Comprehensive Traffic Assignment Analysis using Users Equilibrium & System Optimum: A Case Study of Vadodara City

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Abstract : Travel Demand Forecasting is the attempt of estimating the number of vehicles or people that will use a specific transportation facility in the future. Traffic forecasting begins with the collection of data on current traffic. This traffic data is combined with other known data, such as population, employment, trip rates, travel costs, etc., to develop a traffic demand model for the current situation. High growth of household residents in urban areas developed into a big problem like congestion, delay, over-crowded links, bottlenecks, etc.

In this study, the roads of vadodara city is been selected on which the traffic assignment analysis is going to be done. The study falls under Transportation Planning process. Then the O-D matrix is generated using the Travel survey data sheet using TransCAD software. Creating a Network by providing it all the required attributes fields like speed, distance, no. of lanes, no. of physical stops (Nodes) it contains, vehicle volume count, etc. Then by using the BPR method as a default method the results from Users Equilibrium (UE) and System Optimum (SO) assignment methods are compared, the present V/C ratio is inventoried along with the vehicle operating cost (voc) and similarly the future demand of trips are estimated and the effect of calculated future V/C and voc is studies over each selected link of city. It is assumed that the traffic volume count will be same after 10 and 5 years only the growth is in no. of trips O-D matrix. It is widely accepted that path choice of a trip is dependent on trip characteristics, network attributes, and a travellers personal characteristics. The best known network variables that influence route choice are travel distance, travel cost and travel time. This research attempts to study the influence of other network variables, namely no. of lanes, no. of intersections, and roadway condition and classification on route choice over the present as well as future stage.

IndexTerms - Travel Demand Forecasting; Traffic Assignment; Household Survey.

I. INTRODUCTION

Transportation planning and development of infrastructure for the system is one of the most crucial factors particularly for urban areas, where in high level and rapid urbanization is taking place. Transportation planning process plays an important role in construction of new transport facilities. The basic purpose of transportation planning and management is to match transportation supply with travel demand. It is an important part of overall town and country planning, since it deals with the transport network which is an important channel of communication. Any change in this system is reflected in number of impacts. The transport planning process starts with the decision to adopt planning as a tool for achieving certain desired goals and objectives.

The city is on the major rail and road arteries joining Mumbai with Delhi and Mumbai with Ahmedabad. Because of this Vadodara is known as a ‘Gateway to the Golden Corridor’. National Highway No. 48 & National Expressway No. 1 passes through the city. All superfast and express trains halt at Vadodara Railway Station. Vadodara also has an airport which is very well connected with the other major airports of India.

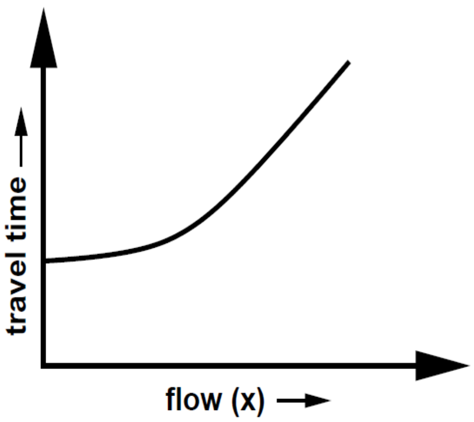
The internal modes of transport in the city are Private Vehicle, Auto, Rickshaw, Vitcos bus service and for NMT footpaths are available on the major roads Arterial and Sub-arterial. There is a 40M wide ring road of six lane from manek park - L&T circle - Race course - Akshar chawk - vadsar - sussen circle - soma talav - sardar estate - manek park.

Road from Lalbaug bridge end - mujmajuda - Akshar chowk - Atladara railway station upto Muncipal limit is of six lane and its give way to the traffic towards padra and jambusar viallage. Then the road from Muktanand - Sangam char rasta - mahavir hall char rasta - kaladarshan - Dabhoi road which is known as inner ring road of six lanes. It creates smooth flow between Dabhoi and Karelibaug the road comes under Sub-Arterial type but an important link of the city. RC dutt road of six lane which is another important part of inner ring road and the Akota Bridge which is of 2.5Km and connects Dandiya Bazar - Akota, old city to western part of the city which reduces traffic density on the parallel roads towards western part of the city & is of six lane with solar panel street lighting system.

The fundamental aim of the traffic assignment process is to reproduce on the transportation system, the pattern of vehicular movements which would be observed when the travel demand represented by the trip matrix, or matrices, to be assigned is satisfied. The traffic assignment procedure basically is to estimate the volume of traffic on the links of the network. The estimation of travel time between trip origin and destination is done for use in trip distribution. To obtain aggregate network measures, e.g. total vehicular flow, total distance covered by the vehicle, total system travel time. The Transport Planning Module helps in developing a Transport policy, issues to be considered and options. It sets up a vision, goal and strategies for cities toward achieving a liveable atmosphere. Understand the nuances of comprehensive mobility planning studies, criteria for setting up a service level benchmarks and Travel Demand Forecast (TDF) as a strategy for improving mobility in cities.

1.1 Link Cost Function

As the flow increases towards the capacity of the stream, the average stream speed reduces from the free flow speed to the speed corresponding to the maximum flow. This can be seen in the graph shown below.



$$t = \text{to}\,[\,1 + \alpha\left(\frac{x}{k}\right)\beta\,]$$

Where, t = link travel time

x = link flow

t_o = free flow travel time

K = Practical Capacity

α, β = 0.15, 4.00 (BPR constants)

Travel time vs Flow graph

That means traffic conditions worsen and congestion starts developing. The inter zonal flows are assigned to the minimum paths computed on the basis of free-flow link impedances (usually travel time). But if the link flows were at the levels dictated by the assignment, the link speeds would be lower and the link travel time would be higher than those corresponding to the free flow conditions. So the minimum path computed prior to the trip assignment will not be the minimum after the trips are assigned. A number of iterative procedures are done to converge this difference. The relation between the link flow and link impedance is called the link cost function and is given in above equation.

II. RELEVANT LITERATURE

Relevant Literature

There are certain assumptions need to be taken before carrying out the assignment process. Here also in this study the assumption are considered, the time period of respective length, compared with the trips, in which it is assumed that in the network the level of congestion will relatively constant either high or low. If the time period is of one or two hour such models are called static models. An input trip matrix gives the flow from origin to destination for each zone. The minimum attributes of road network consists of nodes, zone centroid (were trip generate and attracts), links and link travel time – flow function. If the drivers have perfect information about travel time them it can be said as deterministic approach. Where on the other hand, if there are some perception errors added in the drivers information it turns to little stochastic approach. It is much difficult and not considered where the models contain truly stochastic times.

The process whereby demand in the form of a O-D trip matrix is loaded on to the network created, is referred to as *Traffic Assignment.* There are two ways in which these loading can be done. The loading process should be rational enough with decision making behaviour by trip maker. Altruistic rationality means that the trip maker behaves in a way to maximise the overall benefit to the system and its other users, leading to *System Optimum.* Individualistic rationality means that the trip maker pursue their own interest individually instead to whole system or its users, leading to a *User Equilibrium*. There are two forms examined for traffic assignment using user equilibrium. The first is deterministic user equilibrium assignment in which it is assumed that the trip maker makes his or her first opinion as a cost identically, in order to have a perfect foresight and there is no perception error. The second is stochastic user equilibrium assignment in which it is assumed that certain amount of relaxation in the identical perception of costs and hence allow for the errors due to perception.

Relevant works on Traffic assignment

The watanabe, gotoh, and Tachiin (2006) studied abouth the Network selection to introduce a new transportation system in a hillside urban area in Nagasaki, Japan. They identified the set of attribute data that influence the service quality of whole system. They conducted household survey to collect the attribute data along with the aging rate, which is used to create a system that should be elderly. They used GIS and analytic hierarchy process (AHP) to develop a route system method newly. Their main emphasis is on the elderly residents. The adding distribution data had been undertaken to do the same. To recognise the area characteristics they considered basic attributes data which are qualitative data of control points and quantitative data such as gradient, housing density and distance from the road by the analytic hierarchy process.

The sanchez (2004) studied the Land use and Growth impact from highway capacity increases in Oregon, US. The study is carried out using the data which include aerial photography of 15 cities and the extent of urban development is delineated. Using Gis the data was assembled and the significance of geographic variable like the proximity of highway project, land use zoning classification, city size, and other spatial characteristics are tested using logit regression modelling. The results concluded that the cities population size and the rate of development from 1970 – 1990 is relatively weak, negative coorelation. The author also compared development rate along highway improvement by location of improvements suggested. It comes to a conclusion that the project at or near the city limit boundaries exhibited more lane use conversion than the projects at or near the UGB (urban Growth Boundary). Therefore, the likelihood of urban development decreases wit increase in the distance from urban core, highway, state highway and UGB's, and simultaneously, the likelihood of urban development decreases more rapidly with

increase in distance to highways compared to state highway projects. If the controlling for the distance to the nearest state highway project is done then the likelihood of urban development is also increased slightly over time.
The xiong and Schneider (1992)vstudied the shortest path within polygon and best path around or through the barriers for urban planning, geographic analysis and engineering studies. The barriers may be island, mountain, lake, river, house, etc. They found shortest or best path using two algorithms. The first is algorithm for shortest path in polygon and the second is best path using rectilinear metric and multiple performance criteria. Here they gave an example for a lake as a barrier whichis centred in urban city. The organisations need to find the shortest ferry route from lake shore location to another. This requires the shortest path algorithm in which the lake is considered as a polygon. The first algorithm justify the shortest ferry path. On the other hand, the second algorithm is justify the desire of the organisation that if they want to build a highway to connect the urban areas on both side of the lake. They can either build a bridge through the lake (barrier) or can construct highway around the lake (barrier).

III. DATA COLLECTION

The Government of Gujarat has appointed Vadodara Municipal Commissioner as the Principal Census Officer, Deputy Municipal Commissioner as a Deputy Municipal Commissioner (Census) and Assistant Municipal Commissioner (Revenue) as the City Census Officer for this latest census for the jurisdiction area of Vadodara Municipal Corporation limit & out-growth areas, Census Town areas and Industrial Notified Areas. The city has a population of 16,70,806 with a total area of 159.31 sq. Km. The area should be properly understood & the planner should have experience for designing the data collection survey for the research.

Under this section, we will discuss the basic information required from a data collection, defining the study area, dividing the area into 19 zones, and 49 transport networks links are selected for the route assignment analysis. The analysis is conducted only on the arterial, sub-arterial and collector street of the city. Thou, the links are further connected to the local street and centroids of the zones which is assumed that the all the trip from a particular zone is generated from its respective centroid. To gather data, study includes several surveys and inventory along the existing network of the city which is nominated under study. The surveys can be grouped under Socio-economic data, Travel surveys and Network data.

Socio-economic data: Information regarding the socio-economic characteristics of the study area is collected using Household Survey. 4200 questionnaire household form was collected which then converted into revealed information attribute data to carry out the analysis. Important information includes income, vehicle ownership, family size, etc. which would be converted into an important attribute data. This information helped them in getting the knowledge of generation and distribution zones land use pattern. It supply data on knowing the housing density at residential zones, establishments at commercial and industrial zones. This data is especially useful for trip generation models.

Travel surveys: Origin-destination travel survey was conducted households and traffic data from sample surveying. The total no. of daily commuter trips per household per ward was collected during household survey. The sampled data was collected as per the norms. Then by applying expansion factor the trips will be applied for the whole city. Firstly data include the number of trips made by each member of the household, the direction of travel, destination, the cost of the travel, etc. collected form household survey. Then survey includes the traffic flow count which is done manually as well as video graphic, speed, and travel time measurement. These data will be used primarily for the calibration of the models generated through UE & SO.

Network data: This includes data on the transport network and existing inventories. Transport network data includes road network, inventory survey average speed (considering diff. Vehicle for peak hours), no. of lanes (capacity), distance of each link, type of road, etc. Road link is normally represented with attributes like starting node, ending node, road length, free flow speed, capacity, number of lanes or road width, type of road like divided or undivided etc. in the software also.
All the assignments techniques are based on the selection of route. The choice of route is based on several criteria such as travel time, length of travel, cost if travel, comfort, convenience and safety. Keeping this in mind there are 49 routes selected for the traffic assignment analysis. This covers outer as well as inner ring road of the city. The links are categorised as the Arterial, Sub-arterial, collector street and local street and a centroid connector which connects the centroid of the zones to its nearest link. Design parameters include peak-hour information and condition of the desired links during peak hours. The attribute and other link cost factors are summarised below:

Typr of Road (Category)	Link No.	Distance (KM)	No. of lanes	Speed (KMPH)	Shoulder/ Footpath	Volume Count (PCU/Hr)	Capacity (PCU/Hr)	CC / BITUMINOUS
	86	3.5	4D	45-50	Unpaved		2700+2700	
	51	2	4D	45-50	Unpaved		2700+2700	
	36	3.5	4D	45-50	Paved+Footpath		2700+2700	
	4	3	2+2(Service)' 6D	50	Paved+Footpath		4200+4200	
	5	1.5	6D	40-45	Paved+Footpath		4200+4200	
	55	1.5	4D	40	Unpaved+Footpath		2700+2700	
	6	0.8	4D	40	Unpaved+Footpath		2700+2700	
	53	1.2	4D	50	Paved+Footpath		2700+2700	

ARTERIAL	75	1	4D	45	Paved+Footpath		2700+2700	
	7	1	4D	40-45	Paved+Footpath		2700+2700	
	77	1.6	4D	40-45	Paved+Footpath		2700+2700	
	8	3	4D	50	Paved+Footpath		2700+2700	
	9	0.8	Up-3, Dn-2 (Divided)	Up-55, Dn-45	Paved+Footpath		4200+4200	
	10	1.2	Up-3, Dn-2 (Divided)	Up-55, Dn-45	Paved+Footpath		4200+4200	
	83	0.5	4D	40	Paved+Footpath		2700+2700	
	18	1	4D	40	Paved		2700+2700	
	11	1.2	6D	40-45	Paved+Footpath		4200+4200	
	69	2	4D	4050	Paved		2700+2700	
	15	0.5	4D	5035	Paved		2700+2700	
	24	2.2	4D	40-45	Unpaved+Footpath		2700+2700	
	65	3.5	4D	40	Unpaved+Footpath		2700+2700	
	32	2.2	4D	40	Paved+Footpath		2700+2700	
	34	5	2(Undivided)	45	Unpaved		2400	
	45	1.8	4D	40	Paved		2700+2700	
	1	1.5	6D	60	Paved+Footpath		4200+4200	
	85	1	6D	60	Paved+Footpath		4200+4200	
COLLECT OR STREET	57	0.2	4D	30	Paved+Footpath		2700+2700	
	59	1.2	4D	40	Paved+Footpath		2700+2700	
	43	0.9	4D	30	Paved		2700+2700	
	21	1.2	4D	45	Paved+Footpath		2700+2700	
	20	0.6	4D	35	Paved+Footpath		2700+2700	
	71	1.5	4D	40	Paved		2700+2700	
	29	0.65	4D	45	Paved		2700+2700	
	39	0.9	2(Undivided)	30	Unpaved		2400	
	38	1.1	4D*	40	Paved		2700+2700	
	37	2	4D	45	Paved		2700+2700	
	40	1.5	2(Undivided)	3.-35	Paved+Parking		1200+1200	
SUB-ARTERIAL	23	3.4	2(Undivided)	50	Unpaved		2400	
	31	4	4D	50	Paved+Footpath		2700+2700	
	22	2	6D	45	Paved+Footpath		4200+4200	
	25	0.7	6D	50	Paved		4200+4200	
	67	0.4	2(Undivided)	30	Paved		2400	
	26	0.9	2+2(Service), 6D	40-45	Paved+Footpath		2700+2700	
	33	6.5	6D	50	Paved		4200+4200	
	63	2	2(Undivided)	35	Paved Paved		2400	

	46	3	2(Undivided)	40	Paved		2400	
	47	5	2(Undivided)	40	Paved+Footpath		2400	
	79	1	4D	45	Paved+Footpath		2700+2700	
	19	1.3	4D	50	Paved		2700+2700	
	88	1.1	4D	45	Paved		2700+2700	
	73	2.9	2(Undivided)	25	Paved+Footpath		2400	
	42	1	4D	45	Paved		2700+2700	
	14	2.6	4D	50	Unpaved		2700+2700	
	81	0.6	4D	50	Paved		2700+2700	
	16	0.7	4D	45	Paved+Footpath		2700+2700	
	12	0.35	4D	35	Paved+Footpath		2700+2700	
	17	4	4D	40	Paved+Footpath		2700+2700	
	13	0.5	4D	45	Paved		2700+2700	
	30	0.5	4D	45	Paved		2700+2700	
	28	3.7	6D	50	Paved+Footpath		4200+4200	
	27	3.4	4D	45	Paved		2700+2700	
	3	4.5	4D, 6D	45-50-55	Paved+Footpath		2700+2700	
	35/65	3	4D	45	Paved		2700+2700	

Increasing population of urban areas due to shifting of people from rural to urban areas and thus certainly increasing vehicular population on urban street have caused problems of congestion in urban areas. Road traffic congestion poses a challenge for all large and growing urban areas. This document provides a summary of urban street with respect to their classification, related operational performance measures.

IV. DATA ANALYSIS

The basic inputs for traffic assignment on TransCAD are the O-D matrix, Network file and the volume count. The O-D matrix is tabulated using the excel file which contains the data collected during household survey. This O-D matrix which depicts the sampled trips is actually not an prior matrix to use. To prepare main O-D which tell the vehicular flow the mode choice probability is obtained. Which out to be 0.1342, 0.5401, 0.1037, 0.0164 and 0.0802 for 4W, 2W, 3W, govt. Bus and private bus respectively. The person O-D is then multiplied with the mode choice probability per occupancy factor of each mode and five different set of O-D is generated which represent the vehicle flow and can be known as vehicular O-D. This O-D's are then converted in PCU as per the other data input in the software. All the respective mode matrices are then added up and converted into per hour traffic flow. This O-D is the expanded in order to obtain total city peak hour traffic O-D matrix.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	332.80	60.51	272.29	30.25	121.02	30.25	151.27	221.87	70.59	110.93	221.87	60.51	20.17	40.34	201.70	50.42	50.42	151.27	272.29
2	231.95	70.59	332.80	50.42	60.51	20.17	141.19	352.97	70.59	201.70	181.53	30.25	60.51	0.00	161.36	141.19	312.63	50.42	131.10
3	201.70	0.00	211.78	151.27	50.42	0.00	211.78	564.75	70.59	20.17	110.93	20.17	40.34	131.10	262.20	121.02	20.17	121.02	40.34
4	121.02	110.93	121.02	40.34	242.04	242.04	90.76	141.19	252.12	50.42	40.34	0.00	0.00	40.34	30.25	0.00	90.76	0.00	30.25
5	443.73	0.00	161.36	131.10	80.68	10.08	70.59	393.31	70.59	50.42	151.27	30.25	20.17	242.04	252.12	50.42	0.00	20.17	30.25
6	342.88	0.00	171.44	191.61	20.17	80.68	141.19	574.83	40.34	80.68	90.76	0.00	80.68	282.37	131.10	30.25	10.08	30.25	0.00
7	50.42	80.68	201.70	50.42	60.51	181.53	534.49	262.20	60.51	100.85	141.19	20.17	90.76	201.70	40.34	0.00	40.34	20.17	20.17
8	80.68	100.85	30.25	30.25	10.08	10.08	60.51	564.75	322.71	131.10	121.02	60.51	30.25	80.68	70.59	0.00	100.85	30.25	0.00
9	221.87	30.25	60.51	40.34	0.00	50.42	60.51	423.56	252.12	211.78	141.19	80.68	20.17	20.17	80.68	10.08	90.76	0.00	40.34
10	100.85	50.42	20.17	131.10	40.34	60.51	80.68	423.56	80.68	403.39	221.87	80.68	50.42	70.59	0.00	70.59	110.93	10.08	0.00
11	191.61	40.34	40.34	141.19	20.17	30.25	60.51	171.44	20.17	161.36	363.05	161.36	70.59	141.19	10.08	60.51	60.51	10.08	20.17
12	181.53	40.34	191.61	110.93	0.00	20.17	352.97	494.16	60.51	151.27	423.56	332.80	30.25	121.02	151.27	141.19	161.36	40.34	60.51
13	121.02	0.00	60.51	30.25	20.17	0.00	121.02	292.46	50.42	50.42	70.59	60.51	221.87	70.59	80.68	60.51	110.93	60.51	0.00
14	151.27	10.08	181.53	181.53	10.08	10.08	383.22	211.78	60.51	70.59	70.59	90.76	110.93	272.29	70.59	40.34	110.93	40.34	0.00
15	282.37	10.08	60.51	90.76	30.25	10.08	20.17	332.80	100.85	312.63	242.04	0.00	70.59	141.19	302.54	20.17	40.34	161.36	131.10
16	80.68	0.00	363.05	80.68	0.00	0.00	453.82	110.93	60.51	70.59	20.17	80.68	60.51	312.63	60.51	171.44	50.42	60.51	0.00
17	242.04	443.73	40.34	131.10	30.25	30.25	60.51	191.61	20.17	151.27	191.61	131.10	80.68	110.93	20.17	40.34	40.34	20.17	20.17
18	141.19	70.59	70.59	151.27	80.68	20.17	60.51	252.12	80.68	393.31	242.04	100.85	80.68	121.02	20.17	60.51	40.34	20.17	20.17
19	201.70	0.00	110.93	60.51	20.17	20.17	191.61	494.16	40.34	181.53	121.02	20.17	201.70	80.68	20.17	121.02	272.29	110.93	161.36

O-D matrix with present trip 2018

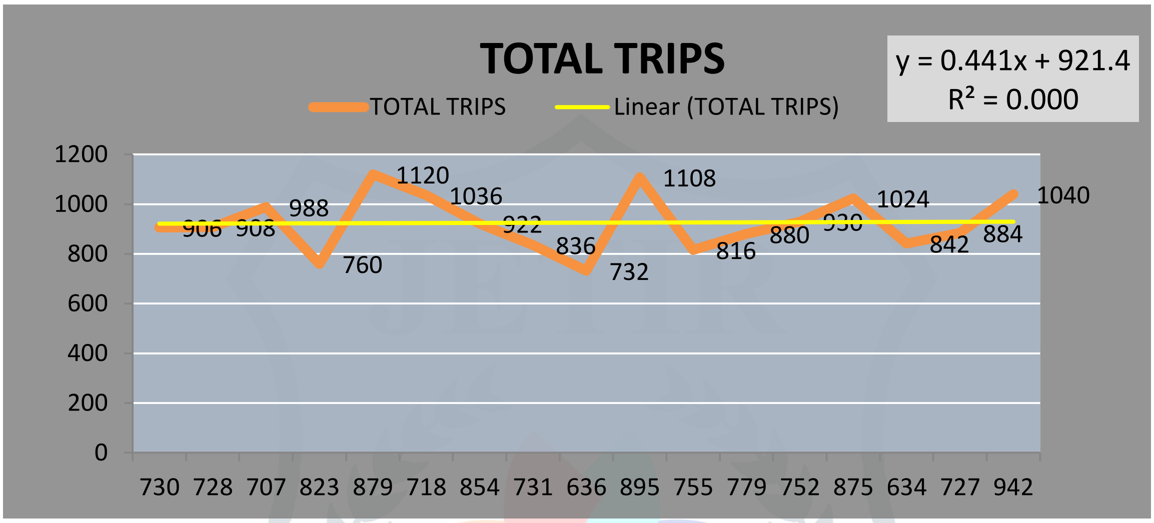
This expanded O-D is used for the present traffic assignment analysis. The traffic route assignment analysis is done to minimise the individual routing cost, minimise the traffic flow counts matching errors and maximise the O-D demand entropies. As the study focuses on analysing the performance measures for the next 10 years and 5 years simultaneously, the O-D matrix needed to be forecasted for the same using Growth Factor method. The computations for Growth Factor and Expansion Factor are mentioned below.

Expansion Factor/Growth Rate

The raw data collected in the survey is processed before applying in the software. This is necessary because of various errors, except in the survey both in the selection of sample houses as well as error in filling data. The Expansion Factor was used to amplify the survey data or sampled data in order to represent the total trips of the city. The past growth rate was calculated from the past available population of 2001 and 2018 in census. It was assumed that the population growth rate is same for the current decade from 2018 to 2028 and for the next five year till 2033. Now the population of 2028 was calculated using average growth factor method with GF of previous decade which comes out to be 1.262 and 1.124 for the year 2028 and 2033 respectively.

$$\textbf{Future Population} = \textbf{Present Population} \times [1+R]^n$$

Then by smoothing the prepared surveyed data to remove the errors and the simple linear regression is done to obtain the expansion factor and growth factor for trips. To bring the value of constants under limit certain correction are applied over the collected data. Suppose the area is highly commercial and the trips generated from this zone are in large amount when compared with the no. of household in that zone. It implies that the responses collected during the survey are either non-existing or not appropriate.



Linear regression is a statistical method that allows us to summarize and study relationships between two continuous (quantitative) variables. Here the variables are trips and population where, 'x' is the population and 'y' no. of trips. The equation is found using the data, observed population and observed no. of trips and that is obtained after smoothening. The future population is found out using above eq. and by putting the population the no. of trips for representative years are calculated and the growth factor between the decade is calculated. This process with the sampled data was performed to get the expansion factor as well as growth factor.

EXPANSION FACTOR	31.365713
GROWTH FACTOR 2018-2028	1.2614337
GROWTH FACTOR 2028-2033	1.1235816
GROWTH FACTOR 2033-2031	1.1078088

Realistic Route Choice Behaviour: Different vehicle type may have different infrastructure available, hence, the route choice set may be different across vehicle type, such that different vehicle type have to be consider explicitly.

Realistic traffic flow propagation: Since, traffic flow consists of different vehicle type that may have very different driving characteristics we distinguish passenger cars and trucks. Trucks impede car more than vice – versa, and trucks drive at a lower speed resulting in longer travel time.

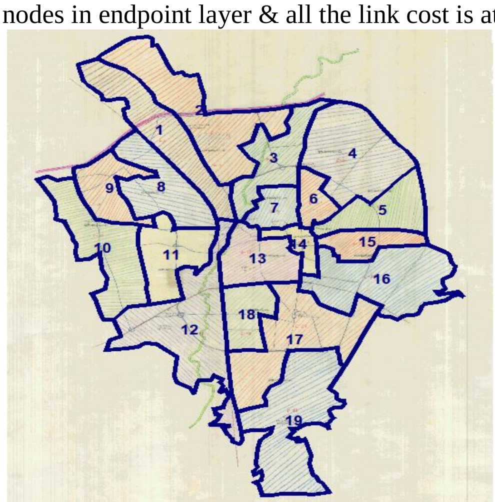
Although traffic assignment traditionally used link performance function to estimate travel time, dynamic traffic assignment uses more realistic microscopic flow models that include congestion propagation, queue spillback and shockwaves. More realistic flow models eliminate many of the nice mathematical properties of static traffic assignment.

SAMPLED		ACTUAL		ACTUAL 2028	
		Population GF = 0.024	Y=0.441x + 921.4	F=P*(1+r)^n	Y=0.441x + 921.4
Observed Population (X)	**Observed Trips (Y)**	**Actual Population (X)**	**Actual Trips (Y)**	**Future Population 2028**	**Future Trips 2028**
730	1243.516	95577	43090.0124	121158.2414	54376.45611
728	1242.6336	91381	41238.7372	115839.1795	52029.686
707	1233.3684	85290	38551.388	108117.9197	48623.06617
737	1246.6044	83022	37550.7464	105242.8881	47354.60224
823	1284.5476	92669	41807.0028	117471.9135	52750.04822
883	1311.0196	86383	39033.6196	109503.4618	49234.36735
879	1309.2548	85665	38716.838	108593.2887	48832.79896
718	1238.2216	86038	38881.4056	109066.1223	49041.41318
854	1298.2248	86517	39092.7404	109673.3270	49309.31186
731	1243.9572	94036	42410.1232	119204.7918	53514.59416
636	1202.0432	87740	39632.328	111223.6637	49993.32041
895	1316.314	82337	37248.5244	104374.5475	46971.49034
755	1254.546	80307	36352.8884	101801.2168	45836.13683
779	1265.1348	87286	39432.0232	110648.1503	49739.40391
752	1253.2224	82932	37511.0384	105128.7996	47304.26637
875	1307.49	86824	39228.1888	110062.4957	49481.01311
634	1201.1608	85211	38516.5332	108017.7753	48578.88246
727	1242.1924	95411	43016.7732	120947.8114	54283.6144
942	1337.0504	94065	42422.918	119241.5537	53530.8135
14785	24030.502	1668691	753733.8292	2115317.1477	950785.2856

4.1 Data Processing in TransCAD

Data are arranged in a tabular format, with rows and columns, and stored in geographic files, databases or spreadsheets. A special TransCAD data structure was created from a reference line layer and is used to analyze the way people and commodities flow from one location to another. Links are conduits that carry directional flow from node to node, every node and link in a network has an ID all the link attributes are mentioned above. TransCAD usually creates two network links for every line feature Line features is designated here as two-way. Network nodes and links contain costs and other attributes. The attributes are taken from the line and endpoint layers. TransCAD procedures require at least one attribute to be present in a network such as link cost, link travel time free flow, average speed, no. of lanes, etc.

The following fig. Shows the Area Layer with its centroids and the Network Geographic file is created which shows link in line layer and nodes in endpoint layer & all the link cost is attached to it & are further connected to respective centroids.

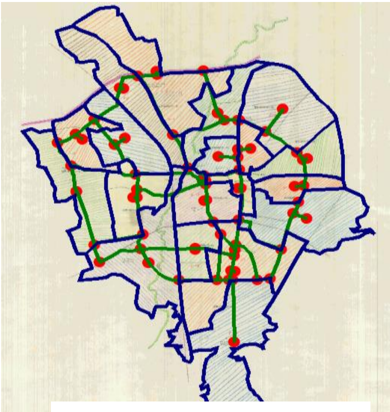


Area Layer Map view

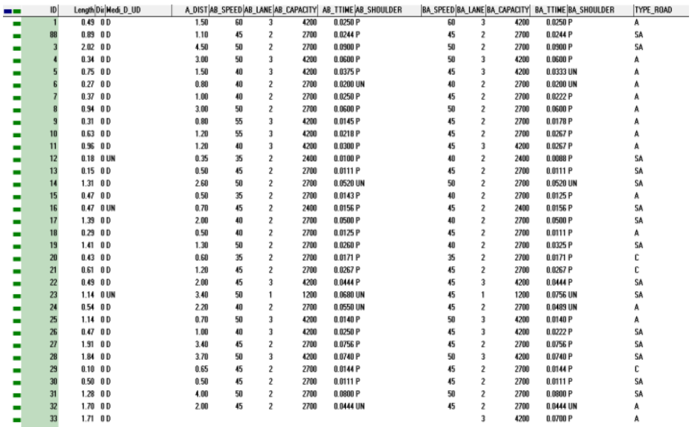
ID	Area	[WARD NO.]	POPULATION	[PER/HH]	[TRIP/HH]	[VEH/HH]
1	3.47	1.00	91381.00	3.26	2.08	2.63
2	4.65	2.00	95577.00	3.14	1.94	2.50
3	2.40	3.00	85290.00	3.17	2.20	2.47
5	2.15	5.00	92669.00	3.72	1.71	2.26
4	4.25	4.00	83022.00	3.67	2.75	2.27
6	0.91	6.00	86383.00	3.45	2.36	4.50
7	1.03	7.00	85655.00	3.61	2.13	2.25
8	2.82	8.00	86038.00	3.57	2.57	2.81
9	1.80	9.00	86517.00	4.07	2.19	2.60
10	3.45	10.00	94036.00	3.48	2.05	1.95
11	2.41	11.00	87740.00	3.11	1.87	2.14
12	5.28	12.00	82337.00	3.74	2.22	2.28
13	2.16	13.00	80307.00	3.75	2.21	2.11
14	0.73	14.00	87286.00	3.70	2.08	2.47
15	1.25	15.00	82932.00	3.58	2.21	2.92
16	4.35	16.00	86824.00	3.82	2.23	2.19
17	1.62	18.00	95411.00	3.11	1.55	2.45
18	4.55	17.00	85211.00	3.49	2.13	2.04
19	4.83	19.00	94065.00	3.75	2.07	2.19

Area Layer Dataview

In this study it is assumed that the traffic flow and the link attributes remain same for the next forecasted years. Only the O-D matrix, which is the basic input for this study is predicted for the next 10 years (2018-2028) and 5 years (2028-2033). The flow obtained with UE and SO methods in TransCAD is then compared with the present traffic count flow.



Line Layer Map view



Line Layer Dataview

The following are the trip O-D estimated by multiplying the present trip O-D with the calculated growth factor:

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	419.9919	76.3622	343.6297	38.1811	152.7243	38.1811	190.9054	279.9946	89.0892	139.9973	279.9946	76.3622	25.4541	50.9081	254.5405	63.6351	63.6351
2	292.7216	89.0892	419.9919	63.6351	76.3622	25.4541	178.1784	445.4459	89.0892	254.5405	229.0865	38.1811	76.3622	0.0000	203.6324	178.1784	394.5378
3	254.5405	0.0000	267.2676	190.9054	63.6351	0.0000	267.2676	712.7135	89.0892	25.4541	139.9973	25.4541	50.9081	165.4514	330.9027	152.7243	25.4541
4	152.7243	139.9973	152.7243	50.9081	305.4486	305.4486	114.5432	178.1784	318.1757	63.6351	50.9081	0.0000	0.0000	50.9081	38.1811	0.0000	114.5432
5	559.9892	0.0000	203.6324	165.4514	101.8162	12.7270	89.0892	496.3541	89.0892	63.6351	190.9054	38.1811	25.4541	305.4486	318.1757	63.6351	0.0000
6	432.7189	0.0000	216.3595	241.8135	25.4541	101.8162	178.1784	725.4405	50.9081	101.8162	114.5432	0.0000	101.8162	356.3568	165.4514	38.1811	12.7270
7	63.6351	101.8162	254.5405	63.6351	76.3622	229.0865	674.5324	330.9027	76.3622	127.2703	178.1784	25.4541	114.5432	254.5405	50.9081	0.0000	50.9081
8	101.8162	127.2703	38.1811	38.1811	12.7270	12.7270	76.3622	712.7135	407.2649	165.4514	152.7243	76.3622	38.1811	101.8162	89.0892	0.0000	127.2703
9	279.9946	38.1811	76.3622	50.9081	0.0000	63.6351	76.3622	534.5351	318.1757	267.2676	178.1784	101.8162	25.4541	25.4541	101.8162	12.7270	114.5432
10	127.2703	63.6351	25.4541	165.4514	50.9081	76.3622	101.8162	534.5351	101.8162	509.0811	279.9946	101.8162	63.6351	89.0892	0.0000	89.0892	139.9973
11	241.8135	50.9081	50.9081	178.1784	25.4541	38.1811	76.3622	216.3595	25.4541	203.6324	458.1730	203.6324	89.0892	178.1784	12.7270	76.3622	76.3622
12	229.0865	50.9081	241.8135	139.9973	0.0000	25.4541	445.4459	623.6243	76.3622	190.9054	534.5351	419.9919	38.1811	152.7243	190.9054	178.1784	203.6324
13	152.7243	0.0000	76.3622	38.1811	25.4541	0.0000	152.7243	369.0838	63.6351	63.6351	89.0892	76.3622	279.9946	89.0892	101.8162	76.3622	139.9973
14	190.9054	12.7270	229.0865	229.0865	12.7270	12.7270	483.6270	267.2676	76.3622	89.0892	89.0892	114.5432	139.9973	343.6297	89.0892	50.9081	139.9973
15	356.3568	12.7270	76.3622	114.5432	38.1811	12.7270	25.4541	419.9919	127.2703	394.5378	305.4486	0.0000	89.0892	178.1784	381.8108	25.4541	50.9081
16	101.8162	0.0000	458.1730	101.8162	0.0000	0.0000	572.7162	139.9973	76.3622	89.0892	25.4541	101.8162	76.3622	394.5378	76.3622	216.3595	63.6351
17	305.4486	559.9892	50.9081	165.4514	38.1811	38.1811	76.3622	241.8135	25.4541	190.9054	241.8135	165.4514	101.8162	139.9973	25.4541	50.9081	50.9081
18	178.1784	89.0892	89.0892	190.9054	101.8162	25.4541	76.3622	318.1757	101.8162	496.3541	305.4486	127.2703	101.8162	152.7243	25.4541	76.3622	50.9081
19	254.5405	0.0000	139.9973	76.3622	25.4541	25.4541	241.8135	623.6243	50.9081	229.0865	152.7243	25.4541	254.5405	101.8162	25.4541	152.7243	343.6297

O-D matrix for year 2028 trip

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	472.0709	85.8311	386.2398	42.9155	171.6621	42.9155	214.5777	314.7139	100.1362	157.3570	314.7139	85.8311	28.6104	57.2207	286.1036	71.5259	71.5259
2	329.0191	100.1362	472.0709	71.5259	85.8311	28.6104	200.2725	500.6812	100.1362	286.1036	257.4932	42.9155	85.8311	0.0000	228.8829	200.2725	443.4605
3	286.1036	0.0000	300.4087	214.5777	71.5259	0.0000	300.4087	801.0900	100.1362	28.6104	157.3570	28.6104	57.2207	185.9673	371.9346	171.6621	28.6104
4	171.6621	157.3570	171.6621	57.2207	343.3243	343.3243	128.7466	200.2725	357.6295	71.5259	57.2207	0.0000	0.0000	57.2207	42.9155	0.0000	128.7466
5	629.4278	0.0000	228.8829	185.9673	114.4414	14.3052	100.1362	557.9020	100.1362	71.5259	214.5777	42.9155	28.6104	343.3243	357.6295	71.5259	0.0000
6	486.3761	0.0000	243.1880	271.7984	28.6104	114.4414	200.2725	815.3952	57.2207	114.4414	128.7466	0.0000	114.4414	400.5450	185.9673	42.9155	14.3052
7	71.5259	114.4414	286.1036	71.5259	85.8311	257.4932	758.1744	371.9346	85.8311	143.0518	200.2725	28.6104	128.7466	286.1036	57.2207	0.0000	57.2207
8	114.4414	143.0518	42.9155	42.9155	14.3052	14.3052	85.8311	801.0900	457.7657	185.9673	171.6621	85.8311	42.9155	114.4414	100.1362	0.0000	143.0518
9	314.7139	42.9155	85.8311	57.2207	0.0000	71.5259	85.8311	600.8175	357.6295	300.4087	200.2725	114.4414	28.6104	28.6104	114.4414	14.3052	128.7466
10	143.0518	71.5259	28.6104	185.9673	57.2207	85.8311	114.4414	600.8175	114.4414	572.2071	314.7139	114.4414	71.5259	100.1362	0.0000	100.1362	157.3570
11	271.7984	57.2207	57.2207	200.2725	28.6104	42.9155	85.8311	243.1880	28.6104	228.8829	514.9864	228.8829	100.1362	200.2725	14.3052	85.8311	85.8311
12	257.4932	57.2207	271.7984	157.3570	0.0000	28.6104	500.6812	700.9537	85.8311	214.5777	600.8175	472.0709	42.9155	171.6621	214.5777	200.2725	228.8829
13	171.6621	0.0000	85.8311	42.9155	28.6104	0.0000	171.6621	414.8502	71.5259	71.5259	100.1362	85.8311	314.7139	100.1362	114.4414	85.8311	157.3570
14	214.5777	14.3052	257.4932	257.4932	14.3052	14.3052	543.5968	300.4087	85.8311	100.1362	100.1362	128.7466	157.3570	386.2398	100.1362	57.2207	157.3570
15	400.5450	14.3052	85.8311	128.7466	42.9155	14.3052	28.6104	472.0709	143.0518	443.4605	343.3243	0.0000	100.1362	200.2725	429.1553	28.6104	57.2207
16	114.4414	0.0000	514.9864	114.4414	0.0000	0.0000	643.7330	157.3570	85.8311	100.1362	28.6104	114.4414	85.8311	443.4605	85.8311	243.1880	71.5259
17	343.3243	629.4278	57.2207	185.9673	42.9155	42.9155	85.8311	271.7984	28.6104	214.5777	271.7984	185.9673	114.4414	157.3570	28.6104	57.2207	57.2207
18	200.2725	100.1362	100.1362	214.5777	114.4414	28.6104	85.8311	357.6295	114.4414	557.9020	343.3243	143.0518	114.4414	171.6621	28.6104	85.8311	57.2207
19	286.1036	0.0000	157.3570	85.8311	28.6104	28.6104	271.7984	700.9537	57.2207	257.4932	171.6621	28.6104	286.1036	114.4414	28.6104	171.6621	386.2398

O-D matrix for year 2033 trip

4.2 Users Equilibrium

The UE assignment assigns trips to the network in a way that no individual can unilaterally reduce their travel time by selecting an alternative route. This is the most commonly used algorithm in the transportation planning industry and transportation research. This method assumes that user choose the route that minimise their individual travel time. If the user found any faster route, then it will be a relatively realistic approach.

It is also an iterative method and the assignment takes place upto convergence is obtained or a maximum number of iteration has been done. Here, in this study the convergence criteria was 0.01 and the maximum number of iteration was 20 as an input. These are the inputs which should set by the planner. The more stringent the convergence criteria, the more iteration required to complete the assignment. Here are some iteration which transCAD had performed for the present as well as future year assignment process.

For 2018

Iteration	Step	Relative Gap	Max. Flow Change	RMSE	%RMSE
1	0.213439	0.037855	762.152503	234.90	21.11
2	0.584991	0.006716	1089.576372	255.84	22.99

For2028

Iteration	Step	Relative Gap	Max. Flow Change	RMSE	%RMSE
1	0.214413	0.130529	1227.980581	393.58	28.27
2	0.161411	0.037267	477.650299	149.96	10.76
3	0.417000	0.015009	586.049387	209.72	15.07
4	0.166839	0.022699	352.474240	124.47	9.09
5	0.408361	0.007145	592.403389	165.43	12.03

For2033

Iteration	Step	Relative Gap	Max. Flow Change	RMSE	%RMSE
1	0.230326	0.057043	837.4936	261.01	16.41
2	0.288705	0.031912	585.4121	197.98	12.50
3	0.127629	0.039114	440.4461	126.88	8.07
4	0.491557	0.012150	712.0042	223.08	14.22
5	0.199864	0.012486	402.3423	96.52	6.25
6	0.104142	0.011912	184.4077	66.56	4.33
7	0.237268	0.006642	256.5814	100.59	6.53

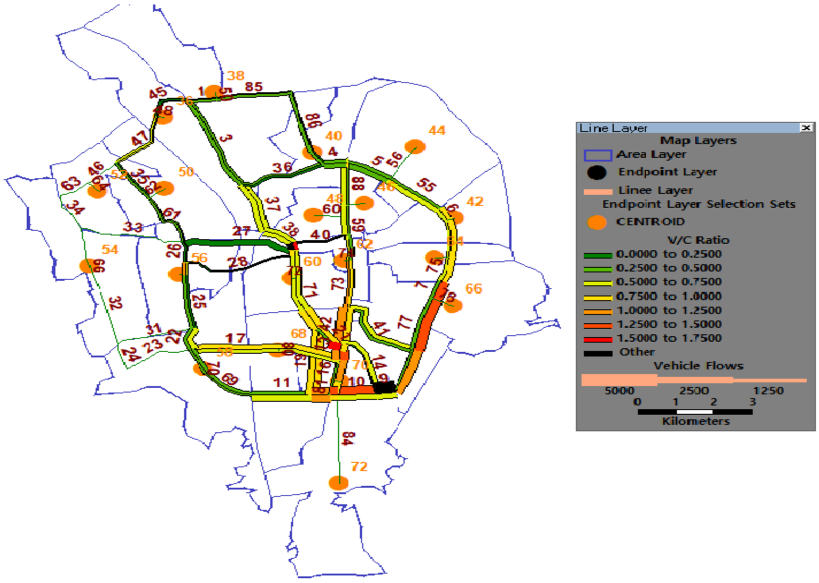
RELATIVE GAP is the *total gap*, which measures how far the current assignment solution is from the ideal shortest route time. Since the travel-time on all used routes will always be greater than or equal to the shortest route, the value of relative gap will never be negative. In most of the applications, the solution is assumed to have converged to an equilibrium solution when the relative gap is less than a pre-specified tolerance level. Convergence occurs through an iterative process consisting of three sequential steps: Network Loading, Path Set Updating, and Path Assignment Adjusting. At each iteration, vehicles are dynamically loaded onto the network based on the path assignment, and new travel times are recorded. These new travel times are used to calculate the new shortest paths for each O-D pair and departure interval. Then, depending on the algorithm, a percentage of trips between each O-D pair and departure interval is assigned to different paths from those they used on the previous iteration, generally moving from higher cost paths to lower cost paths. The process repeats until the convergence criterion such as Relative Gap is met.

VMT give the total travel demand for the whole network system. The demand generally increases when the VMT increases. It is derived by multiplying the number of vehicle travelling over a link with the length of the link, summed over all links. VMT can be influenced by the change in the number of vehicle and change in the trip length at the time of simulation. Here the VMT unit is in KM.

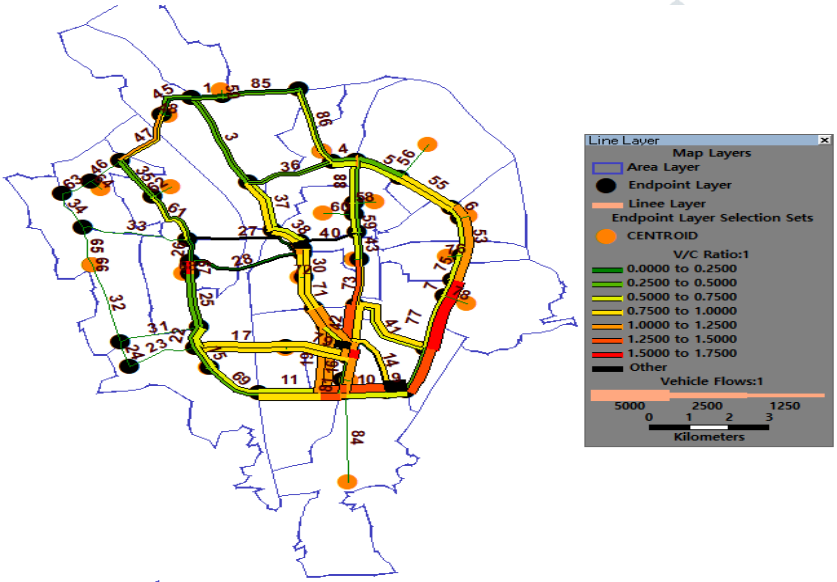
VHT gives an estimation of the amount of time expended travelling on the system. Lower VHT value indicted that the performance of network system is improved and reduction in travelling cost of the users. It is derived by the link volume with the links travel time, summed over all links. VHT can be influenced by change in demand (the number of vehicle) and change in congestion (travel time). Here the VHT unit is in Hr.

Results	2018	2028	2033
Relative Gap	0.01	0.01	0.01
RMSE	255.84	156.43	100.59
% RMSE	22.991	12.03	6.53
Max Flow Change	1089.58	592.40.58	256.58
Equilibrium reached	YES	YES	YES
Total V-Time-T/VHT	6301.49	8767.56	10888.53
Total V-Dist-T/VMT	120189.50	152900.68	172546.66

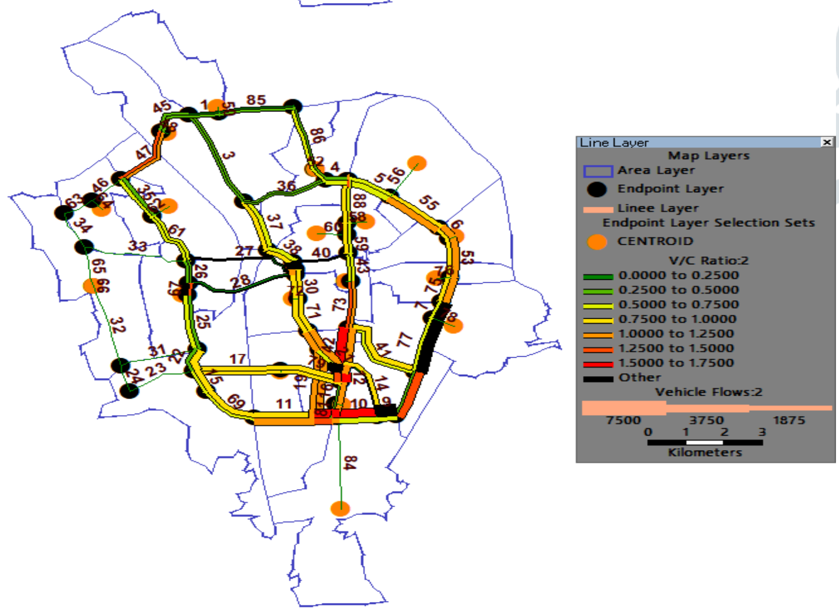
The relationship between the fundamental variables of traffic flow, namely speed, volume, and density is called the fundamental relations of traffic flow. The flow map is generated using transCAD which shows the flow on the network with respect to V/C ratio of each link. We can predict the future flow over the link and the decision can be made to increase the performance and various user facilities. Following fig. shows the flow over the network using user equilibrium assignment method.



Base year (2018) condition using User Equilibrium assignment method



Condition in 2028 after 10 years using User Equilibrium assignment method



Condition in 2033 after 15 years using User Equilibrium assignment method

Following are the critical matrix generated using system optimum assignment method.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	--	--	274.68	30.52	122.08	30.52	152.60	223.81	71.21	111.91	223.81	61.04	20.35	40.69	203.47	50.87	50.87	152.60	274.68
2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
3	203.47	--	--	152.60	50.87	--	213.64	569.70	71.21	20.35	111.91	20.35	40.69	132.25	264.51	122.08	20.35	122.08	40.69
4	122.08	--	122.08	--	244.16	244.16	91.56	142.43	254.33	50.87	40.69	--	--	40.69	30.52	--	91.56	--	30.52
5	447.62	--	162.77	132.25	--	10.17	71.21	396.76	71.21	50.87	152.60	30.52	20.35	244.16	254.33	50.87	--	20.35	30.52
6	345.89	--	172.95	193.29	20.35	--	142.43	579.88	40.69	81.39	91.56	--	81.39	284.85	132.25	30.52	10.17	30.52	--
7	50.87	--	203.47	50.87	61.04	183.12	--	264.51	61.04	101.73	142.43	20.35	91.56	203.47	40.69	--	40.69	20.35	20.35
8	81.39	--	30.52	30.52	10.17	10.17	61.04	--	325.54	132.25	122.08	61.04	30.52	81.39	71.21	--	101.73	30.52	--
9	223.81	--	61.04	40.69	--	50.87	61.04	427.28	--	213.64	142.43	81.39	20.35	20.35	81.39	10.17	91.56	--	40.69
10	101.73	--	20.35	132.25	40.69	61.04	81.39	427.28	81.39	--	223.81	81.39	50.87	71.21	--	71.21	111.91	10.17	--
11	193.29	--	40.69	142.43	20.35	30.52	61.04	172.95	20.35	162.77	--	162.77	71.21	142.43	10.17	61.04	61.04	10.17	20.35
12	183.12	--	193.29	111.91	--	20.35	356.06	498.49	61.04	152.60	427.28	--	30.52	122.08	152.60	142.43	162.77	40.69	61.04
13	122.08	--	61.04	30.52	20.35	--	122.08	295.03	50.87	50.87	71.21	61.04	--	71.21	81.39	61.04	111.91	61.04	--
14	152.60	--	183.12	183.12	10.17	10.17	386.58	213.64	61.04	71.21	71.21	91.56	111.91	--	71.21	40.69	111.91	40.69	--
15	284.85	--	61.04	91.56	30.52	10.17	20.35	335.72	101.73	315.37	244.16	--	71.21	142.43	--	20.35	40.69	162.77	132.25
16	81.39	--	366.24	81.39	--	--	457.80	111.91	61.04	71.21	20.35	81.39	61.04	315.37	61.04	--	50.87	61.04	--
17	244.16	--	40.69	132.25	30.52	30.52	61.04	193.29	20.35	152.60	193.29	132.25	81.39	111.91	20.35	40.69	--	20.35	20.35
18	142.43	--	71.21	152.60	81.39	20.35	61.04	254.33	81.39	396.76	244.16	101.73	81.39	122.08	20.35	61.04	40.69	--	20.35
19	203.47	--	111.91	61.04	20.35	20.35	193.29	498.49	40.69	183.12	122.08	20.35	203.47	81.39	20.35	122.08	274.68	111.91	--

Critical matrix showing present zone to zone critical flow for the year 2018 (UE)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	--	--	343.63	38.18	152.72	38.18	190.91	279.99	89.09	140.00	279.99	76.36	25.45	50.91	254.54	63.64	63.64	190.91	343.63
2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
3	254.54	--	--	190.91	63.64	--	267.27	712.71	89.09	25.45	140.00	25.45	50.91	165.45	330.90	152.72	25.45	152.72	50.91
4	152.72	--	152.72	--	305.45	305.45	114.54	178.18	318.18	63.64	50.91	--	--	50.91	38.18	--	114.54	--	38.18
5	559.99	--	203.63	165.45	--	12.73	89.09	496.35	89.09	63.64	190.91	38.18	25.45	305.45	318.18	63.64	--	25.45	38.18
6	432.72	--	216.36	241.81	25.45	--	178.18	725.44	50.91	101.82	114.54	--	101.82	356.36	165.45	38.18	12.73	38.18	--
7	63.64	--	254.54	63.64	76.36	229.09	--	330.90	76.36	127.27	178.18	25.45	114.54	254.54	50.91	--	50.91	25.45	25.45
8	101.82	--	38.18	38.18	12.73	12.73	76.36	--	407.26	165.45	152.72	76.36	38.18	101.82	89.09	--	127.27	38.18	--
9	279.99	--	76.36	50.91	--	63.64	76.36	534.54	--	267.27	178.18	101.82	25.45	25.45	101.82	12.73	114.54	--	50.91
10	127.27	--	25.45	165.45	50.91	76.36	101.82	534.54	101.82	--	279.99	101.82	63.64	89.09	--	89.09	140.00	12.73	--
11	241.81	--	50.91	178.18	25.45	38.18	76.36	216.36	25.45	203.63	--	203.63	89.09	178.18	12.73	76.36	76.36	12.73	25.45
12	229.09	--	241.81	140.00	--	25.45	445.45	623.62	76.36	190.91	534.54	--	38.18	152.72	190.91	178.18	203.63	50.91	76.36
13	152.72	--	76.36	38.18	25.45	--	152.72	369.08	63.64	63.64	89.09	76.36	--	89.09	101.82	76.36	140.00	76.36	--
14	190.91	--	229.09	229.09	12.73	12.73	483.63	267.27	76.36	89.09	89.09	114.54	140.00	--	89.09	50.91	140.00	50.91	--
15	356.36	--	76.36	114.54	38.18	12.73	25.45	419.99	127.27	394.54	305.45	--	89.09	178.18	--	25.45	50.91	203.63	165.45
16	101.82	--	458.17	101.82	--	--	572.72	140.00	76.36	89.09	25.45	101.82	76.36	394.54	76.36	--	63.64	76.36	--
17	305.45	--	50.91	165.45	38.18	38.18	76.36	241.81	25.45	190.91	241.81	165.45	101.82	140.00	25.45	50.91	--	25.45	25.45
18	178.18	--	89.09	190.91	101.82	25.45	76.36	318.18	101.82	496.35	305.45	127.27	101.82	152.72	25.45	76.36	50.91	--	25.45
19	254.54	--	140.00	76.36	25.45	25.45	241.81	623.62	50.91	229.09	152.72	25.45	254.54	101.82	25.45	152.72	343.63	140.00	--

Critical matrix showing zone to zone critical flow for the year 2028(UE)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	--	--	386.24	42.92	171.66	42.92	214.58	314.71	100.14	157.36	314.71	85.83	28.61	57.22	286.10	71.53	71.53	214.58	386.24
2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
3	286.10	--	--	214.58	71.53	--	300.41	801.09	100.14	28.61	157.36	28.61	57.22	185.97	371.93	171.66	28.61	171.66	57.22
4	171.66	--	171.66	--	343.32	343.32	128.75	200.27	357.63	71.53	57.22	--	--	57.22	42.92	--	128.75	--	42.92
5	629.43	--	228.88	185.97	--	14.31	100.14	557.90	100.14	71.53	214.58	42.92	28.61	343.32	357.63	71.53	--	28.61	42.92
6	486.38	--	243.19	271.80	28.61	--	200.27	815.40	57.22	114.44	128.75	--	114.44	400.54	185.97	42.92	14.31	42.92	--
7	71.53	--	286.10	71.53	85.83	257.49	--	371.93	85.83	143.05	200.27	28.61	128.75	286.10	57.22	--	57.22	28.61	28.61
8	114.44	--	42.92	42.92	14.31	14.31	85.83	--	457.77	185.97	171.66	85.83	42.92	114.44	100.14	--	143.05	42.92	--
9	314.71	--	85.83	57.22	--	71.53	85.83	600.82	--	300.41	200.27	114.44	28.61	28.61	114.44	14.31	128.75	--	57.22
10	143.05	--	28.61	185.97	57.22	85.83	114.44	600.82	114.44	--	314.71	114.44	71.53	100.14	--	100.14	157.36	14.31	--
11	271.80	--	57.22	200.27	28.61	42.92	85.83	243.19	28.61	228.88	--	228.88	100.14	200.27	14.31	85.83	85.83	14.31	28.61
12	257.49	--	271.80	157.36	--	28.61	500.68	700.95	85.83	214.58	600.82	--	42.92	171.66	214.58	200.27	228.88	57.22	85.83
13	171.66	--	85.83	42.92	28.61	--	171.66	414.85	71.53	71.53	100.14	85.83	--	100.14	114.44	85.83	157.36	85.83	--
14	214.58	--	257.49	257.49	14.31	14.31	543.60	300.41	85.83	100.14	100.14	128.75	157.36	--	100.14	57.22	157.36	57.22	--
15	400.54	--	85.83	128.75	42.92	14.31	28.61	472.07	143.05	443.46	343.32	--	100.14	200.27	--	28.61	57.22	228.88	185.97
16	114.44	--	514.99	114.44	--	--	643.73	157.36	85.83	100.14	28.61	114.44	85.83	443.46	85.83	--	71.53	85.83	--
17	343.32	--	57.22	185.97	42.92	42.92	85.83	271.80	28.61	214.58	271.80	185.97	114.44	157.36	28.61	57.22	--	28.61	28.61
18	200.27	--	100.14	214.58	114.44	28.61	85.83	357.63	114.44	557.90	343.32	143.05	114.44	171.66	28.61	85.83	57.22	--	28.61
19	286.10	--	157.36	85.83	28.61	28.61	271.80	700.95	57.22	257.49	171.66	28.61	286.10	114.44	28.61	171.66	386.24	157.36	--

Critical matrix showing zone to zone critical flow for the year 2033(UE)

4.3 System Optimum

The system optimum assignment assigns trips in a way that the total travel time for all the users in the network is minimised. This method does not involve the travel time of an individual as in the UE assignment instead only the total travel time. It is assumed here that individual user can choose alternative route to minimise their own travel time but only at the cost of increasing in travel time of the other users as well of the total system by a greater amount.This assignment gives a solution where congestion is minimised. It can be thought of as a model in which congestion is minimized when drivers are told which routes to use. Obviously, this is not a behaviourally realistic model, but it can be useful to transport planners and engineers, trying to manage the traffic to minimize travel costs and therefore achieve an optimum social equilibrium.

For 2018

Iteration	Relative Gap	Max. Flow Change
1	0.029954	1366.477782
2	0.015260	410.887661
3	0.007199	318.423534

For 2028

Iteration	Relative Gap	Max. Flow Change
1	0.120185	1633.245311
2	0.042519	779.268248
3	0.016307	914.550867
4	0.023137	417.216426
5	0.011534	180.673258
6	0.008537	222.380736

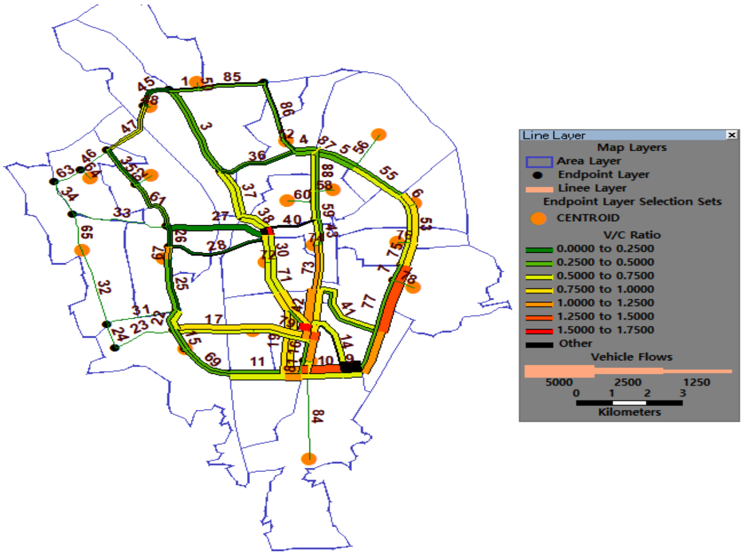
For 2033

Iteration	Relative Gap	Max. Flow Change
1	0.016619	10..904317
2	0.016246	0.004277
3	0.016244	0.004277
10	0.016246	0.004277

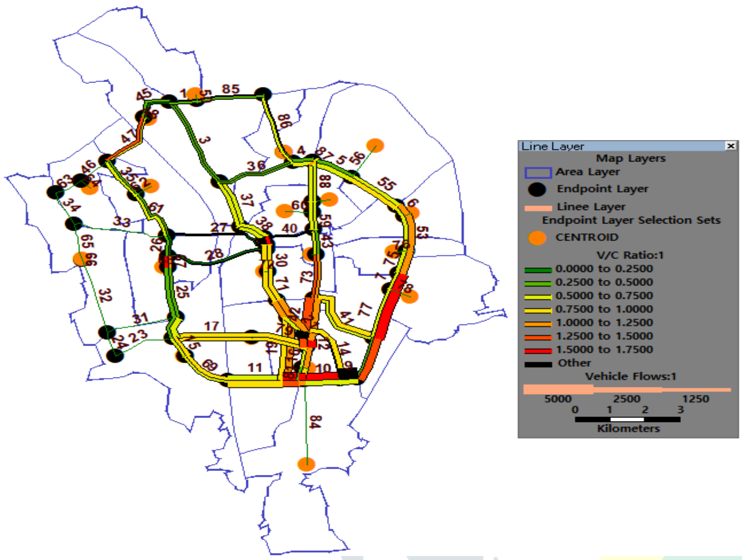
While this may appear to be a very attractive assignment method, it requires that people be told what route to travel along and that they, indeed, follow that route. However, the dominant tendency is for the travellers to minimize their own travel time which negates much of the predictive power of this assignment method.

Results	**2018**	**2028**	**2033**
Relative Gap	0.00	0.00	0.00
RMSE	69.31	73.01	0.00
% RMSE	6.26	5.30	0.00
Max Flow Change	318.42	222.38	11047.70
Equilibrium reached	YES	YES	NO
Total V-Time-T	6203.69	8828.44	174642.84
Total V-Dist-T	120879.95	153257.13	0.00

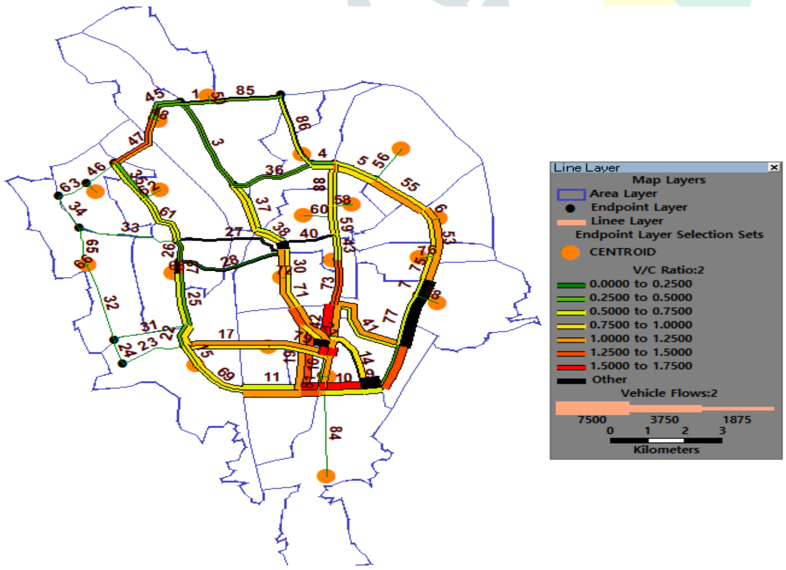
Following fig. shows the flow over the network using system optimum assignment method. Speed, flow and density are the basic parameters of traffic flow. Different measures of speed are used in traffic flow analysis like spot speed, time mean speed, space mean speed etc. Time-space diagram also can be used for determining these parameters. Speed and flow of the traffic stream can be computed using moving observer method.



Base year (2018) condition using System Optimum assignment method



Condition in 2028 after 10 years using System Optimum assignment method



Condition in 2033 after 15 years using System Optimum assignment method

Following are the critical matrix generated using system optimum assignment method.

(Modi, Zala, Umrigar, & Desai, 2011)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	--	--	274.68	30.52	122.08	30.52	152.60	223.81	71.21	111.91	223.81	61.04	20.35	40.69	203.47	50.87	50.87	152.60	274.68
2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
3	203.47	--	--	152.60	50.87	--	213.64	569.70	71.21	20.35	111.91	20.35	40.69	132.25	264.51	122.08	20.35	122.08	40.69
4	122.08	--	122.08	--	244.16	244.16	91.56	142.43	254.33	50.87	40.69	--	--	40.69	30.52	--	91.56	--	30.52
5	447.62	--	162.77	132.25	--	10.17	71.21	396.76	71.21	50.87	152.60	30.52	20.35	244.16	254.33	50.87	--	20.35	30.52
6	345.89	--	172.95	193.29	20.35	--	142.43	579.88	40.69	81.39	91.56	--	81.39	284.85	132.25	30.52	10.17	30.52	--
7	50.87	--	203.47	50.87	61.04	183.12	--	264.51	61.04	101.73	142.43	20.35	91.56	203.47	40.69	--	40.69	20.35	20.35
8	81.39	--	30.52	30.52	10.17	10.17	61.04	--	325.54	132.25	122.08	61.04	30.52	81.39	71.21	--	101.73	30.52	--
9	223.81	--	61.04	40.69	--	50.87	61.04	427.28	--	213.64	142.43	81.39	20.35	20.35	81.39	10.17	91.56	--	40.69
10	101.73	--	20.35	132.25	40.69	61.04	81.39	427.28	81.39	--	223.81	81.39	50.87	71.21	--	71.21	111.91	10.17	--
11	193.29	--	40.69	142.43	20.35	30.52	61.04	172.95	20.35	162.77	--	162.77	71.21	142.43	10.17	61.04	61.04	10.17	20.35
12	183.12	--	193.29	111.91	--	20.35	356.06	498.49	61.04	152.60	427.28	--	30.52	122.08	152.60	142.43	162.77	40.69	61.04
13	122.08	--	61.04	30.52	20.35	--	122.08	295.03	50.87	50.87	71.21	61.04	--	71.21	81.39	61.04	111.91	61.04	--
14	152.60	--	183.12	183.12	10.17	10.17	386.58	213.64	61.04	71.21	71.21	91.56	111.91	--	71.21	40.69	111.91	40.69	--
15	284.85	--	61.04	91.56	30.52	10.17	20.35	335.72	101.73	315.37	244.16	--	71.21	142.43	--	20.35	40.69	162.77	132.25
16	81.39	--	366.24	81.39	--	--	457.80	111.91	61.04	71.21	20.35	81.39	61.04	315.37	61.04	--	50.87	61.04	--
17	244.16	--	40.69	132.25	30.52	30.52	61.04	193.29	20.35	152.60	193.29	132.25	81.39	111.91	20.35	40.69	--	20.35	20.35
18	142.43	--	71.21	152.60	81.39	20.35	61.04	254.33	81.39	396.76	244.16	101.73	81.39	122.08	20.35	61.04	40.69	--	20.35
19	203.47	--	111.91	61.04	20.35	20.35	193.29	498.49	40.69	183.12	122.08	20.35	203.47	81.39	20.35	122.08	274.68	111.91	--

Critical matrix showing present zone to zone critical flow for the year 2018 (SO)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	--	--	343.63	38.18	152.72	38.18	190.91	279.99	89.09	140.00	279.99	76.36	25.45	50.91	254.54	63.64	63.64	190.91	343.63
2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
3	254.54	--	--	190.91	63.64	--	267.27	712.71	89.09	25.45	140.00	25.45	50.91	165.45	330.90	152.72	25.45	152.72	50.91
4	152.72	--	152.72	--	305.45	305.45	114.54	178.18	318.18	63.64	50.91	--	--	50.91	38.18	--	114.54	--	38.18
5	559.99	--	203.63	165.45	--	12.73	89.09	496.35	89.09	63.64	190.91	38.18	25.45	305.45	318.18	63.64	--	25.45	38.18
6	432.72	--	216.36	241.81	25.45	--	178.18	725.44	50.91	101.82	114.54	--	101.82	356.36	165.45	38.18	12.73	38.18	--
7	63.64	--	254.54	63.64	76.36	229.09	--	330.90	76.36	127.27	178.18	25.45	114.54	254.54	50.91	--	50.91	25.45	25.45
8	101.82	--	38.18	38.18	12.73	12.73	76.36	--	407.26	165.45	152.72	76.36	38.18	101.82	89.09	--	127.27	38.18	--
9	279.99	--	76.36	50.91	--	63.64	76.36	534.54	--	267.27	178.18	101.82	25.45	25.45	101.82	12.73	114.54	--	50.91
10	127.27	--	25.45	165.45	50.91	76.36	101.82	534.54	101.82	--	279.99	101.82	63.64	89.09	--	89.09	140.00	12.73	--
11	241.81	--	50.91	178.18	25.45	38.18	76.36	216.36	25.45	203.63	--	203.63	89.09	178.18	12.73	76.36	76.36	12.73	25.45
12	229.09	--	241.81	140.00	--	25.45	445.45	623.62	76.36	190.91	534.54	--	38.18	152.72	190.91	178.18	203.63	50.91	76.36
13	152.72	--	76.36	38.18	25.45	--	152.72	369.08	63.64	63.64	89.09	76.36	--	89.09	101.82	76.36	140.00	76.36	--
14	190.91	--	229.09	229.09	12.73	12.73	483.63	267.27	76.36	89.09	89.09	114.54	140.00	--	89.09	50.91	140.00	50.91	--
15	356.36	--	76.36	114.54	38.18	12.73	25.45	419.99	127.27	394.54	305.45	--	89.09	178.18	--	25.45	50.91	203.63	165.45
16	101.82	--	458.17	101.82	--	--	572.72	140.00	76.36	89.09	25.45	101.82	76.36	394.54	76.36	--	63.64	76.36	--
17	305.45	--	50.91	165.45	38.18	38.18	76.36	241.81	25.45	190.91	241.81	165.45	101.82	140.00	25.45	50.91	--	25.45	25.45
18	178.18	--	89.09	190.91	101.82	25.45	76.36	318.18	101.82	496.35	305.45	127.27	101.82	152.72	25.45	76.36	50.91	--	25.45
19	254.54	--	140.00	76.36	25.45	25.45	241.81	623.62	50.91	229.09	152.72	25.45	254.54	101.82	25.45	152.72	343.63	140.00	--

Critical matrix showing present zone to zone critical flow for the year 2028 (SO)

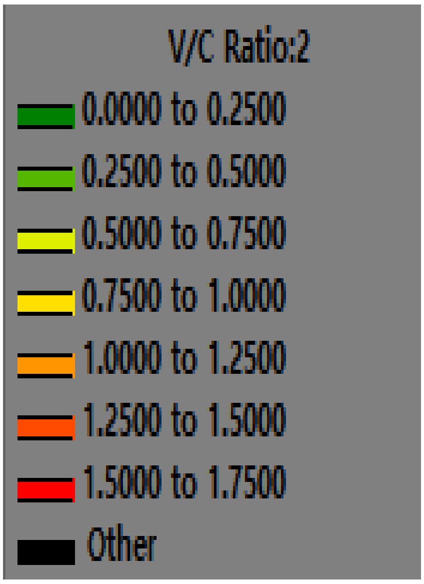
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	--	--	386.24	42.92	171.66	42.92	214.58	314.71	100.14	157.36	314.71	85.83	28.61	57.22	286.10	71.53	71.53	214.58	386.24
2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
3	286.10	--	--	214.58	71.53	--	300.41	801.09	100.14	28.61	157.36	28.61	57.22	185.97	371.93	171.66	28.61	171.66	57.22
4	171.66	--	171.66	--	343.32	343.32	128.75	200.27	357.63	71.53	57.22	--	--	57.22	42.92	--	128.75	--	42.92
5	629.43	--	228.88	185.97	--	14.31	100.14	557.90	100.14	71.53	214.58	42.92	28.61	343.32	357.63	71.53	--	28.61	42.92
6	486.38	--	243.19	271.80	28.61	--	200.27	815.40	57.22	114.44	128.75	--	114.44	400.54	185.97	42.92	14.31	42.92	--
7	71.53	--	286.10	71.53	85.83	257.49	--	371.93	85.83	143.05	200.27	28.61	128.75	286.10	57.22	--	57.22	28.61	28.61
8	114.44	--	42.92	42.92	14.31	14.31	85.83	--	457.77	185.97	171.66	85.83	42.92	114.44	100.14	--	143.05	42.92	--
9	314.71	--	85.83	57.22	--	71.53	85.83	600.82	--	300.41	200.27	114.44	28.61	28.61	114.44	14.31	128.75	--	57.22
10	143.05	--	28.61	185.97	57.22	85.83	114.44	600.82	114.44	--	314.71	114.44	71.53	100.14	--	100.14	157.36	14.31	--
11	271.80	--	57.22	200.27	28.61	42.92	85.83	243.19	28.61	228.88	--	228.88	100.14	200.27	14.31	85.83	85.83	14.31	28.61
12	257.49	--	271.80	157.36	--	28.61	500.68	700.95	85.83	214.58	600.82	--	42.92	171.66	214.58	200.27	228.88	57.22	85.83
13	171.66	--	85.83	42.92	28.61	--	171.66	414.85	71.53	71.53	100.14	85.83	--	100.14	114.44	85.83	157.36	85.83	--
14	214.58	--	257.49	257.49	14.31	14.31	543.60	300.41	85.83	100.14	100.14	128.75	157.36	--	100.14	57.22	157.36	57.22	--
15	400.54	--	85.83	128.75	42.92	14.31	28.61	472.07	143.05	443.46	343.32	--	100.14	200.27	--	28.61	57.22	228.88	185.97
16	114.44	--	514.99	114.44	--	--	643.73	157.36	85.83	100.14	28.61	114.44	85.83	443.46	85.83	--	71.53	85.83	--
17	343.32	--	57.22	185.97	42.92	42.92	85.83	271.80	28.61	214.58	271.80	185.97	114.44	157.36	28.61	57.22	--	28.61	28.61
18	200.27	--	100.14	214.58	114.44	28.61	85.83	357.63	114.44	557.90	343.32	143.05	114.44	171.66	28.61	85.83	57.22	--	28.61
19	286.10	--	157.36	85.83	28.61	28.61	271.80	700.95	57.22	257.49	171.66	28.61	286.10	114.44	28.61	171.66	386.24	157.36	--

Critical matrix showing present zone to zone critical flow for the year 2033 (SO)

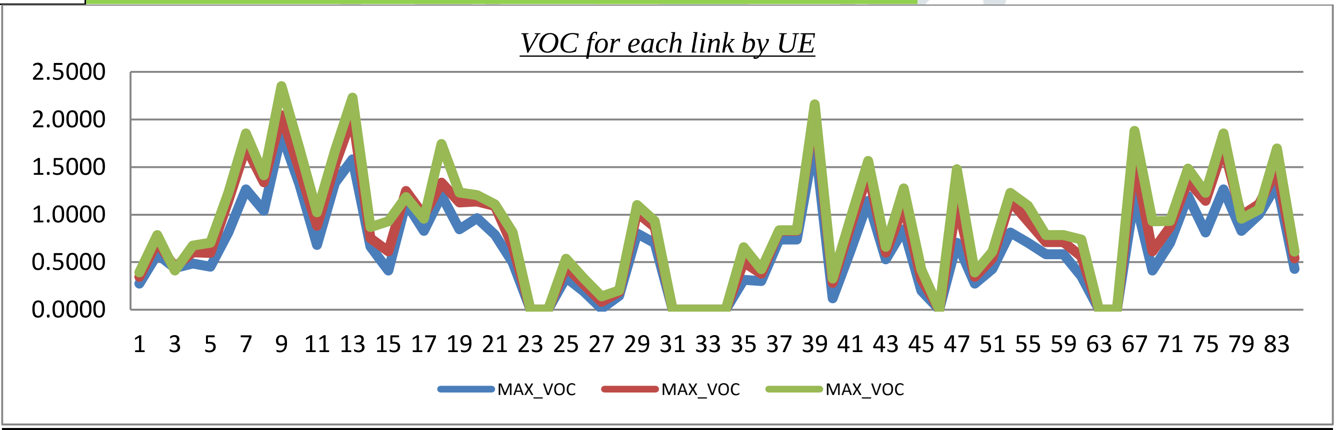
V. RESULTS & RECOMMENDATIONS

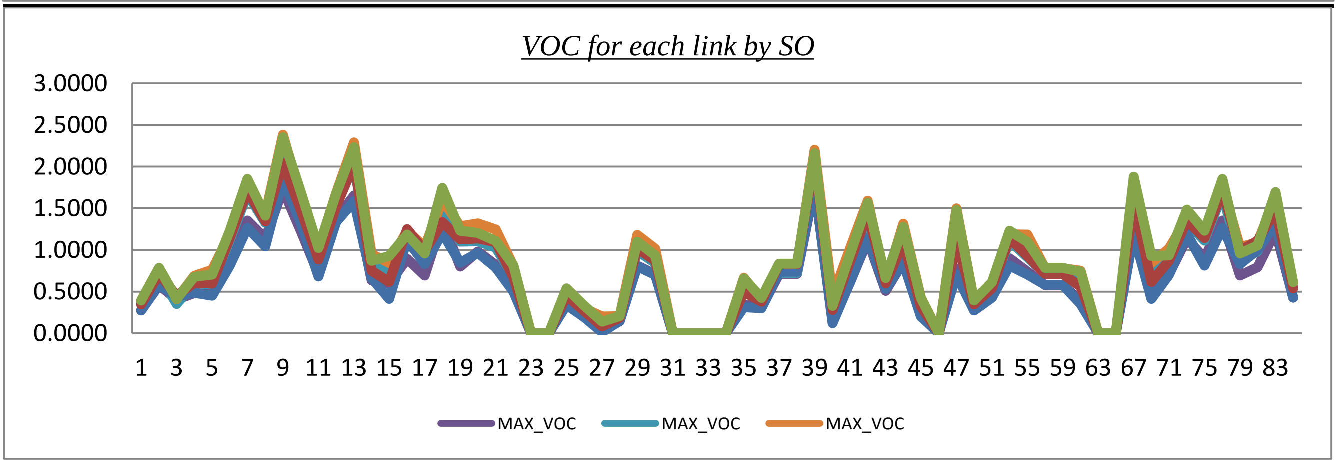
Following are the output of flow using user equilibrium and system optimum assignment method which shows that the specific KM for network need to be taken in observation so as to avoid congestion and make some user benefited decision. Using UE its says that 6.45Km of network will increase its V/C ratio by 1 for the base year condition 2018 and 12.85km and 19.55km in the year 2028 and 2033 respectively. On the other hand using SO it says gives that 3.55km, 16.35km and 22.9km will cross the V/C ratio by 1 in the present and future computed years respectively. There is also an Vehicle Operating Graph which shows the VOC increases as the years passes. The amount of VOC increases can be represented on graph for UE as well as for SO and in shown in below fig.

Link ID	UE			SO		
	2018 v/c	2028 v/c	2033 v/c	2018 v/c	2028 v/c	2033 v/c
1	0.19	0.26	0.29	0.19	0.25	0.29
88	0.54	0.60	0.70	0.47	0.62	0.73
3	0.41	0.41	0.36	0.37	0.35	0.37
4	0.42	0.52	0.58	0.40	0.52	0.58
5	0.38	0.55	0.62	0.43	0.53	0.65
6	0.67	0.90	1.00	0.71	0.88	1.00
7	0.84	1.12	1.23	0.88	1.10	1.20
8	0.71	0.84	0.92	0.75	0.86	0.91
9	1.07	1.19	1.33	1.01	1.25	1.37
10	0.88	0.99	1.11	0.84	1.02	1.09
11	0.55	0.73	0.91	0.62	0.80	0.88
12	1.20	1.37	1.53	1.28	1.43	1.61
13	1.20	1.55	1.73	1.23	1.55	1.75
14	0.39	0.45	0.52	0.37	0.50	0.58
15	0.39	0.56	0.77	0.50	0.65	0.72
16	0.77	0.85	0.84	0.65	0.81	0.89
17	0.74	0.89	0.91	0.66	0.83	0.94
18	1.18	1.31	1.58	1.26	1.41	1.47
19	0.80	1.10	1.15	0.76	1.01	1.20
20	0.93	1.13	1.19	0.95	1.10	1.28
21	0.60	0.87	0.92	0.63	0.86	1.09
22	0.38	0.51	0.62	0.39	0.53	0.60
23	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00
25	0.27	0.38	0.47	0.29	0.39	0.45
26	0.17	0.25	0.32	0.19	0.27	0.30
27	0.01	0.04	0.08	0.02	0.08	0.12
28	0.10	0.13	0.15	0.10	0.13	0.15
29	0.74	0.91	0.96	0.75	0.87	1.02
30	0.69	0.84	0.88	0.70	0.81	0.94
31	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00
33	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00
35	0.27	0.43	0.58	0.31	0.49	0.58
36	0.27	0.37	0.41	0.30	0.35	0.40
37	0.68	0.78	0.77	0.67	0.70	0.77



38	0.68	0.78	0.77	0.67	0.70	0.77
39	1.65	1.95	1.97	1.65	1.78	2.02
40	0.12	0.23	0.29	0.14	0.22	0.35
41	0.51	0.72	0.81	0.51	0.69	0.81
42	1.00	1.20	1.36	0.92	1.21	1.36
43	0.49	0.51	0.59	0.41	0.53	0.60
87	0.78	1.07	1.21	0.84	1.03	1.20
45	0.17	0.27	0.37	0.20	0.32	0.37
46	0.00	0.00	0.00	0.00	0.00	0.00
47	0.61	0.96	1.30	0.69	1.11	1.31
85	0.19	0.26	0.29	0.19	0.25	0.29
51	0.30	0.40	0.46	0.30	0.40	0.45
53	0.67	0.90	1.00	0.71	0.88	1.00
55	0.59	0.85	0.97	0.68	0.82	1.01
57	0.54	0.60	0.70	0.47	0.62	0.73
59	0.54	0.60	0.70	0.47	0.62	0.73
61	0.31	0.48	0.65	0.35	0.56	0.66
63	0.00	0.00	0.00	0.00	0.00	0.00
65	0.00	0.00	0.00	0.00	0.00	0.00
67	0.95	1.31	1.64	1.00	1.38	1.56
69	0.39	0.56	0.77	0.50	0.65	0.72
71	0.69	0.84	0.88	0.70	0.81	0.94
73	1.09	1.14	1.34	0.92	1.20	1.35
75	0.67	0.90	1.00	0.71	0.88	1.00
77	0.84	1.12	1.23	0.88	1.10	1.20
79	0.74	0.89	0.91	0.66	0.83	0.94
81	0.69	0.75	0.74	0.58	0.72	0.79
83	1.13	1.27	1.42	1.07	1.30	1.40
86	0.30	0.40	0.46	0.30	0.40	0.45





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