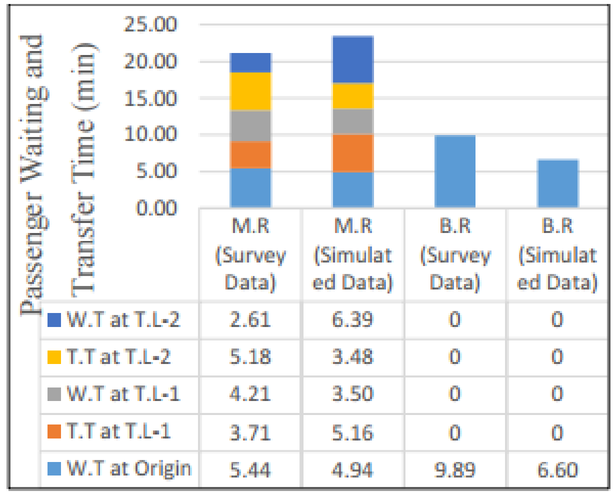
Running index (RI) is defined as the ratio of total enroot service time to the total travel time. As RI increases, the efficiency of the system decreases. Its value can be fixed between 0 and 1. For passengers‟ satisfaction", its value can be fixed between 0.15 and 0.75 depending upon the number of passenger boarding and alighting at different hours of the day. We observe in this case running index of metro (0.162) is more than running index for the bus (0.073). This means metro is efficiently running and providing proper time for passengers boarding and alighting.

Simulation of Travel Times by Using VISSIM Model : Simulation results are obtained from the output database file created by VISSIM through each simulation run. Public (bus and metro) and private (Car and Two-wheeler) travel times and Pedestrian travel times are simulated,

Figure shows Vehicle travel times and signal changes output database file & it shows output window for pedestrian travel times. Simulated travel time results are summarized in table 5.0

Multinomial Logit Model by Using Interviewed Travel Survey Data

Table 5.4 shows the Multinomial Logit model estimation parameter results. The N logit software is selected to calibrate the parameter which is the premier tool for estimating discrete choice models. In this paper the multinomial logit models are applied for alternative choice of the bus route and multimodal transit route. The alternative specific constant represents the average impact of some factors that are not included in the explanatory variables on the traveler's utility.



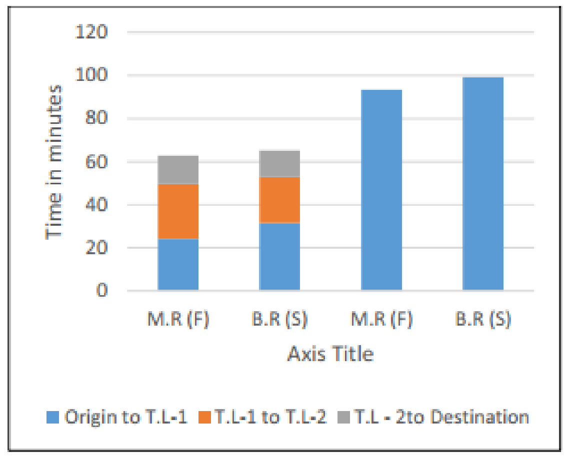


Fig.11.0 Comparison of OVTT & IVTT from Field and Simulated Data

Table 5.0 Multinomial model estimation results

Parameters	Coefficients	Standard Error	Z-Value	P-Value
Constant	-5.26172	2.04067	-2.58	.0099
OVTT	-.05151	.03152	-1.63	.0482
IVTT	-.04725	.01766	-2.68	.0074
Travel Cost	.17681	.10659	1.66	.0572
Age	-.28614	.30651	-.93	.1505

Gender	.58162	.50817	1.14	.0824
Comfort	.58515	.42629	1.37	.0699
Reliability	2.78836	.45095	6.18	.0000

Utility Equation Derivation

Depending upon the value of regression coefficient selection of the attribute/ choice set was done for derivation of utility equation

M.R ------- (7)

B.R ----------- (8)

Where

a_i = Utility Constant.

$a_{1,2,3}$ = Utility coefficient for out vehicle travel time (OVTT), IVTT, Travel Cost

The estimated logit is obtained from the above equation. The equation for utility value of bus route and multimodal transit route come out as following.

$U_{M.R}$ = -5.26172 -.05151 * 24.81 -.04725 * 63.30 +.17681*27.65 -.28614 *2.506 + .58162*0.707 + .58515 *0.427 + 2.78836 *0.427 = -3.507

$_{B.R}$ = -2.724

Probability of Alternative Route Choice

Probability of choosing route choice are found below

$P_{M.R}$ =

------------------------ (9)

$P_{M.R}$ = =0.314

$P_{B.R}$ =

----------------------- (10)

$P_{B.R}$ = =0.686

The probability of alternative multimodal transit route being chosen wrt direct bus route would be = 1 – 0.686 = 0.314

Multinomial Logit Model by Using Simulated Travel Time's Data

Table 6.0 shows the Multinomial Logit model estimation parameter results from simulated data. The N logit software is selected to calibrate the parameter which is the premier tool for estimating discrete choice models.

$U_{\cdot M.R}$ ------------------- (11)

$U_{\cdot M.R}$ = 0.014875

$_{B.R}$ = -0.05784*99.6-0.09969*7.033+0.17*13.067 = 0.08712

-------------------- (12)

Table 6.0 Multinomial Logit model estimation results from simulated travel times

Parameters	Coefficients	Standard Error	Z-Value	P-Value
Constant	-4.81694	0.034	-1.9	0.0502
OVTT	-0.05784	0.067	-1.47	0.0961
IVTT	-0.09969	0.114	1.49	0.0933
Travel Cost	0.17	2.559	-1.88	0.0498
Age	-0.4816	0.570	0.87	0.2828
Gender	0.17273	0.394	-0.47	0.0521
Comfort	1.00499	0.518	1.94	0.0527
Reliability	3.03453	0.529	5.74	0

Probability of Alternative Route Choice

Probability of choosing route choice are found below:

$P_{M.R}$ = = 0.146

--------------------- (13)

$P_{B.R}$ = = 0.854

--------------------- (14)

The probability of alternative multimodal transit route being chosen w.r.t direct bus route would be = 1 – 0.854 = 0.146

Calibration and Validation of Models

This is presented in Table 7.0. It was seen that predicted percent shares of modes is near to those of observed. The validation sample was 10 percent of the total sample.

Table 7.0 Observed and Predicted Probability of Choice

Generation	Choice	Observed Probability	Probability Obtained from equation
From field data	Multimodal transit route	0.378	0.314
	Direct bus route	0.622	0.686
From simulated data	Multimodal transit route	0.50	0.146
	Direct bus route	0.50	0.854

CONCLUSIONS

Conclusions

Route choice is influenced by some factors such as route travel time, travel cost, waiting time, quality of service, personal characteristics etc. In this paper it is concluded that how these factors affect the performance of bus route, multimodal transit route and the choice of alternative routes.

- From this study RTT says averagely 15% of travel time will be reduced by multimode transit, as per survey and simulated data.

- Passenger choice depends upon the relative travel service ratio, if larger the ratio, the less attractive route becomes as an alternative choice. In this study the average RTS value is 3.528, revealing multimodal transit route is less attractive than direct bus route.
- Travel cost of multimodal transit route is more because of number of mode transfers involved. Provision of single fare system to multimode public transport can improve the performance of multimodal transit route and it can reduce the service time to collect ticket at every transfer.
- OVTT & transfer times can be reduced by improving access & egress facilities, transfer facilities, and card access at public transit systems.
- The interconnectivity ratio derived for the different (access–main–egress) mode combinations will be permitted and unrealistic mode chains are eliminated.
- The travel time coefficients indicate the negative effect depicting travel time of transit increases, its probability of choosing decreases. The model results demonstrates that
- Cost, in-vehicle time and out-vehicle travel time are playing a significant role in traveler's choice behavior
- Attribute 'age' is having negative impact which means, as age of the individual increases, interest to travel in multimodal transit route reduces.
- Attributes comfort and reliability are calculating utility for multimodal transit route, their increase in value increases the probability in choosing multimodal transit route.
- As per simulated travel time metro takes very less IVTT '22' minutes (from Dwaraka mor to Moti Nagar) compared to bus travel '56' for same distance. Because bus has to face congestion and traffic signals which were almost absent in case of metro.

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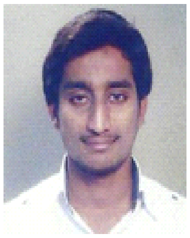

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