A Study on Designing A Feasible And Efficient Mass Rapid Transit System For Warangal Tricity

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Abstract- *Rapid Urbanization and intense commercial developments in the recent past have resulted in steep rise in travel demand putting Warangal tri-city transport infrastructure to stress. Presently city buses operated by TSRTC is the main public transport available in the Warangal Tri-city.However, with increasing travel demand, existing public transport modes is not enough to meet the future demands.*

The Purpose of this study is to find a feasible and efficient Mass Rapid Transit System for Warangal Tri-City. Based on maximum passenger per hour per direction in Warangal – Hanamkonda – Kazipet via DPO junction. Electric coach system with overhead tractionand "Battery Electric Bus" can be considered as suitable options for Warangal. Both the systems will be able to carry the projected traffic demand on the corridors. However, considering comparative features, Electric coach system with overhead traction is considered effective for the city. And this system is named as "Metro Neo"

Keywords- Metro, Mass Rapid Transit System, Warangal Tri City, Growth Rate.

I. INTRODUCTION

The Three urban areas Kazipet-Hanamkonda-Warangal are together known as Warangal Tri-city. Warangal is one of the two metropolitanurban communities in the territory of Telangana. Warangal filled in as capital of the Kakatiya administration which was set up in 1163. The landmarks left by the Kakatiya's incorporate posts, lakes, sanctuaries, and stone passages which in the present helped the city to turn into a mainstream vacation destination. The Kakatiya Kala Thoranam was remembered for the image of Telangana by the State Government.

The Warangal Tri-city has marked rapid demographic growth and has witnessed steep rise in the last couple of decades with a population of 8.3 Lakhs as per census 2011. Warangal has an estimated population of 10.4 lakhs in 2019. The population is expected to reach 17.0 and 27.6 lakhs in 2031 and 2051 respectively.

Rapid Urbanization and intense commercial developments in the recent past have resulted in steep rise in travel demand putting Warangal tri-city transport infrastructure to stress. The increase in capacity of transport system has not been compatible with transport demand. Presently city buses operated by TSRTC is the main public transport in the Warangal Tri-city. However, with increasing travel demand, existing public transport modes is not enough to meet the future demands. Information Technology is another sector in which the city is making steady progress with its Incubation centre at Madikonda. Recently Tech Mahindra & Cyient have opened their development centres and many other IT majors like Mindtree, quadrant resource will be opening their offices shortly.

To meet the increasing travel demand of the Warangal Tri-city. The Kakatiya Development Authority has decided to introduce an efficient, safe, and high capacity mass transit system in Warangal Tri-city.

1.1 Demographic Profile

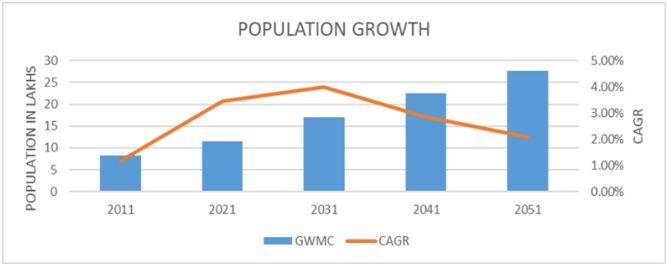


Figure 1: Population Growth of Warangal Area

The total population of Warangal was 8.2 lakhs in 2011, registering a Cumulative Annual Growth Rate (CAGR) of 1.2%. The estimated population as on 2019 is 10.4 Lakhs. The average sex ratio is 974 females to 1000 males. Demography profile of Warangal area is presented inand population growth is presented in

Table 1: Demographic profile of Warangal area

YEAR	POPULATION IN LAKHS	CUMULATIVE ANNUAL GROWTH RATE %
	WMC	WMC
1981	3.4	-
1991	4.6	3.20%
2001	5.3	1.40%
2011	6.2	1.58%
	GWMC	
2001	7.3	-
2011	8.2	1.17%
2021	11.5	3.44%
2031	17	3.99%
2041	22.5	2.84%
2051	27.6	2.06%

1.2 Transportation Characteristics

The registered vehicles in Warangal increased significantly over the years led to congestion and reduction in speeds in the city's core area. Approximately 5.0 Lakhs vehicles were registered till date as per the Road Transport Authority (RTA). Increase in the growth rate is observed till 2011 with a Compounded Annual Growth Rate (CAGR) of 15% in 2011 and later decreased to 7% in 2019.

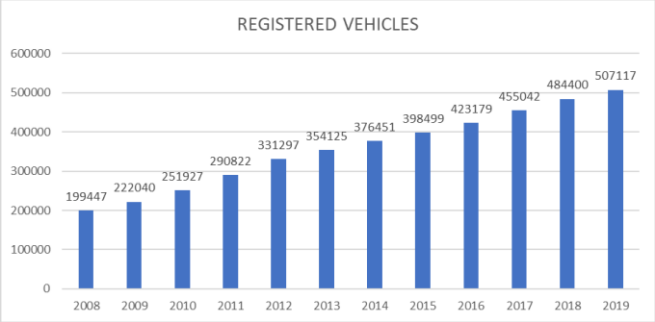


Figure 2: Registered Vehicles in Warangal Area

1.3 Object of the Study

Finding a feasible and efficient Mass Rapid Transit System for Warangal Tricityto meet the increasing travel demand.

II. LITERATURE SURVEY

In this chapter an attempt has been made to prevent a review of past works carried out so far by different researches on the relevant topic. A study on designing a feasible and efficient mass transit system are reported in the following section.

2.1 Rail Based Mass Rapid Transits

2.1.1 Metro Rail

Metro Rail system is most prevalent mass transit system adopted worldwide. In India, MRTS is operational in various cities viz. Delhi, Kolkata, Mumbai, Bangalore, Kochi, Jaipur etc. It is a grade separated system with exclusive right of way characterized by short distances of stations spaced at about 1 km and modern state of the art rolling stock having high acceleration and deceleration with maximum speed of 80-120 kmph. The structures are designed with 16 Tonne or above axle load. Sharpest curve of 120m radius is permitted for MRTS mainline.

Figure 3: Delhi Metro Rail

2.1.2 Light Rail Transit

Light rail systems are characterized by light weight (axle weight ≤12 T), Lesser width (2.6-2.7m as compared to 2.9-3.2m metro rolling stock) trains. Light Rail Systems typically have the capacity of up to 30,000 PHPDT. The lower axle load and low viaduct width (8m -9m) results in lower viaduct cost.

Light Rail Transit (LRT) system is popular system in large number of European countries. LRT system can have elevated, underground or at grade (with signalised crossings with road) alignment. Exclusive right of way for LRT allows the trains to run at higher speed and higher frequency. LRT has high acceleration and deceleration characteristics. LRT permits sharper curves (up to 60m mainline), thus minimizing need for property acquisition. LRT has the capability to climb steep gradients.

Figure4: Honkong Monorail

2.1.3 Supercapacitor based Tram/Light Rail System

Supercapacitor based tram systems are one among the latest innovative technologies for rail-based transit systems. The technology utilizes the onboard supercapacitors for the traction power requirements. The super capacitors get automatically charged from a ground-level power supply at stops. The super capacitors can be charged in a very short period of time (average of 20 seconds) by allowing very high current flow. This allows charging at stops during boarding/alighting. Guangzhou city has tram system operational with the super capacitor technology.

With the exception of the Guangzhou super-capacitor-only train, all others use super-capacitor/battery hybrids. The batteries help to provide power through maintaining speeds on level segments of track while the super-capacitors help to provide additional high-current power during acceleration and climbing gradients. Alstom Citadis, CAF's 'Rapid Charge Accumulator' (ACR), Bombardier's 'Mitrac Energy Saver' (MES), and Siemens' 'Hybrid Energy Storage' (HES) are few supercapacitors enabled systems available in market.

Figure 5: Japanese Light Rail

Bus Based Mass Rapid Transits

2.1.4 Electric coaches with overhead traction

The system has electric coaches that draw power from overhead wires using spring loaded poles. This system is very popular mode of transit in the European countries. This technology is a proven technology which is being used in several parts of the world over the decades. The system is suitable for the cities with lesser traffic demand. It is capable to handle PHPDT up to 15000. The system generally has low-vibration and ensures quieter operation. These coaches have rubber tyres which provide better adhesion than the rail-based systems. This also gives them better climbing capability and braking. Today, these systems are equipped with advanced technologies which, for example enable the coaches to operate, over short distances without being connected to an overhead contact line. Modern systems can operate without the Overhead Contact Wire for distances up to 20 km.

Figure 6: European Traction Buses

2.1.5 Battery Buses

A battery electric bus is an electric bus that is driven by an electric motor and obtains energy from on-board batteries. They eliminate infrastructure needed for a constant grid connection and allow routes to be modified without infrastructure changes compared to a Trolleybus. The battery buses are charged at the charging stations located in the depot or stations. There are various technologies ranging from plug in to inductive charging which can be used for charging at the terminal station. The main problem of the battery buses is the capacity of the storage unit. The weight of the batteries increases with the increase in capacity. Therefore, in order to optimize the size of batteries for the battery bus system, it is essential to have intermediate charging stations. These stations may be located after every second or third stop. However, in such cases, the buses would have to stay longer at many stops than necessary boarding alighting time.

At present, buses of sizes 9m and 12m are in operation. This kind of system is suitable for lower PHPDT say up to 5000.Battery buses have less range, higher weight, higher procurement costs.

Figure 7: Russian Electrical Buses

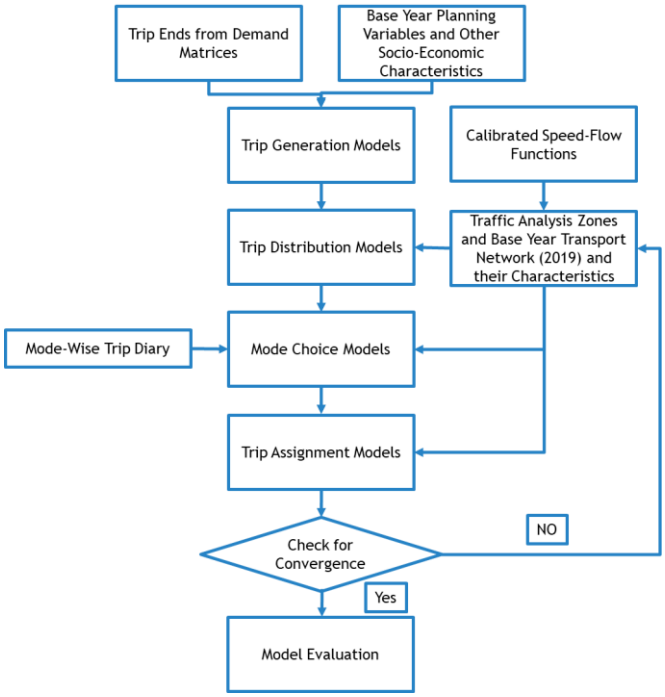
III. METHODOLOGY

PRIMARY SURVEYS

The travel and traffic characteristics were assessed through analysing the data of the following surveys,

- Household Surveys
- Inner Cordon Surveys
- Origin and Destination Survey at Outer Inner Locations
- Screen Line Surveys
- Vehicle Occupancy Survey
- Terminal Counts
- Terminal Passenger Surveys
- Boarding and Alighting Counts
- Bus Passenger Survey at Bus stop Locations
- On Board Bus Passenger Counts
- Stated Preference Survey

Travel Demand Modelling is a process of simulating the "real world" transport system and forecasting the demand and the state of the system for the horizon years. Travel analysis through UTP Models are developed to assist in making informed transportation planning decisions. These models are often developed by using advanced state of the art computer packages such as CUBE, EMME2, TRANSCAD, TRANPLAN etc. built explicitly for such purposes. In case of KUDA, CUBE (software) has been used.



The framework for four stage model gets inputs from the demand matrices, planning variables such as population, employment, resident workers, students etc., for building a mathematical equation for simulating the base year and future travel demand for the purpose of planning and policy making.

IV. RESULTS

TRIP GENERATION MODEL

Trip generation is the first stage of travel demand modelling which involves the process of estimating total number of trips produces by (Oi) and attracted to (Dj) each zone of a study area. Trip generation model outputs the scalar data (column data).

Table 2: Trip generation Model

PURPOSE	TG	TRIP END MODELS	R^2	F-VALUE	TG (OBSERVED)	TG (MODELLED)	% ERROR
HBW	TP	0.233*Population t-stat (57.75)	0.94	3336	362852	357197	-1.6%
	TA	0.599*Employment t-stat (36.18)	0.87	1309	362852	355871	-1.9%
HBE	TP	0.129*Population t-stat (31.75)	0.84	1008	201566	198154	-1.7%
	TA	1.895*Student Enrolment t-stat (25.73)	0.78	662	201566	199638	-1.0%
HBO	TP	0.054*Population t-stat (21.44)	0.74	460	84041	82934	-1.3%
	TA	0.140*Employment t-stat (19.87)	0.68	395	84041	83160	-1.0%
NHB	TP	0.051*Employment t-stat (18.34)	0.62	336	30029	30752	2.4%
	TA	1.051*Trades t-stat (18.09)	0.64	327	30029	30851	2.7%
All Purpose	**Trip Production**				**678489**	**669037**	**-1.4%**
	Trip Attraction				**678489**	**669519**	**-1.3%**

***Values in parenthesis represents t-statistic at 99% confidence level**

Trip production of home-based work (HBW), home based education (HBE) and home based other (HBO) purposes are influenced by Population of a zone, while for non-home-based trips (NHB) employment of a zone is influencing the trip production.

Trip attraction of home-based work (HBW) and home based other (HBO) purposes are influenced by employment in a zone. Home based Education trips (NHB) is influenced by student enrolment in a zone while for non-home-based trips (NHB) trades in a zone is influencing the trips attraction.

The calculated t-statistic were compared with the critical t-value of 2.34 at 99% confidence level.

Intra-zonal trips are excluded from the generated trips using intra-zonal model presented below,

$TP_{intra} / TA_{intra} = 558.17 \left(\frac{1}{Population}\right)$, $R^2 = 0.50$ with t = 12.34 at 99% confidence level.

TRIP DISTRIBUTION MODEL

Trip generation outputs are fed into the trip distribution model to generate the production-attraction matrix. Trip generation output is a scalar data (column data), which is converted to scalar data (matrix data) using the trip distribution model.
In this study doubly constrained gravity model is used for trip distribution, which works based on the principle of Newton's concept of gravity. The calibrated deterrence function for trip distribution is presented in the table below.

Table 3: Calibrated Deterrence Fuction

TRIP PURPOSE	N	β (BETA)	R^2	OBSERVED AVG. TL (KM)	MODELED AVG. TL (KM)	COINCIDENCE RATIO
HBW	0.390	-0.020	0.58	10.2	11.6	0.80
HBE	0.524	-0.035	0.71	10.7	10.0	0.90
HBO	0.570	-0.030	0.75	10.6	10.8	0.80
NHB	0.579	-0.025	0.74	9.8	10.8	0.80
All Purpose				**10.4**	**11.0**	**0.90**

The comparison of trip length frequency distribution between observed and modelled trips is shown in the below graph

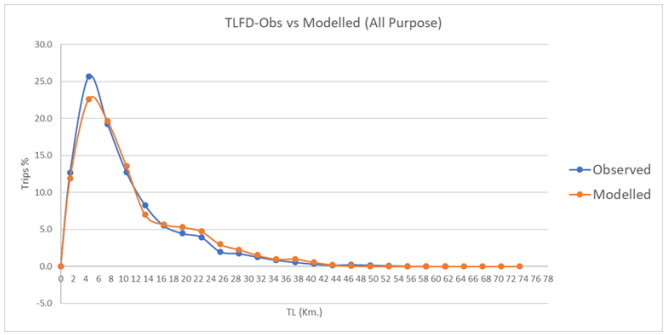


Figure 8: Observed and Modeled trip length frequency distribution.

MODE CHOICE MODEL

The function of mode choice model is to split the travel patterns by modes. Trip distribution model results an aggregated matrix populated between zones; the mode choice model splits the single matrix to mode wise matrices based on number of travel modes considered in the model. In this study multinomial logit (MNL) model has been developed to model the choice of mode. MNL model is a utility-based model, which assumes that people choose their mode which has the highest utility (least disutility).
In this study the model modes are two-wheeler, car, taxi, auto-rickshaw and bus. The choice probabilities of MNL model are given as,

$$P_j = \frac{e^{vj}}{\sum_{all} e^{vi}}$$ **Equation** Error! No text of specified style in document.**-1**

Where,

Pj = probability of choosing mode j,
Vj = deterministic component of utility for mode j
i and j are indices for modes
Revealed preference data (Household Interview Survey data) has been used to build the multinomial logit choice model and the calibrated utility equations using Biogeme software to determine the choice probabilities and they are given below,

Utility equation for Two-Wheeler,V1 = - 0.267*TTT TW - 0.142*TTC TWEq **Error! No text of specified style in document.**-2
Utility equation for Car, V2 = 1.45 - 0.267*TTT CAR – 0.142*TTC CAR Eq **Error! No text of specified style in document.**-3
Utility equation for Auto, V3 = 0.96 - 0.267*TTT AUTO – 0.142*TTC AUTO Eq **Error! No text of specified style in document.**-4

Utility equation for Bus, V4 = - 0.267*TTT BUS - 0.142*TTC BUS Eq **Error! No text of specified style in document.**-5

Where, TTT = Total Travel Time (Wait time + Access Time + In Vehicle Time + Egress Time) for respective modes.

TTC = Total Travel Cost (Access Egress Cost + Travel Cost) for respective modes

Summary of the model parameters are,

ρ^2 = 0.446; Initial log likelihood = -4881.92; Final log likelihood = -2705.397;

Likelihood ratio test for the initial. Model = 4353.05; Smallest eigenvalue = 13.14

Value of time estimated can be estimated using the calibrated mode choice model.

VOT = $\frac{\beta_{TT}}{\beta_{TC}} = \frac{-0.267}{-0.142}$ = 1.88 Rs/Minute.

Table 4: Observed vs Modelled mode share

MODE	OBSERVED MODE SHARE (%)	MODELLED MODE SHARE (%)	% ERROR
Two-Wheeler	44%	49%	5%
Car	4%	6%	2%
Auto Rickshaw	33%	29%	-4%
Bus	19%	16%	-3%
Total	100%	100%	

TRIP ASSIGNMENT MODEL

Trip assignment involves the highway assignment and public transport assignment. The calibrated BPR function for performing highway assignment is presented in the below table and the capacity derived from the for each lane configuration are considered for highway assignment.

Table5: Calibrated BPR Functions

LINK CLASS	LANE CONFIGURATION	CAPACITY PCU/HR/ LANE	CAPACITY PER DIRECTION. (PCU/HR)	V_f	V_c	A	B
1	1L-2W-UD	720	360	28	16	0.78	1.1
2	1.5L-2W-UD	720	540	36	20	0.78	0.97
3	2L-2W-UD	1200	1200	39	22	0.8	0.97
4	4L-2W-UD	1250	2500	46	24	0.9	1.28
5	4L-2W-D	1500	3000	52	27	0.9	1.1
6	6L-2W-D	1560	4680	57	32	0.8	4
22	Centroid Connectors	99999	99999	60	52	0.15	4

* 2W – Two way; UD – Undivided; D – Divided

Public transport assignment is carried out intuitively by CUBE based on the crowd model. The crowd model is an iterative process, which evaluates the attractive routes and loads the demand and the balance between demand and capacity (seating and crush capacity of bus) continues based on the link travel time and wait times.

Goods vehicles demand is preloaded to the network before performing the highway (private vehicle) assignment. The estimated daily commercial vehicle demand using Analyst program is 33,080 PCUs, which works on the principle of entropy maximization.

EXTERNAL PASSENGER TRIPS

The external travel patterns such as internal to external (I-E), external to internal (E-I) and external to external (E-E) are obtained from the combined demand matrices merged from various origin destination (O-D) surveys. The estimated external demand is presented in the below table

Table 6: External Trips

MODE	TRIPS (LAKHS)
Two-Wheeler	0.60
Car	0.32
Auto-Rickshaw	0.24
Bus	0.78
Total	1.94

TRAVEL DEMAND FORECASTING

Planning variables such as population, employment, trades and student enrolment considered for the years 2020, 2024, 2031, 2041 and 2051 are presented in the below table.

Table 7: Planning variable in Wrangal

PLANNING VARIABLE	2020	2024	2031	2041	2051
Population	10.97	13.16	17.00	22.50	27.50
Employment	5.04	5.1	8.69	11.83	12.79
Student Enrollment	0.89	0.94	1.15	1.33	1.38
Trades	0.27	0.28	0.48	0.65	0.70

The maximum passenger per hour per direction (PPHPD) for the Kazipet-Hanamkonda-Warangal route is presented for the horizon years 2024 to 2051. The DPO junction to Warangal railway station records per hour per direction of 13 thousand passengers out of which the MRT system caters to 8 thousand passengers in the horizon year 2051.

Table 8: PPHPD for Horizon Years

Name of the Corridor	Length (km)	Horizon Year	Metro-Neo (MRT) PPHPD	Total PT PPHPD	Total PPHPD
Kazipet - Hanamkonda-Warangal	15	2024	3919	4135	9603
		2031	5733	5957	10901
		2041	6670	6928	11213
		2051	8194	8665	13208

V. CONCLUSION

Based on maximum passenger per hour per direction in Warangal – Hanamkonda – Kazipet via DPO junction and from literature studies. Electric coach system with overhead traction. and "Battery Electric Bus" can be considered as suitable options for Warangal. Both the systems will be able to carry the projected traffic demand on the corridors. However, considering comparative features, Electric coach system with overhead traction is considered effective for the city.

MoHUA, GoI, Committee report on standardization of specification of rubber tyres electric driven bus system named **Metro Neo** – Report Version 7 dated 20th April 2020.

"Metro Neo" is the Feasible and Efficient Mass rapid transit system for Warangal Tri-city.

VI. FURTURE SCOPE

Based on Sixth Central Pay Commission's recommendations in 2008 the cities are classified as X, Y, Z. The cities which are classified as Y such as Guntur, Vellore, Madurai etc the Metro Neo system can be more effective and Less cost of project. In European countries the Metro neo system working proper and efficient manner.

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