MODELLING OF TRIP DISTRIBUTION: A CASE STUDY OF VADODARA CITY

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Abstract : The main objective of this study is to present an overview of the travel distribution modelling for transportation planning. Mainly there are four stages model that is trip generation, trip distribution, modal split and trip assignment. After the first stage of transportation planning i.e. trip generation, it is necessary to determine the direction of flow. The number of trips generated in various zones of the area under study must be proportioned to the various zones to which these trips are attracted. These generated trips from each zone are then distributed to all other zones based on the choice of destination i.e. Trip Distribution. This paper gives a framework for the trip distribution for the city of Vadodara based on Household Survey, as the data is main input for generating O-D matrix. The trips are combination of work trips, educational trips, shopping trips, recreational trips and business trips. This study covered 19 wards of Vadodara city in which it is divided by the local authorities. The study methodology developed for gravity model calibration. The cost matrix (travel time and distance) is derived from household survey data as perceived by users. The gravity model was calibrated for aggregate trips and various trip types based on types of deterrence functions. Based on occupancy rates the trips were converted to vehicles trips.

The forecasted O-D matrix and desire line help for planning transportation facilities were derived. A moderate size city selected through which we can work for such other cities in future keeping this work in consideration. The calibrated gravity model is used to forecast trip distribution and accommodate new landmark to be developed.

Index Terms **- O-D survey, Trip Distribution, Deterrence functions, TransCAD, Household survey, Transportation planning, SPSS software, gravity model.**

I. INTRODUCTION

Transportation planning process plays an important role in construction of new transportation facilities. The basic purpose of transportation planning and management is to match the supply and demand of the population which can create a need. Transportation planning is one field where approach has already been tried and found extremely useful. Operations research is mainly concerned with optimizing the performance of a system. Transportation planning process includes four stages i.e.: Trip Generation, Trip Distribution, Modal Split and Traffic Assignment. For any city like Vadodara which already facing the problem of Traffic it is important to know about Future Traffic Conditions.

With increase in population, Vadodara started facing problems of traffic, parking, pedestrians' safety, congestion in the city. The solution may include,

- Land use and city planning controls.
- Transportation studies are to be carried out and plans for new roads and reorganization of existing network are to be formulated.
- Traffic restraint measures like restriction in parking, road charges etc.

It is the process that leads to decisions on transportation policies and program. In this process, planner develops information about the impacts of implementing alternative courses of action involving transportation services such as new roadways, introduction to new modes of public transport, etc. or parking restrictions.

Very often known as the cultural capital of Gujarat, Vadodara may not have had a colorful history like Calcutta or Bombay or seen the great empire builders like Delhi. But then, unlike these cities, its history begins somewhere in the mid-Pleistocene period. There are evidences of the existence of the early man of old stone age at the Mahi River valley at several sites within 10 to 20 kms. To the North-East of the present Vadodara. Vadodara formerly known as Baroda is the third-largest city in the Western Indian state of Gujarat, after Ahmedabad and Surat. It is the administrative headquarters of Vadodara District and is located on the banks of Vishwamitri river, 141 kilometers (88 mi) from the state capital Gandhinagar. As of 2011, Vadodara had a population of almost 16.66 million people.

II. OBJECTIVE AND SCOPE

There is constant increase in the number of privately-owned vehicles in the region. The trips by private vehicles and auto rickshaws constitute most trips leading to increased demand for parking and add to the noise and air pollution problems. The increasing numbers of vehicles and inadequate carrying capacity of road along the improper geometry of road network are major causes for traffic congestion, delay, and accidents. So due to increase in number of private vehicles and due to increase in population and income, numbers of trips increase.

Following issues which identified in Vadodara related to transportation:

I. Areas in the old city are highly congested
II. Lack of pedestrian facilities
III. Rapid growth in private vehicles
IV. Improper ratio of public and private vehicles

V. Poor road geometry
VI. Need of improvement of existing road networks
VII. Public transports in the urban region are inadequate to cater to the commuters beyond the arterial roads
VIII. Reduction in road width due to the improver parking practices
IX. Absence of traffic sense which again leads to travel time and uncontrollable situations
X. Proper implementation of traffic rules is missing

The above issues can be resolved by understanding distribution of trips among various zones of Vadodara city.

III. LITERATURE REVIEW

A. OVERVIEW

The decision to travel for a given purpose is called tip generation. The decision to choose destination from origin is directional distribution of trips forms the second stage of travel demand modelling. Trip distribution is determined by the numbers of trips end originated in zone I to number to trips attracted to zone J, which can be understood by the matrix between zones the matrix is called origin-destination (O-D) matrix. Trip distribution is the important stage in transportation planning process. Table 1 represents typical O-D matrix.

TABLE1: TRIP DISTRIBUTION MATRIX

	DESTINATION ZONES							**Originated trips from zone i**
ORIGIN ZONES	ZONES	**1**	**2**	**.....**	**j**	**.....**	**N**	**Oi**
	1	T_{11}	T_{12}	....	T_{1j}	.....	T_{1n}	O_1
	2	T_{21}	T_{22}	....	T_{2j}	.....	T_{2n}	O_2
	....	....	.....	....	....	.....	.....	.....
	i	T_n	T_{12}	....	T_{ij}	.....	T_{in}	O_i
	....	....	.....	.....	....	.....	.....	.....
	N	T_{n1}	T_{n2}	.....	T_{nj}	.....	T_{nn}	On
Attracted trips in zone j	**Dj**	D_1	D_2	.....	D_j	.....	Dn	T= $\sum_{j=1}^{n} Oi$

Where, $O_i = \sum_j T_{ij}$ $D_j = \sum_i T_{ij}$ $T = \sum_{ij} T_{ij}$ $O_i = \sum_{i=1}^{n} Tij$

B. REVIEWS

Study done by S A Veentra in Netherlands (2010) aims a new trip distribution model for destinations that are not homogeneously distributed. The model is a gravity model in which the spatial configuration of destinations is incorporated in the modelling process. The performance was tested on a survey with reported grocery shopping trips in the Dutch city of Almelo.

Study done by Thomas Hudecek in Prague (2017) searched for places with the highest potential for the construction of new parks and attempted to determine the level of the need for public investment for these individual localities. It has been shown, however, that the time-related accessibility of parks is only one aspect, and therefore, the step was taken to expand and deepen the methodologies used. Information about population density as an indicator of the lack of parks has been added. Finally, the results of this research will help the City of Prague in the process of making a new metropolitan land-use plan.

Study done by Zala K in (2013) describe the calibration of a gravity model for various trip purposes like business, service and home and for the same, the value for the deterrence functions ranges between 1 to 3 depending upon travel factors.

Study done by Guler in Turkey (2014) aims to calculate the transportation demand of the Marmaray corridor. The model was used to estimate freight and passenger transportation between Istanbul and other Turkish provinces. The estimated results were used to calculate the required train numbers daily through the Marmaray corridor and some suggestions were put forward to increase the capacity of this corridor.

IV. GRAVITY MODEL

This model is originally generated from an analogy with Newton's gravitational law i.e. the attractive force Newtons' law of gravity which says that the force of attraction between two bodies is directly proportional to the product of the masses of the two bodies is inversely proportional to the square of the distance between them. Similarly, in the gravity model, the number of trips between two zones is directly related to activities in the two zones and inversely related to the separation between the zones as a function of travel time, cost and length.

$$T_{ij} = \frac{k \times Oi \times Dj}{f(dij)},$$

Where, f (dij) = $\frac{1}{dij^c}$ inverse function

Where, k & c = parameter of model estimates through calibration using base year data
Dj = total trip attraction at zone j
Oi = total trip production at zone i
dij = impedance between zone i and zone j

Using the usual mathematical modelling terminology, the trips are the dependent variables, the production, attraction and impedances are the independent variables. The constant k and c are the parameters of the model that must be estimated through calibration using base year data.

- CLASSIC FORM OF GRAVITY MODEL

$$Tij = \frac{Oi \times Dj \times F(dij) \times Kij}{\sum\{Aj \times F(dij)\}}$$

Where, Tij = total number of trips between zone i to zone j
F(dij) = friction factor and impedance factor
Kij = socioeconomic adjustment factor

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V. STUDY AREA

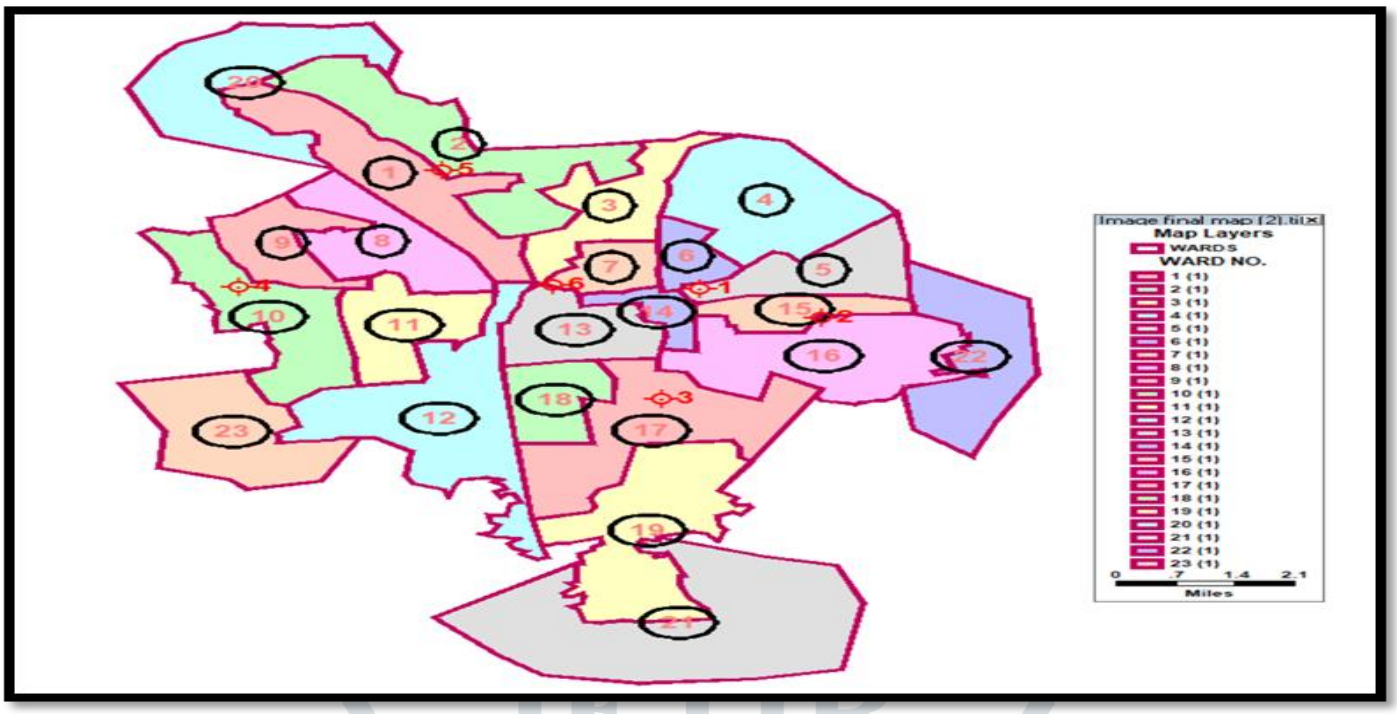
Vadodara has a population of almost 16.66 lacs people as per census 2011. Vadodara is the third largest city in the Gujarat state. It is the administrative headquarters of Vadodara district. The main two institutions involved in planning and development of Vadodara are VMC (Vadodara municipal corporation) and VUDA (Vadodara urban development authorities). The city is on the major rail and road arteries joining Mumbai with Delhi and Mumbai with Ahmedabad. Due to this Vadodara is known as a Gateway to the Golden Quadrilateral.

The study area is divided into 19 wards based on population data and ward size data. After conducting HH survey we came to know that there are internal trips (having both destination and origin within study area), intrazonal trips (having both origin and destination in same zone)and interzonal trips (trips travelling between two different zones).The zoning of Vadodara city done in TransCAD software taking care of trips whose origins are within the zoning area but destination as outside the zoning areas for these instead of 19 wards 23 wards are taken into consideration and whole study has been conducted which is shown below in fig 2.showing 19 ward map in transcad.

According to the 2011 India census, Vadodara metropolitan area had a population of 1,670,806. In Vadodara, 9% of the population is under 6 years of age. Gujarati, Urdu, Marathi, Hindi and English are the languages spoken in the city. Males constitute 52% of the population and females 48%.

People speaking different languages stay in the city. Apart from Guajarati's and Marathi, a significant population of North Indians, Rajasthani, South Indians and Bengalis have settled in the city. All of them have various associations and community bodies in the city.

FIGURE1: ZONNING MAP OF VADODARA CITY



VI. DATA COLLECTION

The transportation planning is first required transport survey to collect various data on all factors that are influencing the travel pattern. The data collection involves number of surveys to collect the information on existing travel pattern, existing transport facilities and information on existing land use and economic activities. The cost involved for survey is high and it is also time consuming, so this emphasized on the need for proper organization and careful planning for sample size.

In many urban areas the travel survey data plays an important role. Sometimes this data is collected for forecasting and then for modelling. In other cases, the data is used mostly to draw a picture of the existing situation.

FIGURE 2: STANDARDS FOR SAMPLING SIZE FOR HHIS

POPULATION OF STUDY AREA	SAMPLE SIZE
Under 50,000	1 in 5 households
50,000 – 150,000	1 in 8 households
150,000 – 300,000	1 in 10 households
300,000 – 500,000	1 in 15 households
500,000 – 1,000,000	1 in 20 households
Over 1,000,000	1 in 25 households

Household information survey is one of the most reliable types of survey to collect data on origin and destination. The survey is intended to collect data on the travel pattern of the members of the household and the general characteristics of the household influencing trip making. Several techniques are available for household information surveys are full interview techniques and home questionnaire techniques. The full interview technique involves interviewing as many members of the household as possible and directly recording all the information. In home questionnaire techniques, the interviewer collects only details of the household characteristics and leaving forms for household members to fill the information regarding trips. The completed forms are collected by the interviewer after a day or two.

Out of 18,836 actual sample size we have successfully collected 4000 samples from all zones. This data is transformed in excel sheet and imported into TransCAD for analysis. Fig 3 shows excel sheet data and fig 4 shows TransCAD datasheet.

FIGURE 3: EXCEL SHEET OF DATA COLLECTION

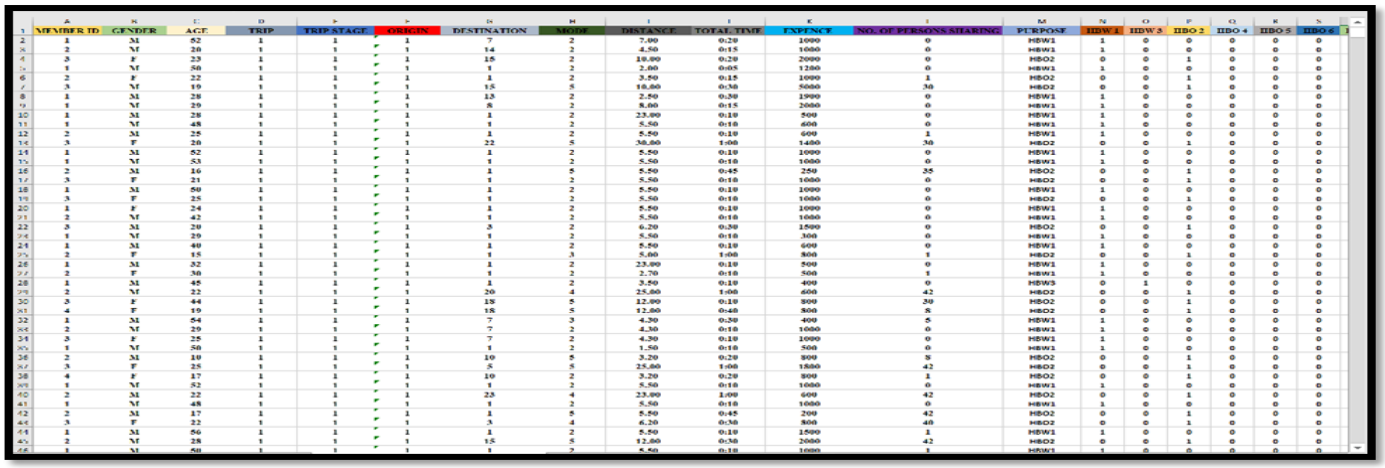
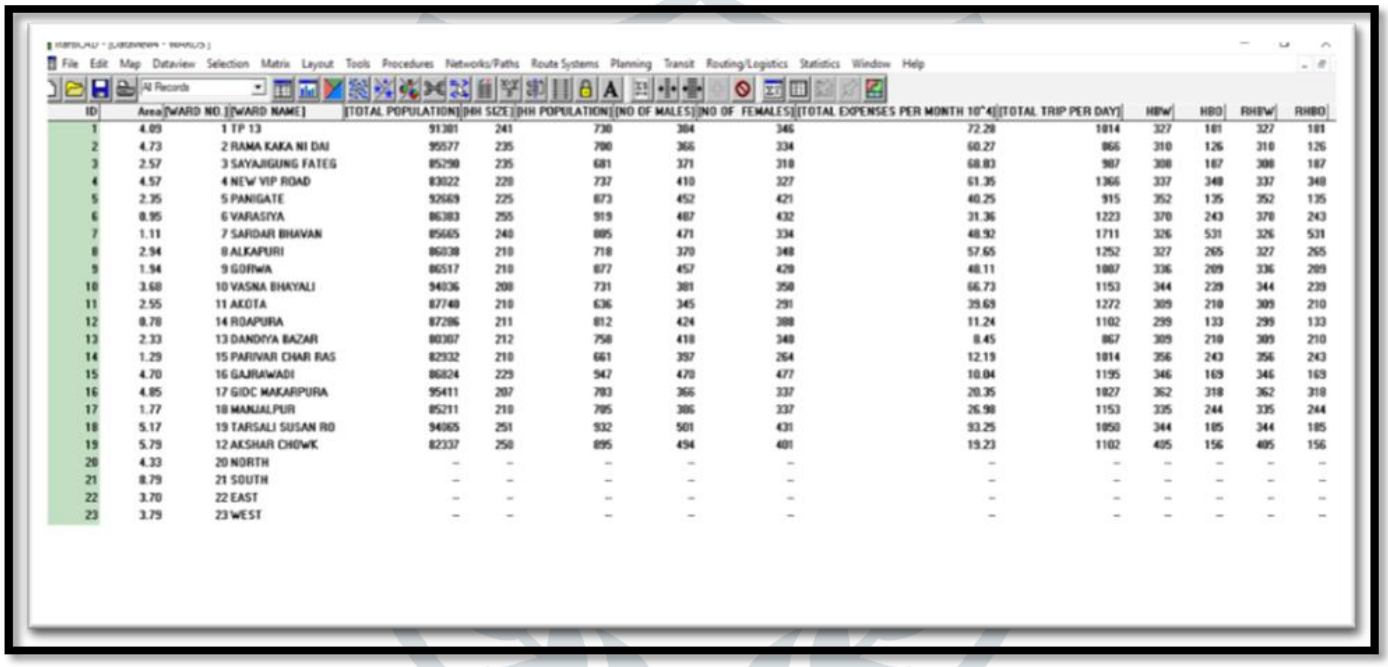


FIGURE 4: TRANSCAD DATA SHEET



ID	Area	WARD NO.	WARD NAME	TOTAL POPULATION	HH SIZE	HH POPULATION	NO OF MALES	NO OF FEMALES	TOTAL EXPENSES PER MONTH 10^4	TOTAL TRIP PER DAY	HBW	HBO	RHBW	RHBO
1	4.09	1	TP 13	91381	241	730	384	346	72.28	1814	327	181	327	181
2	4.73	2	RAMA KAKA NI DAI	95577	235	780	366	334	60.27	866	310	126	310	126
3	2.57	3	SAYAJIGUNG FATEG	85290	235	681	371	310	68.83	987	308	187	308	187
4	4.57	4	NEW VIP ROAD	83022	220	737	410	327	61.35	1366	337	348	337	348
5	2.35	5	PANIGATE	92669	225	873	452	421	40.25	915	352	135	352	135
6	8.95	6	VARASIYA	86383	255	919	487	432	31.36	1223	370	243	370	243
7	1.11	7	SARDAR BHAVAN	85665	240	885	471	334	48.92	1711	326	531	326	531
8	2.94	8	ALKAPURI	86038	210	718	370	348	57.65	1252	327	265	327	265
9	1.94	9	GOTRI	86517	210	877	457	429	48.11	1087	336	209	336	209
10	3.68	10	VASNA BHAYALI	94036	200	731	381	350	66.73	1153	344	229	344	229
11	2.55	11	AKOTA	87740	210	636	345	291	39.69	1272	309	210	309	210
12	8.78	14	RAOPURA	87286	211	812	424	388	11.24	1102	299	133	299	133
13	2.33	13	DANDIYA BAZAR	88387	212	758	418	340	8.45	867	309	210	309	210
14	1.29	15	PARIVAR CHAR RAS	82932	210	661	397	264	12.19	1814	356	243	356	243
15	4.70	16	GAJRAWADI	86824	225	947	470	477	10.84	1195	346	169	346	169
16	4.85	17	GIDC MAKARPURA	95411	207	783	366	337	20.35	1827	362	318	362	318
17	1.77	18	MANJALPUR	85211	210	785	386	337	26.98	1153	335	244	335	244
18	5.17	19	TARSALI SUSAN RO	94065	251	932	501	431	93.25	1850	344	185	344	185
19	5.79	12	AKSHAR CHOWK	82337	250	895	494	401	19.23	1102	405	156	405	156
20	4.33	20	NORTH	–	–	–	–	–	–	–	–	–	–	–
21	8.79	21	SOUTH	–	–	–	–	–	–	–	–	–	–	–
22	3.70	22	EAST	–	–	–	–	–	–	–	–	–	–	–
23	3.79	23	WEST	–	–	–	–	–	–	–	–	–	–	–

VII. DATA ANALYSIS

Data analysis is the important step after data collection. The population data for each zone has been forecasted for horizon years. The data from household information survey is entered in Microsoft Excel. Then these entered data is imported into Transcad software for analysis purpose.

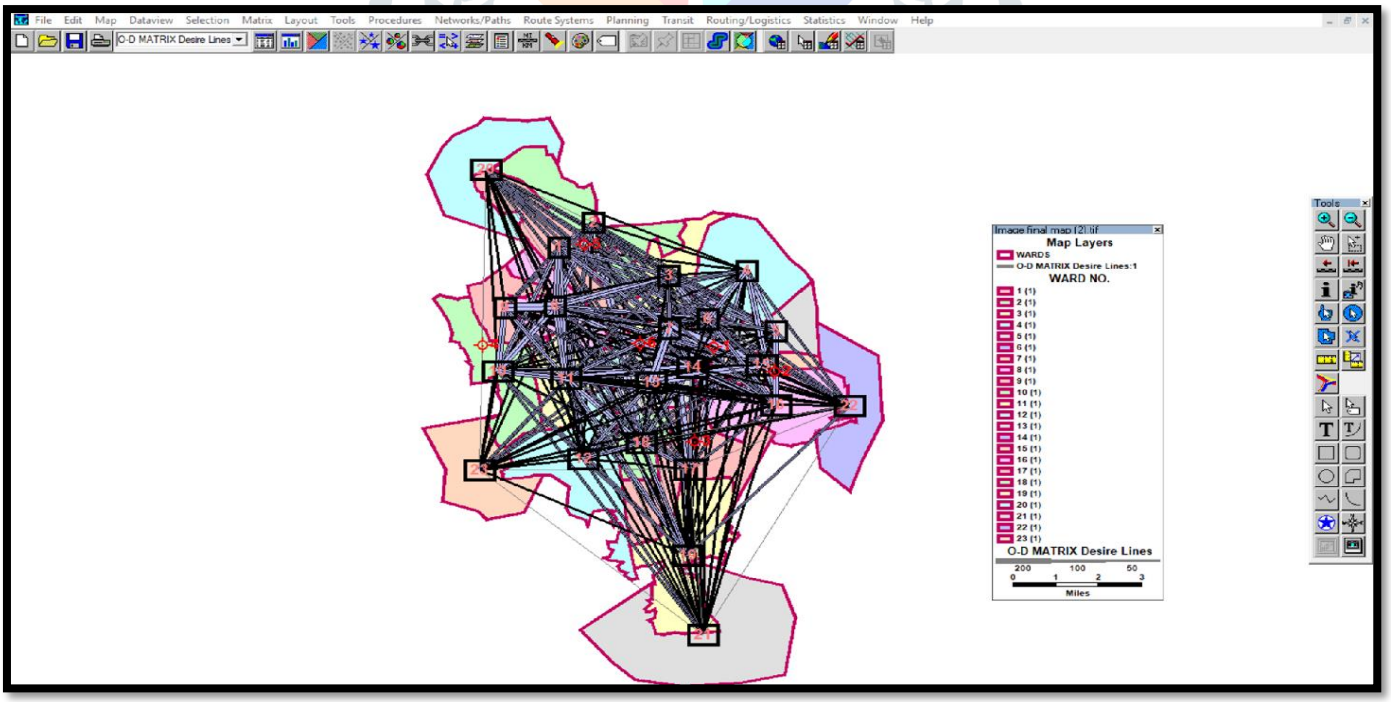
Trip distribution can be understood by matrix between zones . The matrix is called origin – destination matrix (O-D) matrix. Matrix involves trip data like travel distance, travel time and number of trips which is important for trip distribution. A matrix is generated after analysis of 4000 samples collected from 19 wards of Vadodara and then calculating the numbers of trip per ward through which an O-D pattern has generated which is shown below in figure 5.

Desire line map is made up many such desire lines, the density of which indicates the volume of trip moving between origin and destination. Here desire line indicates the flow of peoples depending upon their purposes from origin to destination which are based upon the matrix obtained through transcad and map generated in transcad. Combination of O-D matrix and generated map gives the result of desire line diagram which is shown in figure 6.

FIGURE 5: OBSERVED O-D MATRIX BY TRANSCAD

ZONE		DESTINATION																							TOTAL
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
ORIGIN	1	202	74	64	25	80	59	60	104	48	58	96	53	25	40	42	18	48	61	91	4	7	6	5	1270
	2	74	16	40	36	13	15	57	100	33	48	76	40	14	2	25	80	130	26	36	0	0	1	0	862
	3	64	40	86	36	61	108	75	99	14	38	43	8	47	51	93	72	21	64	41	2	1	1	1	1066
	4	25	36	36	121	112	92	48	79	60	28	31	13	7	41	102	87	34	20	27	11	6	5	4	1025
	5	80	13	61	112	68	62	43	66	12	21	44	14	27	44	86	31	32	27	7	6	4	3	2	865
	6	59	15	108	92	62	58	75	94	19	21	29	10	15	42	79	32	33	17	2	6	8	6	6	888
	7	60	57	75	48	43	75	514	76	35	32	55	51	131	220	51	149	50	36	45	12	4	8	4	1831
	8	104	100	99	79	66	94	76	394	174	147	100	110	78	52	105	24	58	71	75	9	5	6	3	2029
	9	48	33	14	60	12	19	35	174	340	91	64	36	17	21	23	7	26	29	13	5	7	8	5	1087
	10	58	48	38	28	21	21	32	147	91	220	89	83	25	33	66	27	45	80	34	4	3	2	1	1196
	11	96	76	43	31	44	29	55	100	64	89	242	133	31	37	47	22	90	69	29	3	2	4	3	1339
	12	53	40	8	13	14	10	51	110	36	83	133	94	15	46	29	15	79	58	26	5	5	5	6	934
	13	25	14	47	7	27	15	131	78	17	25	31	15	226	116	26	33	35	38	65	6	4	8	4	993
	14	40	2	51	41	44	42	220	52	21	33	37	46	116	112	39	46	43	43	26	3	1	2	1	1061
	15	42	25	93	102	86	79	51	105	23	66	47	29	26	39	234	21	38	44	33	6	9	9	4	1211
	16	18	80	72	87	31	32	149	24	7	27	22	15	33	46	21	130	68	43	16	0	0	0	0	921
	17	48	130	21	34	32	33	50	58	26	45	90	79	35	43	38	68	66	68	74	4	3	3	3	1051
	18	61	26	64	20	27	17	36	71	29	80	69	58	38	43	44	43	68	20	45	6	6	2	4	877
	19	91	36	41	27	7	2	45	75	13	34	29	26	65	26	33	16	74	45	122	6	8	8	7	836
	20	4	0	2	11	6	6	12	9	5	4	3	5	6	3	6	0	4	6	6	0	0	0	0	98
	21	7	0	1	6	4	8	4	5	7	3	2	5	4	1	9	0	3	6	8	0	0	0	0	83
	22	6	1	1	5	3	6	8	6	8	2	4	5	8	2	9	0	3	2	8	0	0	0	0	87
	23	5	0	1	4	2	6	4	3	5	1	3	6	4	1	4	0	3	4	7	0	0	0	0	63
TOTAL		1270	862	1066	1025	865	888	1831	2029	1087	1196	1339	934	993	1061	1211	921	1051	877	836	98	83	87	63	21673

FIGURE 6: OBSERVED DESIRE LINE DIAGRAM



VIII. CONCLUSIONS

The data analysis of Vadodara helps to draw following conclusion.

The GIS data base in TransCAD for Vadodara is prepared in intelligent database used in planning.

- The population growth rate in the last decade (2001 -2011) is 22.2%.
- The trip rate observed is 5.1 trips /HH/day.
- The total number of trips were 21673 which includes all purposes like work, business, education, hospital and health, recreational trips.
- Home based trips are 6402 trips
- Non homebased trips are 4451
- NHBW trips are 10853
- The HH survey of 4000 HH helped to generate O- D matrix as given in fig 5 and required desire line diagram given in fig 6.

REFERENCES

[1] Zala K., Dr. L.B.Zala '''GRAVITY MODEL CALIBRATION AND USE IN TRIP DISTRIBUTION", Journal of International Academic Research for Multidisciplinary (2013), Vol. 1 Issue 4, ISSN 2320- 5083BR

[2] Prof. Rinkal Sutaria, Prof. Sapna Shah, "TRIP DISTRIBUTION ANALYSIS OF VADODARA CITY", Global Research and Development Journal for Engineering March 2016, e-ISSN: 2455-5703

[3] Dian-Hai Wang1. (2006). Entropy Models of Trip Distribution. Journal of Urban Planning and Development.

[4] Easa, M. (1993). URBAN TRIP DISTRIBUTION IN PRACTICE 1: CONVENTIONAL ANALYSIS. Journal of Transportation Engineering , VOL 119. ASCE.

[5] Ease, M. (1993). URBAN DISTRIBUTION IN PRACTICE 2: QUICK RESPONSE AND SPECIAL TOPICS.

[6] Guler, H. (2014). MODEL TO ESTIMATE TRIP DISTRIBUTION : CASE STUDY OF THE MARMARAY PROJECT IN TURKEY. Journal of Transportation Engineering . ASCE.

[7] Hanwen Yi, Thomas E , Mulinazzi and Joe Lee. (2005). TRAFFIC - COUNT BASED DISTRIBUTION MODEL FOR SITE IMPACT STUDIES . Journal of Transportation Engineering . ASCE.

[8] Liu, D. (2016). ANALYTICAL FORECASTING OF POPULATION DISTRIBUTION OVER YEARS IN A NEW RAIL TRANSPORTATION CORRIDOR. Journal of Urban Planning and Development . ASCE.

[9] S.A. VEENSTRA, T. THOMAS, S.I.A. TUTERT. (2010). TRIP DISTIBUTIO FOR LIMITED DESTINATION: A CASE STUDY FOR GROCERY SHOPPING TRIPS IN THE NETHERLANDS., (pp. 663-676). NETHERLANDS.