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Research paper

Travel demand estimation through corridor level analysis for hyderabad metro rail

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Abstract

Urbanisation around the world is occurring in a rapid manner. Due to which peoples' lives are in measurable situation like damaging the environment via increase in usage of private vehicles. In this line, transportation engineering plays a vital role in terms of sustainable development. Sustainability is the term used for balancing the three main components like social, environment and economic; not to trouble much of natural resources so as to preserve them for the future generations. To address the problems related to the transportation like traffic congestion, increase in pollution etc., Mass Rapid Transit System (MRTS) is the best alternative. To plan the MRTS in urban areas, it is necessary to estimate the travel demand, so as to fulfil the financial viability criteria.Corridor level analysis is performed to estimate the travel demand for Hyderabad Metro Rail, India. Multinomial Logit model (ULOGIT) is used to obtain the probability of MRT desired upon various modes. The results revealed that there would be adequate demand for the proposed MRT if the MRT could have double fare than that of bus fare and has half of the travel time to that of the current bus.

Keywords: *Sustainability; Travel Demand; Ulogit; Transit Patronage.*

1. Introduction

The growth of urban areas in developing countries increases exponentially in terms of population and vehicles, hindering the healthy economic development of an area. Migration of people from rural areas to cities in developing countries is the effect of swift urbanization and industrialization, causinginadequate public transportation facilities in most of the cities. Factors such asregularity, reliability, ease and suitability force commuters to prefer personalized vehicles or paratransit, depending upon their affordability. Easy availability of finance coupled with high disposable income is increasing the vehicle ownership in cities.

The mobility requirements of all sections of society leads to mixed traffic conditions consisting of travel modes such as pedestrians, cycles, auto rickshaws, buses, cars, vans, cycle rickshaws, animal drawn vehicles etc. and the demand for travel is increasing day by day. On the supply side, the urban road capacity which is being shared by moving vehicles and encroachers in most of the developed countries can be tried practically on case to case basis to ease the traffic congestion. Traffic congestion can be curbed to some extent by making mass transport facilities attractive to all class of commuters.

Urban traffic congestion must be understood in the context of city dynamics and growth [16]. Traffic congestion ismainly the outcome of unplanned economic development, employment, housing and lack of policy measures in regulating the traffic and land use. For example, Hyderabad vehicle composition in percentage is personalized vehicles-94.39percentage, IPT-5.23percentage and public transport-0.38percentage. There has been little progress in development of mass urban transit system in the country. In the case of public transport bus system, the fleet size increase has been almost nil for many cities and suburban rail transit system exists in just four out of thirty-five Indian cities with population in excess of one million. The share of public transport in Hyderabad is 45% with population of 9.3 million. If the private modes are allowedto continue, the entire system will get choked up with capacity vehicles occupying more road spaces per person trip. As per the recommendations, Hyderabad city should have 70% share by public transport as against 45% even for the present population level. Keeping in view the requirements and the demand for the route space it is absolutely necessary to reorient the mode of travel in Hyderabad and encourage high occupancy vehicles for carrying more passengers per vehicle requiring less space for person trips. Hence, travel demandestimation is vital and the most important phase in planning of Mass Transportation System [3].

2. Literature review

Conventional transport demand models are reviewed in the present study. Generally,in conventional transport modelling,the study area is divided into zones to consider the generators and attractors of trips.The modelling process in steps of four sub-modelsis as follows [1], [2], [4], [5], [6], [2], [2]:

- Generation of Trip: The zonal data is used to generate number of trips "generated from" and "attracted to" each zone.
- Distribution of Trip:Here the "origin-destination matrix"(i.e., the number of trips from each zone to each zone) is formed. Gravity type model is usually preferred.
- Modal split: Mode choice made by each traveler is replicated.
- Assignment: Route tracked by each trip is demonstrated. The output includes link flows and modified measure of costs of travelling between each pair of zones.

Economic approach for determining demand is also found in literature [20-21]. In this view author simplified the procedure for small

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scale projects. Data collection techniques are also important in planning [7]-the most efficient and relatively less complex procedures are adopted based on the review carried out. Mode choice models are vastly mentioned and reviewed [10], [12], [13], [14], [18] and best possible models were adopted as discussed in following sections.
In India, MRT studies are carried out [1], [2], [8], [9], [15] in Delhi, Mumbai, Chennai and Hyderabad as well.

3. Methodology

As city expands to accommodate the growth in population and activities, the spatial separation between the population and employment locations increase; increasing needs for travel modes are felt. The daily needs of residents for work, education, business, shopping and recreation create enormous demand on transport system. In order to understand the travel behaviour for transportation planning and management, the patronageis to be estimated. Once the patronage is estimated, suitable planning models could be developed and relevant management policies can be adopted to tackle many of urban problems. The patronage was estimated in the past by the urban transportation planning (UTP), which was eventually a four-step conventional planning process. This analysis employs huge amount of data, consuming large amount of time, the process gives the demand directly by way of the desire line diagram for a specified purpose for each route serving a particular land use. However, this method consumes enormous time for data collection and data analysis.
In view of above difficulties encountered in the UTP analysis, it is necessary to estimate the transit demand utilizing small amount of data by (a) alighting counts to get an appropriate outcome and (b) passenger interview surveys to capture the preference on introducing new mode of public transport i.e., metro rail. The present study aimed to utilize these data sources for the present selected corridor analysis.

3.1. Application of LOGIT model for mode choice

Logit model belonging to the group of qualitative choice model is selected for mode wise corridor level O-D estimation. In any choice situation, the person making the trip has two or more different alternatives among which a person has to choose depending upon the disutility function. Hence, the calibration of the model is done based on the values of the coefficients of disutility function developed from the observed data. For this, likelihood maximization technique is adopted to calibrate the logit model. In general, the calibration is carried out in three stages namely; data preparation, variables selection and estimation of the parameters. The logit model is calibrated to determine the present mode share.
Identification of choice set
In analysis, a qualitative choice situation is defined wherethe decision maker meets the following criteria [11]

- Limited alternatives in the choice set
- Necessity of choosing one alternative at a time exclusively
- Comprehensive set of alternatives
- Functional form of disutility function

Every traveller, intending to travel chooses the mode whose characteristics like time, cost, speed, comfort etc., are weighed by his or her importance to him, producing the most favourable combination (least disutility) relative to other modes. In support of this hypothesis the following assumption are made:

- Rationality: Rationality means that a traveler would behave in a manner of the classical economic man.
- Limited resources: for a meaningful choice problem, it is necessary to assume that the economical resources available to the traveler are limited i.e., his income is fixed.
- Perfect knowledge: it is assumed that the traveler is aware of the characteristics of all the modes.

The functional form of disutility functioning general is

$$V_{in} = \beta_{i\,o} + \Sigma_k \beta_{i\,k} X_{i\,k}^{(\lambda_k,\mu_k)} \quad (1)$$

Where λ_k and $\mu_k$are transformation parameters of variables X, B is vector of model parameters and X is vector of independent variable
Setting the vector $\mu = \mu_1 + \ldots\ldots\ldots\ldots \mu_k = 0$ and $\lambda = \lambda_1\lambda_2 \ldots\ldots\ldots\ldots \lambda_k = 0$
The disutility expression would be

$$V_{in} = \beta_{i\,o} + \prod_k \beta_{i\,k} X_{i\,k} \quad (2)$$

If $\lambda = \lambda_1 + \lambda_2 + \ldots\ldots\ldots\ldots \lambda_k = 1$

This utility function which is linear in modelling parameters is used in the present work.
From the utility equations, the road users who are likely to shift to MRT is assessed.

4. Study area

The study area for the present research is Hyderabad. The study corridor selected is fromMiyapur to Nampally. This corridor comprisesof 17 proposed MRTS stations as given in Fig. 1. This is along the NH-9 passing through center of the city and connecting important activity centers, such as Kukatpally, Balanagar, Ameerpet, Punjagutta and Nampally. Kukatpallyis a well knowndeveloped residential zone, Balanagar isoccupiedby industries, whereasAmeerpet, Punjagutta and Nampally are significantly commercially developedcenters. This corridor has some important feeder routes across connection road at various places.

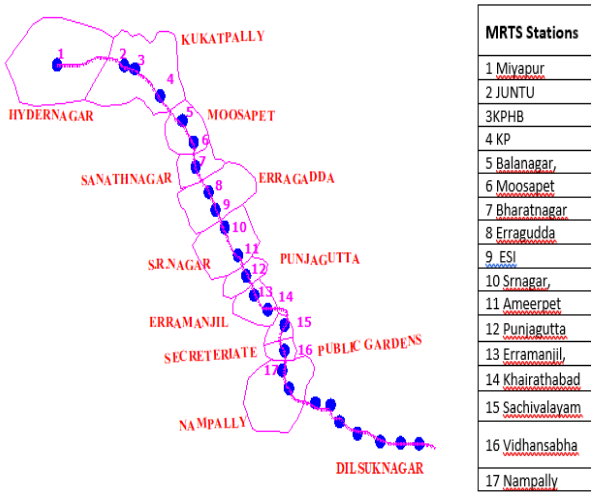


Fig. 1: MRTS Corridor with Stations.

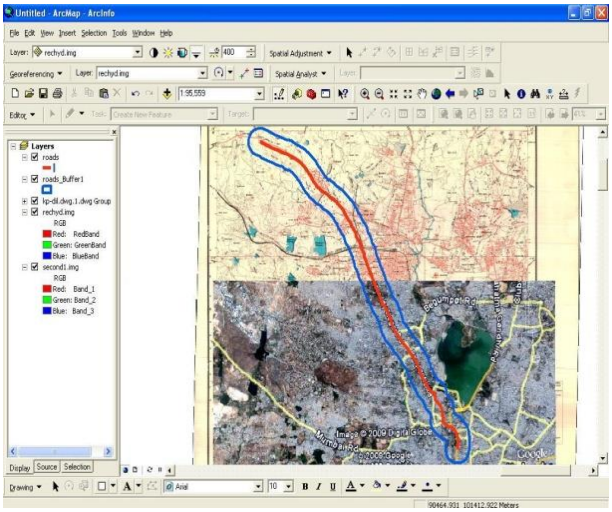


Fig.2: Hyderabad TOPO Sheet with Identified Corridor Boundaries.

5. Data and analysis

The questionnaire was prepared for the bus stop passenger, two-wheeler and car passengers. The questions are related to the following basic data [19].

1) Travel related data of passenger covering Origin, Destination address and purpose.
2) Trip data of passenger covering ingress distance, egress distance and waiting time for the bus.
3) Socio economic characteristics of passengers covering income, vehicle ownership.
4) Comparative psychometric three-point scaling technique was adopted with [3] attributes of same as bus fare, one and half times as bus fare and two times as the bus fare. In addition, other three attributes of speed is double, waiting time is half and comfort.

5.1. Application of U-logit

The sharing of the travel by public transit and personal modes depends upon the relative levels of service and the commuter behaviour of mode choice. This behaviour by individuals depends on levels of service factors like time, cost, comfort and convenience along with the reliability and dependability of the modes. The detailed investigations appropriate modelling to understand the commuter behaviour of mode choice is needed to provide the required levels of service for encouraging the public transport. It is desired to achieve a favourable split towards the mass transport, the competing capability of all other modes are to be kept in view. Keeping in view the superiority of logit model over other models like probit and discriminate analysis and in computing multi choice environment, the multinomial logit model (ULOGIT) is adopted which is developed by U.S.DOT and subsequently modified by CHARI and GUPTH for mode spilt analysis. The cross-elasticity of demand and theeffect of changes in the policy variables of one system over the patronage of others is determined by this technique [17]. The Fig 3 shows Mass Rapid Transit Desire in multi-mode environment using multinomial logit model.

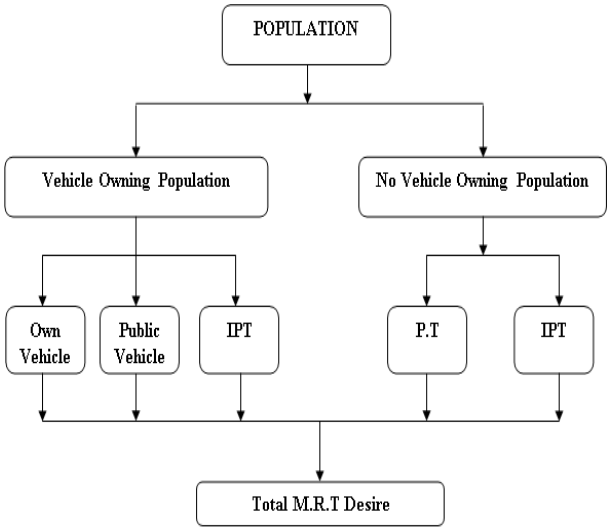


Fig. 3: Mode Choice Options for Different Classes of Population.

The data required for calibration of MULTINOMINAL LOGIT is a set of observations consisting of door to door travel time and out of pocket expresses for all modes included in the study and the mode selected for the particular trip. The data from bus passenger interview and private vehicle passenger interview are classified into two set viz., Vehicle Owing Population (VOP) and No Vehicle Population (NVP). Distances are known along the corridor, with the help of average journey speeds of various modes, the travel time is computed for each sample. Costs of travel by own vehicle (OV) i.e. cars and scooters are calculated by assuming their fuel consumption rates per kilometer as 12Km/liter and 40Km/liter respectively. For public transport, cost of travel is the actual ticket fare and for intermediate public transportation (IPT), the actual paid. The MRT travel time and cost are taken in term of bus travel time and cost. The dependent variable namely the probability of choosing a mode among several alternatives is a dummy variable in which the chosen mode takes a value of 1 and the next of zero. The time and cost of all the modes available for each trio, and the mode selected for the particular trips are recorded and the sample details are given to MULTINOMINAL LOGIT program.Data is prepared for VOP and as well as NVP.

Table 1: Summary of Results (Disutility Expressions)

VOG	OV=0.0069*Travel Fare-0.0234*Travel Time+26.727
NVP	IPT=0.0069* Travel Fare -0.0234*Travel Time+27 BUS=0.0069* Travel Fare -0.0234*Travel Time+27.3 BUS=0.0406*Travel Fare-0.0098* Travel Time-0.0007Waiting Time+30.36 IPT=0.0406*Travel Fare-0.0098* Travel Time+27.3 WALK=-0.0098*Travel Time+27.3456

The disutility expressions are given in Table 1. From these expressions, probability of using MRT by different group of population is presented in Table 2 and Table 3. It is observed that the fare of metro is estimated to be twice than that of bus fare and travel time is more or less half in terms of bus. The desire of MRT system is obtained by multiplying the probability matrix by estimated OD matrix. The results are presented in Table 4 for above policy options. Also, the probability for travel cost of MRT is 1.5 times than that of bus travel cost as presented in Table5.

Table 2: Probability of Choosing MRT by VOP

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	0.64	0.64	0.63	0.61	0.61	0.61	0.61	0.58	0.59	0.59	0.58	0.55	0.53	0.51	0.50	0.50	0.72
2	0.64	0.64	0.62	0.61	0.58	0.58	0.59	0.59	0.58	0.59	0.58	0.55	0.52	0.50	0.50	0.50	0.69
3	0.63	0.62	0.64	0.62	0.60	0.59	0.59	0.59	0.58	0.57	0.57	0.57	0.55	0.53	0.51	0.50	0.68
4	0.61	0.62	0.62	0.64	0.61	0.61	0.58	0.58	0.58	0.57	0.56	0.56	0.56	0.54	0.54	0.52	0.68
5	0.60	0.60	0.61	0.61	0.64	0.62	0.61	0.59	0.59	0.58	0.57	0.55	0.55	0.54	0.54	0.53	0.66
6	0.60	0.60	0.61	0.63	0.62	0.64	0.63	0.62	0.60	0.58	0.56	0.55	0.54	0.54	0.55	0.53	0.66
7	0.58	0.60	0.61	0.61	0.62	0.63	0.64	0.62	0.60	0.58	0.57	0.56	0.55	0.55	0.54	0.54	0.65
8	0.56	0.60	0.60	0.60	0.62	0.63	0.61	0.64	0.63	0.61	0.60	0.59	0.57	0.55	0.53	0.54	0.64
9	0.56	0.59	0.60	0.60	0.61	0.62	0.61	0.62	0.64	0.62	0.61	0.58	0.58	0.56	0.54	0.53	0.64
10	0.57	0.58	0.59	0.60	0.59	0.59	0.61	0.63	0.62	0.64	0.62	0.59	0.56	0.56	0.54	0.53	0.62
11	0.55	0.57	0.59	0.59	0.58	0.58	0.59	0.62	0.62	0.61	0.64	0.62	0.59	0.56	0.54	0.53	0.61
12	0.52	0.53	0.58	0.58	0.57	0.56	0.57	0.60	0.61	0.61	0.62	0.64	0.62	0.59	0.56	0.56	0.60
13	0.50	0.50	0.56	0.57	0.57	0.56	0.56	0.57	0.60	0.59	0.61	0.61	0.64	0.62	0.61	0.58	0.62
14	0.48	0.48	0.53	0.56	0.55	0.55	0.56	0.56	0.58	0.59	0.59	0.60	0.62	0.64	0.61	0.59	0.60
15	0.47	0.48	0.51	0.55	0.55	0.54	0.56	0.56	0.56	0.57	0.59	0.60	0.61	0.61	0.64	0.60	0.60
16	0.46	0.48	0.50	0.54	0.54	0.53	0.54	0.55	0.55	0.56	0.55	0.58	0.61	0.61	0.62	0.64	0.62
17	0.45	0.46	0.48	0.51	0.52	0.51	0.51	0.52	0.55	0.54	0.54	0.55	0.59	0.60	0.59	0.61	0.64

Table 3: Probability of Choosing MRT by NVP

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	0.51	0.48	0.48	0.45	0.45	0.46	0.46	0.43	0.44	0.45	0.45	0.44	0.44	0.45	0.46	0.47	0.58
2	0.48	0.51	0.48	0.47	0.44	0.45	0.45	0.46	0.44	0.45	0.45	0.44	0.44	0.43	0.45	0.46	0.54
3	0.48	0.48	0.51	0.48	0.47	0.45	0.45	0.46	0.46	0.43	0.45	0.45	0.45	0.45	0.44	0.45	0.52
4	0.45	0.48	0.48	0.51	0.47	0.48	0.45	0.45	0.46	0.46	0.43	0.44	0.44	0.45	0.45	0.45	0.50
5	0.45	0.45	0.47	0.48	0.51	0.48	0.48	0.45	0.45	0.45	0.45	0.43	0.44	0.44	0.45	0.45	0.49
6	0.46	0.45	0.46	0.48	0.47	0.51	0.48	0.48	0.45	0.44	0.44	0.44	0.42	0.43	0.44	0.44	0.47
7	0.45	0.46	0.46	0.46	0.46	0.47	0.51	0.48	0.47	0.44	0.44	0.44	0.44	0.42	0.44	0.44	0.46
8	0.43	0.46	0.46	0.46	0.46	0.46	0.47	0.51	0.48	0.48	0.45	0.45	0.45	0.44	0.42	0.43	0.45
9	0.44	0.44	0.46	0.46	0.46	0.46	0.45	0.47	0.51	0.48	0.47	0.45	0.45	0.45	0.44	0.42	0.45
10	0.45	0.45	0.44	0.46	0.46	0.45	0.45	0.46	0.47	0.51	0.48	0.47	0.44	0.44	0.44	0.44	0.43
11	0.45	0.45	0.45	0.44	0.44	0.45	0.44	0.46	0.46	0.47	0.51	0.48	0.47	0.44	0.44	0.44	0.45
12	0.44	0.44	0.45	0.45	0.44	0.43	0.45	0.45	0.45	0.45	0.47	0.51	0.48	0.47	0.45	0.45	0.45
13	0.44	0.44	0.45	0.45	0.44	0.43	0.43	0.45	0.45	0.44	0.45	0.47	0.51	0.48	0.48	0.45	0.45
14	0.44	0.44	0.45	0.45	0.45	0.43	0.43	0.43	0.45	0.45	0.44	0.45	0.47	0.51	0.48	0.47	0.45
15	0.46	0.45	0.45	0.45	0.44	0.44	0.44	0.43	0.43	0.45	0.45	0.46	0.46	0.45	0.51	0.47	0.47
16	0.46	0.46	0.45	0.46	0.46	0.44	0.44	0.44	0.43	0.43	0.45	0.45	0.46	0.46	0.45	0.51	0.48
17	0.48	0.46	0.46	0.46	0.45	0.44	0.43	0.43	0.44	0.43	0.43	0.45	0.45	0.46	0.45	0.45	0.51

Table 4: Corridor Level MRT Passenger Trip Matrix (MRT Cost Is 2 Times That of Bus)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	0	4116	5319	2823	3312	2380	17675	5192	4440	3984	5282	5643	895	2254	956	3902	14795
2	451	0	4476	3154	2766	2724	50655	14083	6252	4436	2213	2161	450	836	373	2314	7193
3	1058	1018	0	15745	16964	5062	44344	8816	5974	8839	4447	5891	2284	2906	1673	8689	15253
4	3627	3614	3251	0	3767	6495	51026	9744	13922	9552	1747	1828	366	594	516	28	2252
5	51	5857	10431	8102	0	45340	17670	7520	5183	2015	2008	4552	740	2073	708	1717	2832
6	2118	1965	3421	3267	16244	0	82450	12108	2594	932	590	768	255	444	163	332	600
7	840	1116	1425	2586	148	19579	0	4693	10079	17460	8457	12123	4053	12797	3580	8881	12486
8	915	1330	990	1701	1398	2815	1155	0	14190	4373	14518	45372	6587	10841	3690	11022	19596
9	920	899	1265	2214	1472	6048	3415	35265	0	13821	13352	19119	8337	23068	5027	16416	28441
10	2387	2852	3991	36868	3721	8726	5999	3221	11261	0	68835	3762	17968	40285	12695	7493	9336
11	3585	1998	3204	1419	2132	4785	7089	9765	12313	26418	0	67381	14219	19580	7400	18681	21679
12	2044	2012	2610	1749	3289	6620	6545	9888	15769	8240	10808	0	923	24989	22676	7512	45411
13	3931	4746	4786	9580	4920	7800	9381	7842	13305	15236	13795	4761	0	16317	712	20856	82531
14	7524	3333	10741	12654	16158	18720	57213	33259	39894	38960	49452	78481	1677	0	4014	16553	26149
15	617	232	207	88	986	1184	2415	296	1585	3678	2060	1045	5987	8770	0	56361	65399
16	7981	3787	1734	1007	10717	10444	25889	2004	13457	7770	10954	27478	66830	31034	18396	0	104305
17	4959	2747	1462	779	7798	3805	516	1885	10815	12656	30485	39533	33897	49358	102491	118709	0

Table 5: Corridor Level MRT Passenger Trip Matrix (MRT Cost Is 1.5 Times That of Bus)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	0	4183	5307	3013	3415	2422	17989	5391	4543	4076	5419	5759	915	2304	977	4013	15035
2	459	0	4553	3195	2859	2813	51586	14347	6490	4540	2265	2216	460	856	382	2387	7322
3	1072	1035	0	16016	17196	5229	45777	8981	6088	9188	4555	6036	2342	2968	1711	8887	15478
4	3740	3661	3307	0	3833	6521	52713	10065	14188	9738	1817	1874	375	610	527	29	2286
5	52	6053	10569	8244	0	46121	17905	7763	5351	2053	2047	4737	759	2127	727	1754	2876
6	2156	2028	3527	3309	16668	0	83841	12265	2677	943	602	783	266	455	168	341	610
7	857	1136	1469	2667	153	20079	0	4750	10215	18044	8723	12373	4141	13326	3447	9125	12741
8	952	1355	1007	1755	1440	2899	1186	0	14430	4431	14982	44773	6511	11061	3847	11312	20004
9	943	933	1288	2254	1518	6233	3520	36168	0	14056	13557	19755	8614	23523	5131	17116	29108
10	2445	2930	3103	37539	3790	9008	5775	3317	11550	0	17127	3814	18597	41679	13232	7647	6560
11	3676	2046	3278	1472	3274	4877	7325	10060	12685	27112	0	68537	14415	20270	7668	19082	22069
12	2089	2065	2673	1790	3417	6805	6670	6074	16255	8497	11091	0	939	25043	23461	7771	44199
13	3470	4855	4906	9811	5040	8116	9756	7992	13932	15755	14229	4865	0	16595	721	21550	85064
14	7705	3413	10969	12764	16565	19199	59482	34586	40752	40238	50845	80649	1720	0	4084	16781	29036
15	632	239	211	90	1022	1215	2475	308	1649	3750	2127	1078	5759	9162	0	57371	64257
16	8206	3886	1774	1028	10939	10832	26356	2055	14063	8078	11178	28383	68089	32083	19203	0	106960
17	4494	2832	1497	796	7968	3993	537	1937	11093	13389	31757	34219	35009	45352	105766	124029	0

6. Summary and conclusions

Thevast vehicular population growth results in limited right of way, overcrowding, accidents, insufficient parking and environmental deterioration, the challenging issues for Hyderabad city. To resolve the above issues, MRT system is essential. To propose such arrangement, there is a need to find the demand for the proposed MRT. The data collected through primary survey are traffic volume counts, bus boarding and alighting counts and passenger interview survey with stated preference.

The multi nominal logit (ULOGIT) is used to bring out the disutility expression. Finally, probability matrices multiplied by various population groups by various modes are achieved. These zone-to-zone desires are assigned on the corridor. Thus, MRT travel desire is obtained.

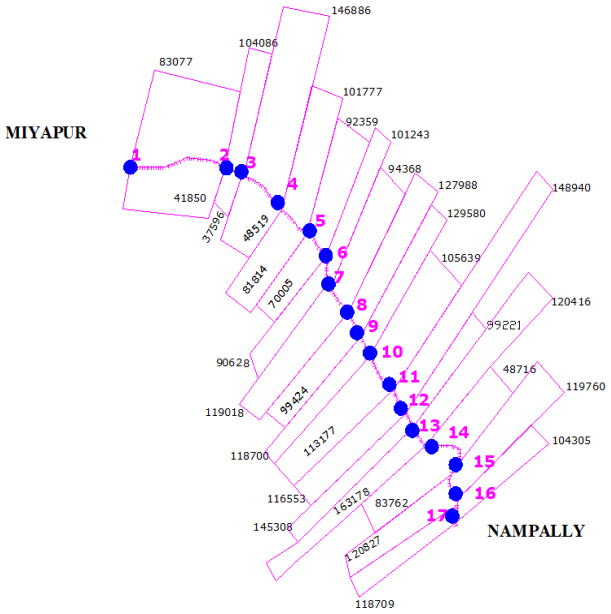


Fig. 4: Section Loads on MRT Network.

Following are the conclusions drawn from the current study

- From the past study of Hyderabad city, one can observe that Miyapur to Nampally is one of the major corridors.
- Estimation of corridor level O-D matrix from traffic counts is reliable than that of conventional models.
- From the traffic counts, one can observe that the public passengers' mode share is 46%, but ideal public mode share is 75%. To achieve this share, public mode transport should be encouraged.
- ULOGIT model brought out the disutility expressions, which is used to estimate the probability of choosing the MRT.
- As patronage estimated, it is recommendable for the MRT system.

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