Modeling Economy-Traffic Relationship for Inter-regional Highway in India: A Case Study

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Abstract: A region generates commercial and passenger vehicle trips to meet the demand of various sectors of economy. Highways play an important role in development of the region. Therefore, it becomes essential to assess linkage and connectivity of the region in relation to its economy to forecast performance of transport system with change in economy. The present study attempts to correlate traffic growth on an inter-regional highway corridor with regional economic indicators. The development of highway, NH 6, in Surat district is gauged by economic growth for period of 2001-11. **In**vestment-**Emp**loyment (INEMP) model is developed to show strong relation between these two economic base indicators of the region. A simple approach is formulated for traffic projection using econometric models and times series models with mean absolute percentage error (MAPE) and R^2 as measure of performance. Then volume to capacity (V/C) analysis is performed using Indian Road Congress (IRC) and Indonesian-Highway Capacity Manual (IHCM) guidelines to find period of time by which transport planners need to be proactive for maintaining desired level of service (LOS) of the highway.

Keywords: Region, NH 6, INEMP, Time series, LOS

1. INTRODUCTION

Transportation is a key promoter of sustainable economic growth. Particularly in India. Raghuram and Babu (2001) noted that transportation is a critical infrastructure required for economic growth. Indeed, transportation infrastructure importance is known for economic growth since long (Phang, 2003).As it is evident, a good transportation infrastructure increases the productivity of a nation or region, by mobilization of available resources thus enhancing productivity of the resources. This could be justified by the fact that since growth of civilization, most centres of economic activities prospered along river banks and coast lines as waterways were the major carrier of goods and passenger at that time. Thus, transport is a pivotal infrastructure that promote economic development (Shah, 1992; Sanchez-Robles, 1998; Esfahani and Ramirez, 2003; Phang, 2003; Short & Kopp, 2005).

Several studies are conducted to find effect of development of transport infrastructure on region's economic growth. Pradhan and Bagchi (2013) found that transport infrastructure

also affects gross capital formation beside economic growth in Indian context. There is a bidirectional causality of road transport infrastructure with economic growth and gross domestic capital formation at Country (macro-economy) level. Mirwaldt et al. (2005) formed a framework which lays stress on need for transport and communication strategies to reduce accessibility gaps between places in Europe.

India as a developing nation has always looked for allocation of budget to transportation in all 5-year plan since 1951. Around 13-18% of fund is allocated for appraisal of transport infrastructure in country in last 2 decade. India has its own highway development plans each of span of 20 years. Currently 4th twenty year Road Development Plan (2001-2021) Vision: 2021 is under process which is focusing on accessibility through the Pradhan Mantri Gram Sadak Yojana (PMGSY) and also development of Golden Quadrilateral for mobility. Most of the nations including European Union, United States of America, China, Japan and Australia etc. have invested equally high on transport infrastructure having faith in its growth-enhancing capabilities. World Bank, an international organization, also share the enthusiasm for transport infrastructure by devoting around 15% money lending for transportation infrastructure projects in fiscal 2002-2007.

Roads are developed through public investment projects, thus forecasting the demand for an existing or proposed facility is among the most important factor as urged by Saha and Fricker (1988). The pattern of traffic growth rate, projected traffic volumes and economic growth rate have been recognized as prime factors in most analyses of highway projects. The traffic growth factor or forecasted traffic volume puts a significant effect on highway investment projects pertaining to increase the capacity of existing highway or construction of new highway so as to maintain desired level of service. Traffic forecast for a new highway project includes normal traffic, generated traffic and developmental traffic (IRC: 108-2015, 2015). Normal traffic is projected using historical traffic data and periodic fluctuations. Generated traffic consist of diverted and induced traffic which gets generated due to new facility. Developmental traffic consist of traffic generation due to development in area surrounding the facility. Most of the studies carried out for traffic forecast are based on historical traffic data and economic data. This study also uses historical traffic data and economic data, and since the study is based on an existing highway thus growth in historical traffic data will also account for generated and developmental traffic. The studies carried out on traffic forecasting could be broadly classified into three category growth factor based model, time series model and econometric model. Here we have used both econometric model and time series model for aggregate and disaggregate analysis respectively.

The accuracy of a prediction model is an important concern. Carbone and Armstrong (1982) surveyed 75 practitioners and 70 academicians for criteria's of evaluating extrapolative forecasting methods. The result showed 86% respondents marked accuracy as one criteria with majorly mean absolute error (MAE) and mean absolute relative error (MARE) as measure of accuracy. Armstrong and Collopy (1992) compared error measures for forecasting methods and found out that Median Absolute Percentage Error (MdAPE) works better with large series while Median Relative Absolute Error (MdRAE) with few series. The parameter used in this study as measure of accuracy is mean absolute percentage error (MAPE).

The present study is aimed at delving speculated bond between the state of transport infrastructure and economic growth observed in Surat district in Gujarat, India during 2000-2012. Armstrong (1984; 1986) recommended simple methods which should be inexpensive and easy to understand by the practitioners. He proposed complex models should be avoided until they become absolutely necessary. In this study, considerable efforts are put to develop an approach which can be used by transport planners to decide in advance when transport

infrastructure needs upgradation through models that are simple, easy to understand and implement.

The rest of the paper is organized as follows: Section 2 presents a brief of study area profile that include demographic dynamics, population growth, economy and transportation linkage details. Section 3 describes data collection from different agencies of Surat district with data description and calculation of employment multiplier for the district. Section 4 Addresses the employment generation scenario of Surat district based on investment to quantify effect of economic growth. Section 5 describes econometric models and time series analysis used in the study for forecasting traffic of NH 6. Section 6 presents V/C analysis for the forecasted traffic using each method to analyse how the level of service on existing highway deteriorates over time period, and the discussion thereof. The final section offers conclusion.

2. CASE STUDY: SURAT DISTRICT

Cities play a critical role in the economic development process of the nation. They are the engines of economic growth and places of high productivity. They contribute more than the proportionate share towards the region's income. With no barriers, attractiveness of a city as an investment destination depends on the quality of infrastructure, social safety and connectivity. Competitive businesses and industries are going to result in employment and increased revenues to the local government. Growth of city in terms of population, vehicular growth or economic growth all tend to increase traffic on the existing road network in the area. Thus it becomes very crucial to have congestion free transportation planning in the city and within regional linkages of city.

Surat district is in Gujarat state of India with Surat city as the administrative headquarters. According to a global study of fastest developing cities conducted by The City Mayors Foundation, (2011) an international think tank on urban affairs; Surat ranks fourth in the list of fastest developing cities in the world. Economically, it is the fastest growing Indian city. Surat is located on west coastline of the country as shown in Figure 1.

Figure 1. Study Area – Surat District

Surat is the major engine of economic growth and employment generation in South Gujarat. Textile and Diamond businesses are very popular in the city. Surat is known as the diamond capital of the world, nowadays it is also known as the textile capital of India. Surat's economic base is mainly dependent on manufacturing sector and finished goods that are transported to other parts of country, hence it is important to study its economic characteristics for transportation planning. Chemical and gas based large industries are established at Hazira by leading industry houses such as ONGC, Reliance, ESSAR, and Shell. The district has 9 taluka as shown in figure. Major industries and almost 87% of the population is concentrated in Olpad, Choryasi, Bardoli and Palsana taluka as shown in figure 2.

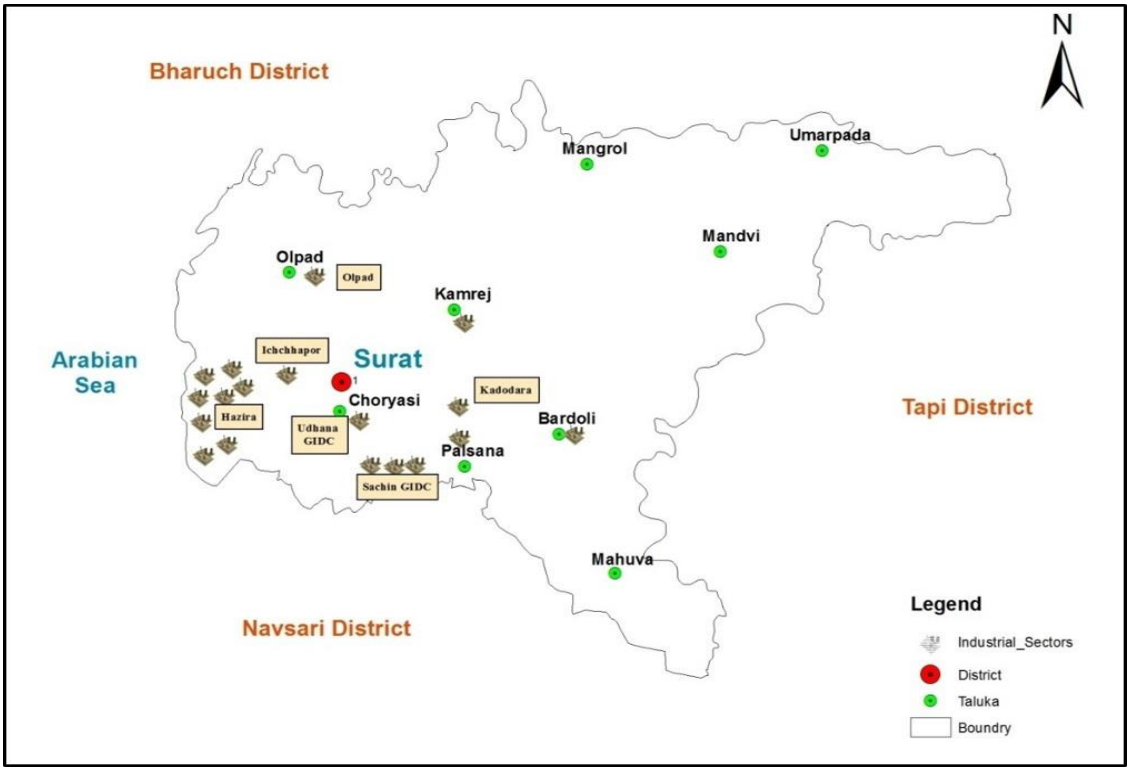


Figure 2. Location of industries in Study Area

It is India's ninth and Gujarat's second most populous city as per Census 2011. It became a metropolis in 1991. In 2011, Surat district had population of 6.08 million with density of 1,376 persons per sq. km. The urban population of district is 4.85 million, thus 80% population lives in urban areas. The district is growing at very high rate and is in increasing growth rate section of logistic population growth curve with 42% growth rate in last decade of 2011 census.

It is well connected with other parts of the state and country through transportation linkages. The city is located 306 km south of state capital Gandhinagar, and 290 km north of India's financial capital Mumbai. The area has good road network consisting highways NH6 and NH8 of length 124km and 43 State Highway of length more than 500km in district. NH6 has one end point within region itself. The district also has good connectivity through railway, airport and sea port as shown in figure 3.

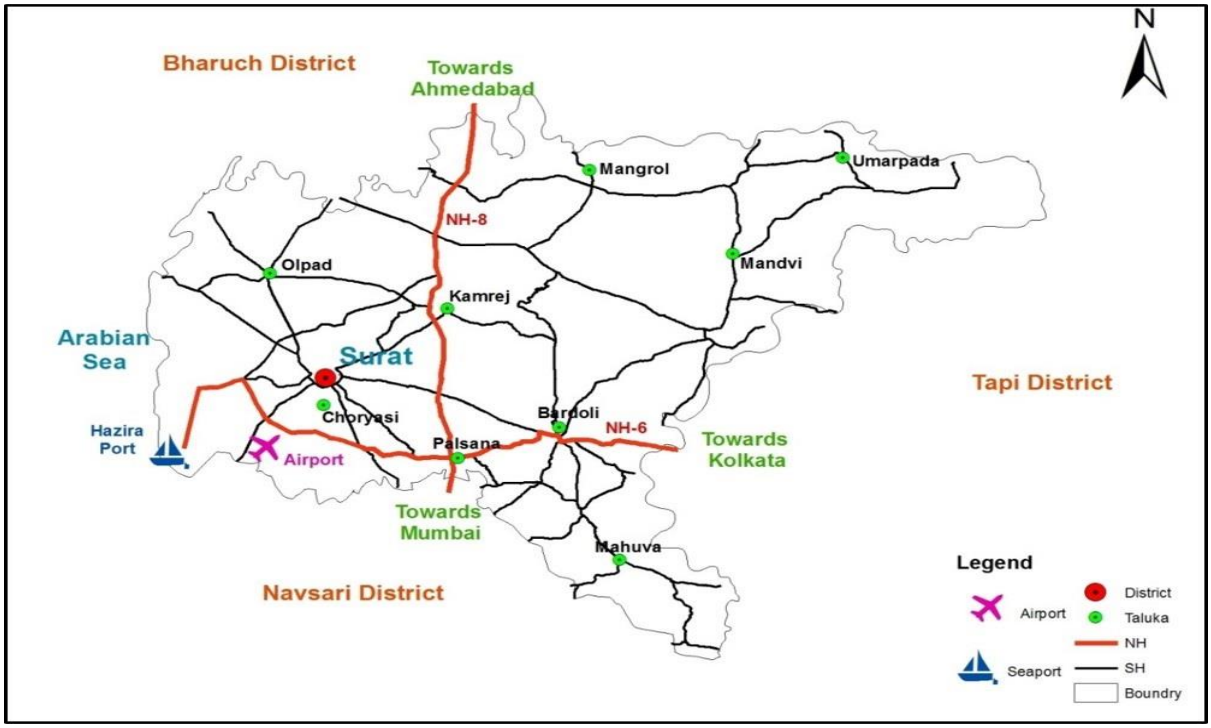


Figure 3. Transportation Linkages in Study Area

2.1 Data Collection

Present study aims at regional traffic forecasting on national highway (NH); hence it requires collection of traffic data of NH 6 in the district. The important factor for traffic growth is accelerated economic activities. Therefore the study requires the secondary data which include economic, demographic, traffic data etc.
The data collected includes:

1. Economic data for past 12 year collected from Surat District Collector office which includes Investment amount in million rupees, number of industries and their employment in Surat district as well as in each taluka of Surat district.
2. The classified traffic volume data for past 12 year of Sachin – Palsana section is collected from Gujarat state PWD (i.e. Road & Building Department). Data collected by state PWD is as per IRC: 9-1972 (1972) on half yearly bases (i.e. Pre-monsoon (April) and Post-monsoon (October)).
3. The population data of Surat district is collected from the census website. This includes taluka wise population from rural and urban areas.
4. Vehicle Registration data is collected from Regional transport office (RTO) Surat.
5. Gross Domestic Product (GDP) and Gross State Domestic Product (GSDP) data is collected from Planning Commission website.

Seven variables used are divided into three category i.e. economic, demographic and traffic. District Employment, District Investment, GSDP, GDP are economic variable, Number of Industry and Vehicle registration are demographic variable and Average Annual Daily Traffic is traffic variable. Economic variable, employment consist of basic and non-basic employment which imply economic growth of region is explained in next section.

2.2 Employment Multiplier

Hildebrand and Mace (1950) suggested that, from economic point of view, regional employment should be divided into export and consumption sector employment. Export sector generates E_B, Basic Employment while consumption sector generates E_N, Non-basic Employment. E_B are primary workers directly related to economy while E_N depends on E_B. Total Employment E is sum of E_B and E_N. The ratio of E_N to E_B is termed as Base ratio. The employment multiplier is the factor that summarizes total number of jobs in the economy or region that will be created by addition of new jobs in the base industry of economy.

Total number of workers in Surat district as per 2011 census is 25,53,542 with work participation rate (WPR) of 0.42. This includes basic, non-basic and agricultural employment. The workers involved in agricultural and industrial sector are 4,35,288 and 6,59,035 respectively. Thus E_B of Surat district is 10,94,323 which consist of agriculture and industrial sector, while E_N is 14,59,219.

$$\text{Total Employment } E = E_N + E_B$$

$$E_N = (E_N / E_B) * E_B$$

Where base ratio; E_N / E_B is assumed constant over time.

$$\text{Hence } E = (E_N / E_B) * E_B + E_B \text{ 'or' } E = (1 + E_N / E_B) * E_B$$

The base ratio of employment is calculated and it is 1.33 for Surat district.

Finally the employment multiplier is calculated using expression $E = (1/1-(E_N/E))$

$$E_N / E = 1290899 / 2287400 = 0.571$$

$$\text{Employment Multiplier} = (1 / (1-0.571))$$

$$\text{Hence } E = 2.33\ E_B$$

The calculated value of employment multiplier is 2.33 for Surat district. The employment multiplier indicates that the total employment in district is 2.33 times the basic employment. Table 1 shows demographic and economic indicators for all the nine blocks of the study region:

Table 1. Employment Multiplier for Talukas in Surat District (2011)

Name of Block	Total Population	Total Employment	WPR	Basic Employment	Non Basic Employment	Employment Multiplier
Surat & Chorysai	46,97,074	19,09,368	0.41	6,28,529	12,80,839	**3.04**
Olpad	1,96,846	88,706	0.45	54,433	34,273	1.63
Kamrej	1,84,554	80,530	0.44	52,644	27,886	1.53
Mangrol	2,09,054	87,021	0.42	64,168	22,853	1.36
Mandvi	1,95,949	1,02,445	0.52	84,777	17,668	1.21
Bardoli	2,24,164	1,03,128	0.46	61,225	41,903	1.68
Mahuva	1,44,906	69,286	0.48	56,185	13,101	1.23
Umarpada	83,723	44,483	0.53	40,496	3,987	**1.10**
Palsana	1,45,052	68,575	0.47	51,865	16,710	1.32
District	**60,81,322**	**25,53,542**	**0.42**	**10,94,322**	**14,59,220**	**2.33**

*WPR – Work Participation Rate

The multiplier is highest for Surat and Choryasi block as Surat city lies within this region, thus creating maximum employment opportunities than any other block. The Umarpada has lowest multiplier of 1.10 and highest WPR of 0.5 which tells most of the population in the

block is involved in basic sector of agriculture. Thus the values indicate that district is prospering in terms of employment generation. And this is due to constant flow of investment in the region.

2.3 Investment and Employment Relationship

The economy of any region depends on investment in its various sectors, because they are the major generator of employment and development in that particular region. As the region grows economically it creates employment opportunities, people from nearby region shifts there and population of that particular region increases. Hence employment and population depends on investment or economic prosperity of the region, their combine effects need a very good transportation infrastructure to meet the demand. Figure-4 shows that the investment and employment in region does not follow a linear trend but the same trend and depict a good relation.

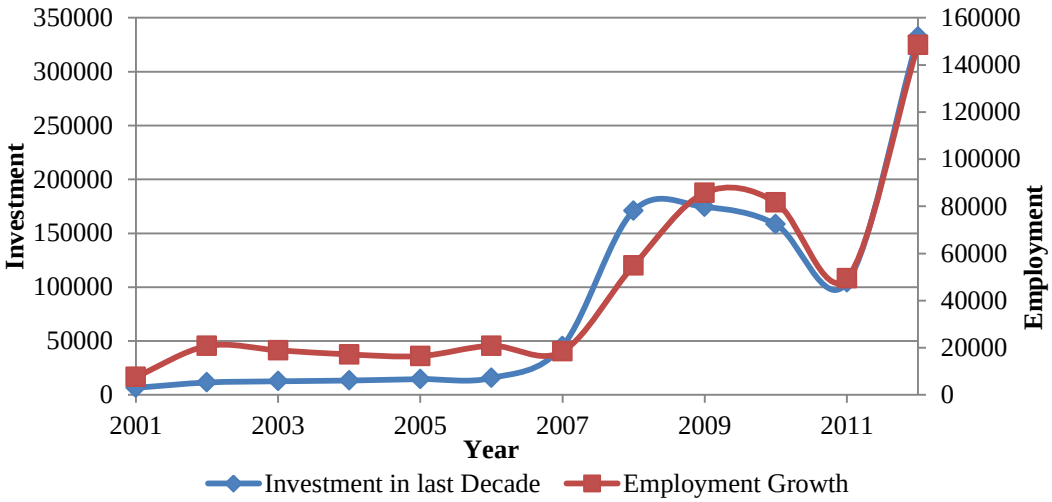


Figure 4. Graph of Employment & Investment Growth

2.4 Employment Prediction Model: INEMP

It is already discussed that investment is an important parameter in employment growth and population growth. The relationship developed between **In**vestment and **Emp**loyment is designated as INEMP model.

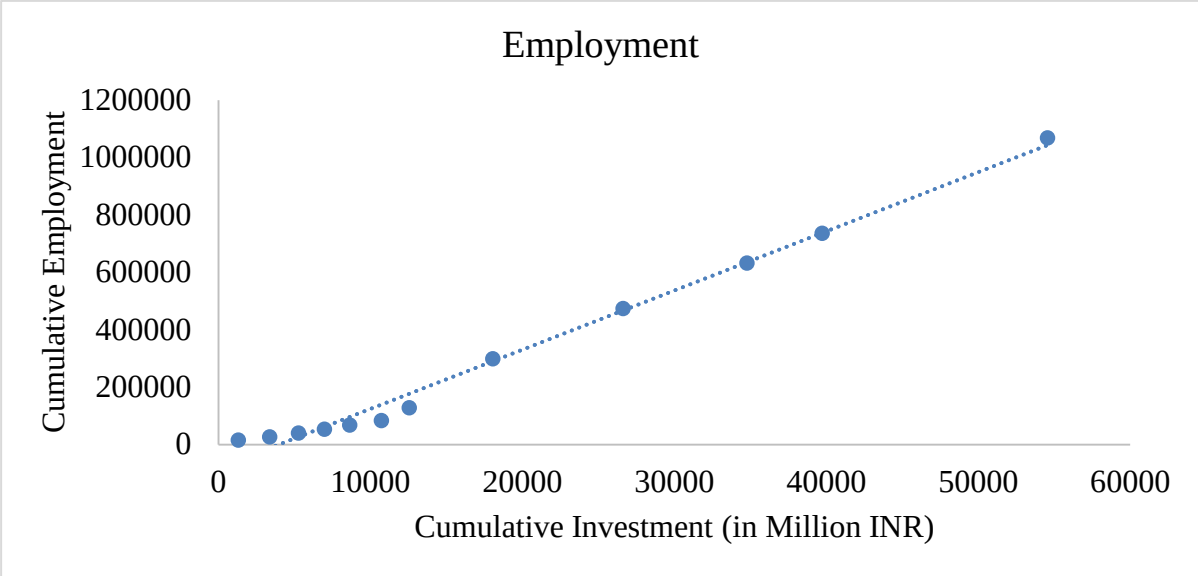


Figure 5. Relation between Cumulative Investment & Cumulative Employment

A linear regression model was performed for finding the relationship between investment and employment as shown in figure 5. This was accomplished by cumulative addition of investment and employment.

One component of this relation is to examine the influence of investment on employment changes. Results of regression analysis demonstrate a positive and statistically significant correlation between the two variables, where R^2 = 0.9897, indicating that investment accounts 98% variance in employment. The regression coefficient for investment is 20.6 which means for every additional investment in million Indian National Rupee (INR) the employment is increased by 20.6 times of investment. The INEMP relationship model is given below in equation 1.

$$\textbf{Emp = 20.6*In -81549} \quad (1)$$

Using this model employment is predicted with MAPE of about 12%. This relation developed between economic parameters could be used to count for variation in traffic growth. And the next section deals with formulation of traffic prediction models.

3. TRAFFIC PREDICTION FOR NH – 6

NH-6 in Sachin – Palsana section is part of outer ring road of Surat city. It is the east west corridor which connects Surat (Hazira) with Kolkata and other major cities of central and western India. It covers a stretch of 72 km in Surat district with Sachin – Palsana as the busiest section. Hazira and Sachin are the major industrial sectors of Surat district; hence they are major generator and attractor of traffic, especially commercial traffic. At Palsana, the section connects with NH-8, and the commercial traffic coming from south India and east India will have to pass through this section to reach Sachin or Hazira. Sachin Apparel Park, Special Economic Zone (SEZ) is being developed in this section only, so it is needed to forecast traffic on NH – 6 to meet the future demand. The data collected from Roads & Building department of Surat district is used for forecasting traffic on NH-6. The data collected is of April and October month only hence available two months data is used for calculation of Average annual daily traffic (AADT) in terms of vehicles. Finally these values

are converted into PCUs to express different class of vehicle into one common unit as per IRC 64-1990 and a single value AADT in terms of PCU per day is obtained. Two types of models are developed, aggregate models and disaggregate models for traffic forecasting on the selected highway.

3.1 Aggregate Traffic Forecast Models for Economic and Demographic Variables

In aggregate analysis, models are developed for each of the 6 variables. The 4 economic variables are Employment (Emp), Investment (Invest) in million INR, GSDP and GDP in billion INR, and 2 demographic variables are Number of Industries (NOI) and Cumulative Vehicle Growth (CVR). Correlation of the subject variables with traffic and among themselves is shown in table 2. The correlation analysis shows that variables are highly correlated with traffic (AADT) (Pearson correlation lies between .79 and .94). The analysis also shows that subject variables are correlated among themselves and thus for better performance subject variables should be used independently for regression analysis. Although, presence of multi-collinearity among independent variables does not hinder our capability to obtain a good fit nor does it tend to affect predictions, as long as these predictions are made within the expanse of observations (Neter *et al.*, 1985). Table 2 also shows that all correlation are significant at the 0.01 level for 2-tailed.

Table 2. Correlation Matrix for different subject variables

		AADT	Emp	Invest	NOI	GSDP	GDP	CVR
AADT	Pearson Correlation	1	.920**	.940**	.790**	.925**	.934**	.901**
	Sig. (2-tailed)		.000	.000	.004	.000	.000	.000
	N	11	11	11	11	11	11	11
Emp	Pearson Correlation	.920**	1	.972**	.773**	.926**	.937**	.883**
	Sig. (2-tailed)	.000		.000	.005	.000	.000	.000
	N	11	11	11	11	11	11	11
Invest	Pearson Correlation	.940**	.972**	1	.733*	.910**	.921**	.890**
	Sig. (2-tailed)	.000	.000		.010	.000	.000	.000
	N	11	11	11	11	11	11	11
NOI	Pearson Correlation	.790**	.773**	.733*	1	.838**	.857**	.764**
	Sig. (2-tailed)	.004	.005	.010		.001	.001	.006
	N	11	11	11	11	11	11	11
GSDP	Pearson Correlation	.925**	.926**	.910**	.838**	1	.999**	.986**
	Sig. (2-tailed)	.000	.000	.000	.001		.000	.000
	N	11	11	11	11	11	11	11
GDP	Pearson Correlation	.934**	.937**	.921**	.857**	.999**	1	.978**
	Sig. (2-tailed)	.000	.000	.000	.001	.000		.000
	N	11	11	11	11	11	11	11
CVR	Pearson Correlation	.901**	.883**	.890**	.764**	.986**	.978**	1
	Sig. (2-tailed)	.000	.000	.000	.006	.000	.000	
	N	11	11	11	11	11	11	11
**. Correlation is significant at the 0.01 level (2-tailed).								
*. Correlation is significant at the 0.05 level (2-tailed).								

The data used in present analysis is annual and depicts no cyclic affect may be due to less data points. Using regression analysis, 6 models are developed with each of subject variable for forecasting traffic (AADT) as shown in table 3. The employment, investment and industries data used for modelling is of Surat & Choryasi taluka, because only this taluka is likely to influence the traffic of NH – 6 in this section as the highway originates from Surat. The parameters used to compute accuracy of models are MAPE, root mean square error (RMSE), coefficient of determination (R^2). T-test and f-test are also performed between observed and predicted AADT for all models to compare mean and variance.

Table 3. Aggregate models for different subject variables

Variable	Equation	MAPE	RMSE ('1000)	R^2	Adj R^2	t-test	f-test
Emp	Y = 0.286Emp + 9674	15	3.57	0.85	0.83	1.00	0.80
Invest	Y = 1.373Invest + 10486	13	3.11	0.88	0.87	1.00	0.85
NOI	Y = 1.133NOI + 12769	31	5.59	0.62	0.58	1.00	0.47
CVR	Y = 0.024CVR + 4134	25	3.97	0.81	0.79	1.00	0.75
GSDP	lnY = 0.823lnGSDP + 3.21	23	3.74	0.73	0.70	0.60	0.53
GDP	lnY = 0.942lnGDP - 0.267	19	3.33	0.79	0.76	0.66	0.70
Y = Average Annual Daily Traffic (AADT)							

In all the models subject variables are positively correlated with AADT which shows that increase in subject variable increases traffic on highway. Invest, NOI, GSDP and GDP model are having regression coefficient in range of 0.82-1.37 and hence are having almost same rate of change of conditional mean. The Emp and Invest models are performing well analogous to accuracy parameters MAPE (<=15%), RMSE and R^2 (>=0.8). The obtained MAPE value of 13% and 15% can be considered as fair values as Lewi's scale of interpretation (Kenneth and Ronald, 1982; Lewis, 1982). T-test and f-test shows that both model are able to explain the mean and variance of observed data.

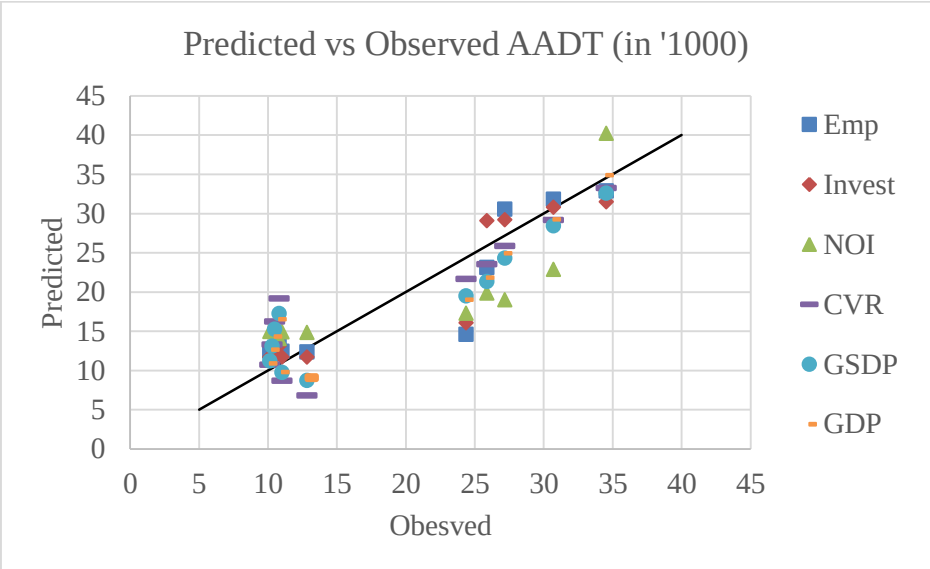


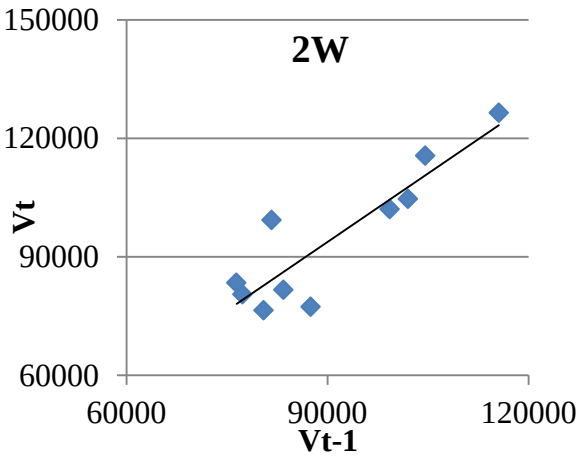
Figure 6. Scatter plot of Predicted against Observed AADT for all models

The scatter plot of figure 6 shows the predicted data against observed data for all subject variable models. The high variation in data points about 1:1 line is mainly due to small data size and presence of outliers.

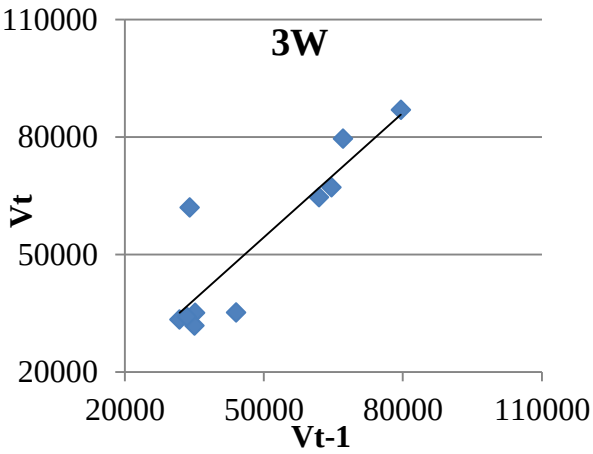
The **In**vestment and **Em**ployment model with A**AD**T are designated as INAD and EMPAD respectively. The INAD and EMPAD model are used for forecasting the AADT on Sachin – Palsana section for the horizon year 2021. The forecasting is carried out by using exponential growth rate to forecast investment and employment. The forecasts are carried out with optimistic (OGR), normal (NGR) and pessimistic (PGR) growth rate, where optimistic and pessimistic are taken as 125% and 75% of actual growth rate. Thus three scenarios are developed of each model for comparison. Growth rates used for investment are 42%, 33% and 34%, while for employment 30%, 24% and 18%. Till now we were modelling the growth of overall traffic while the growth of each vehicle category is needed to be addressed individually as the factors affecting them are different.

3.2 Time Series Based Traffic Forecasting Models

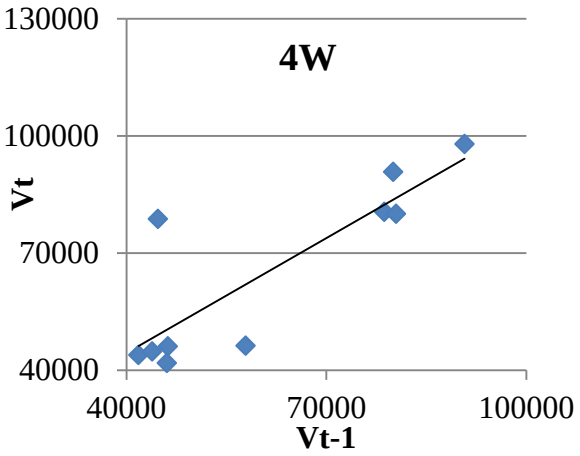
In this section, the traffic volume for each vehicle category at disaggregate level is forecasted using time series analysis technique. The need for disaggregate analysis arises to look for change in growth pattern of each vehicle category as the factors affecting them are quite different in nature. For example passenger vehicle are affected positively by employment generation and negatively by automation in industry whereas freight could increase more with automation. The traffic data contains the April and October month traffic from year 2001 to year 2012. Since it is easy to compare the influence of previous year's traffic on present year's traffic for same month the analysis is divided into two parts i.e. April month traffic and October month traffic analysis. The present year traffic volume for particular vehicle type is designated as V_t and previous year traffic is designated as V_{t-1}. The models developed for **Apri**l month **t**raffic are designated as **APRIT**, and the models developed for **Octo**ber month **t**raffic are designated as **OCTOT**. For forecasting purpose most recent value of predicted traffic is considered and using that value future traffic is forecasted by applying developed model of respective month. For analysis purpose the effect of last two years traffic on present year traffic is also considered but the relations were not coming significant, hence only Autoregressive 1 (AR1) models are introduced for each vehicle category.



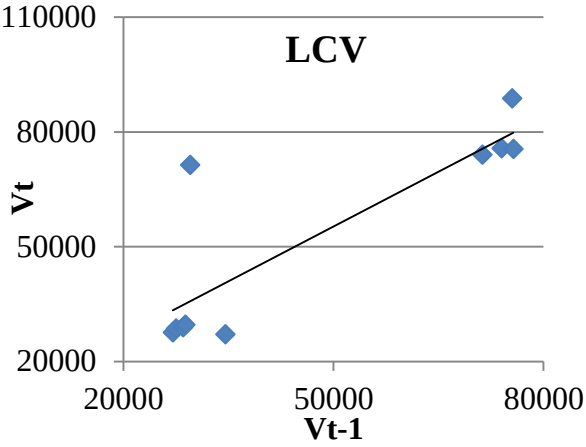
(a) Two Wheeler (2W)



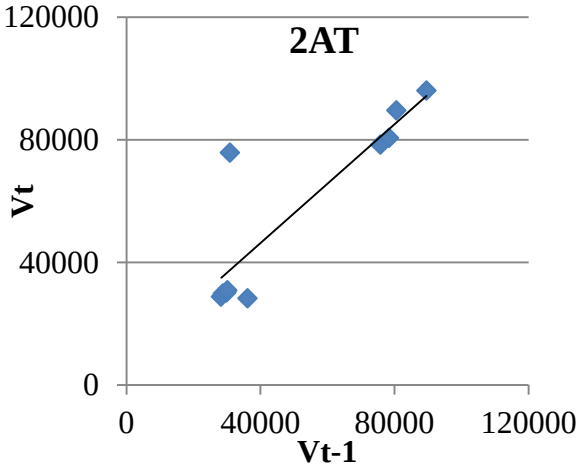
(b) Three Wheeler (3W)



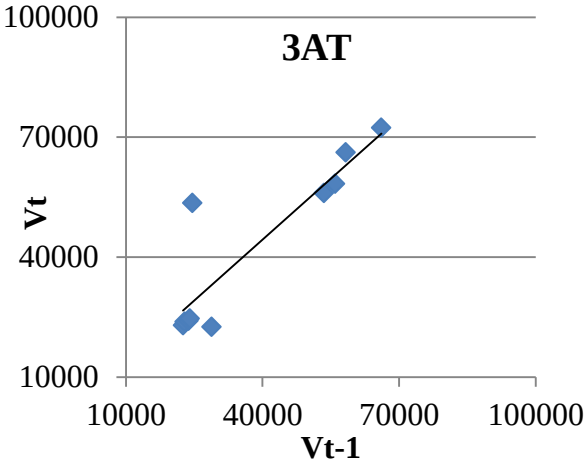
(c) Car (4W)



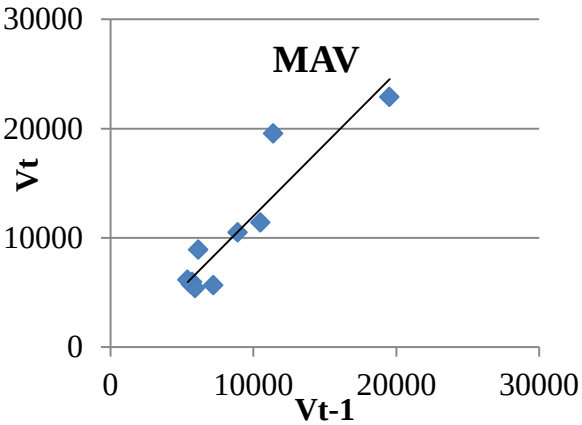
(d) Light Commercial Vehicle (LCV)



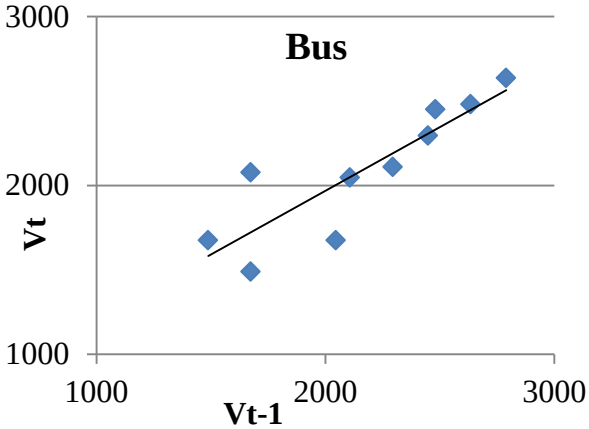
(e) 2-Axle Truck (2AT)



(f) 3-Axle Truck (3AT)

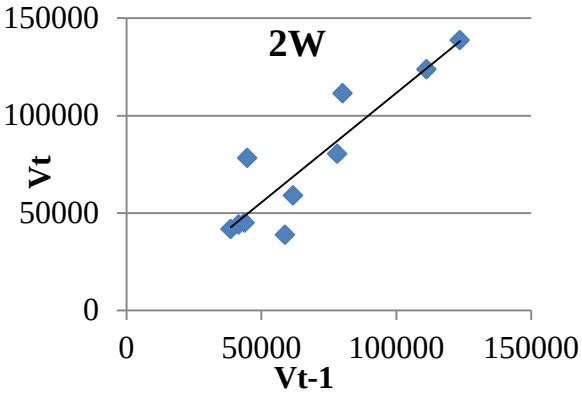


(g) Multi Axle Vehicle (MAV)

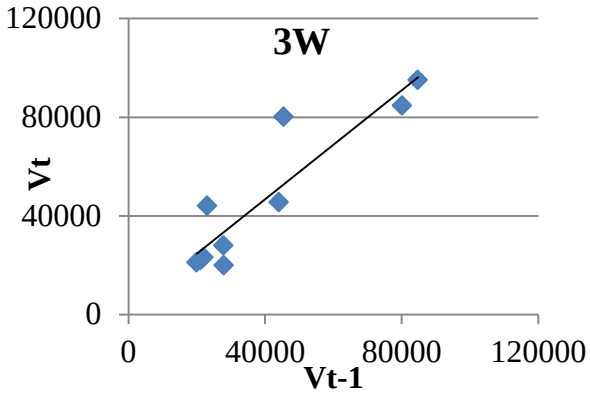


(h) Bus

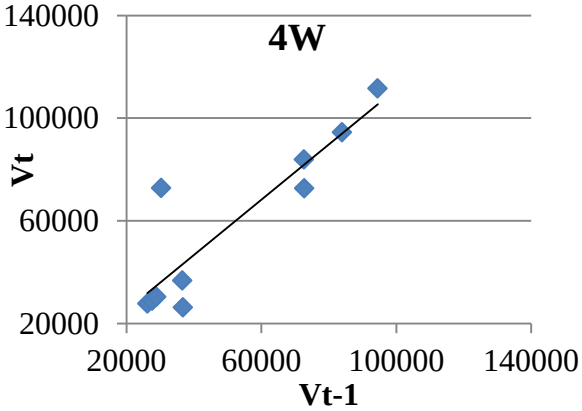
Figure 7. Scatter plot between predicted and observed traffic for APRIT model of each vehicle category (a) 2W, (b) 3W, (c) 4W, (d) LCV, (e) 2AT, (f) 3AT, (g) MAV and (h).Bus



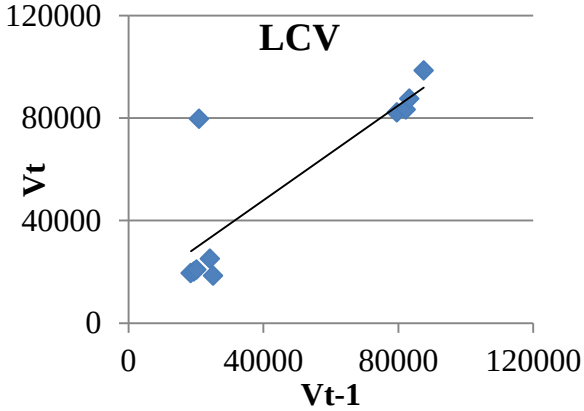
(a) Two Wheeler (2W)



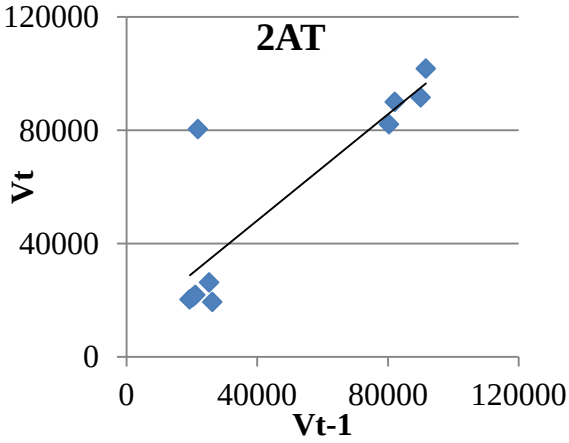
(b) Three Wheeler (3W)



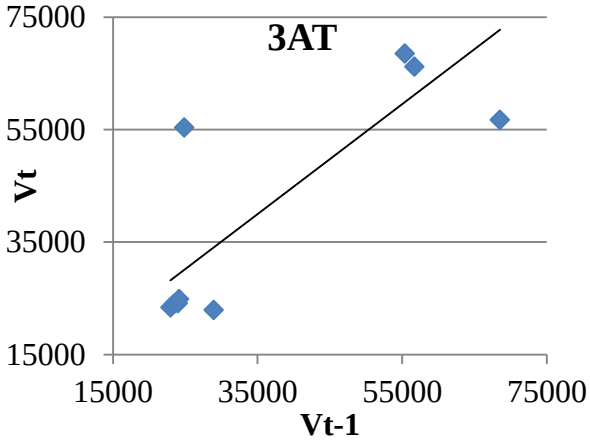
(c) Car (4W)



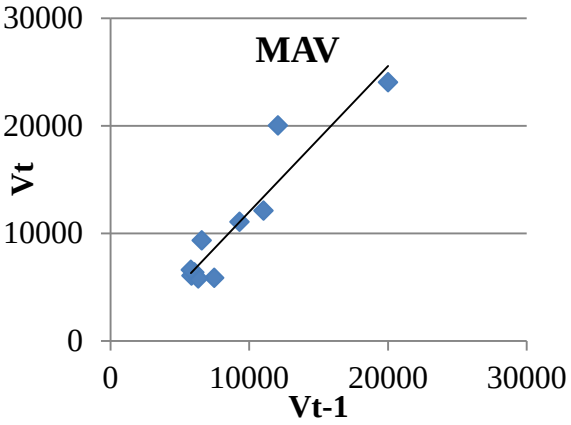
(d) Light Commercial Vehicle (LCV)



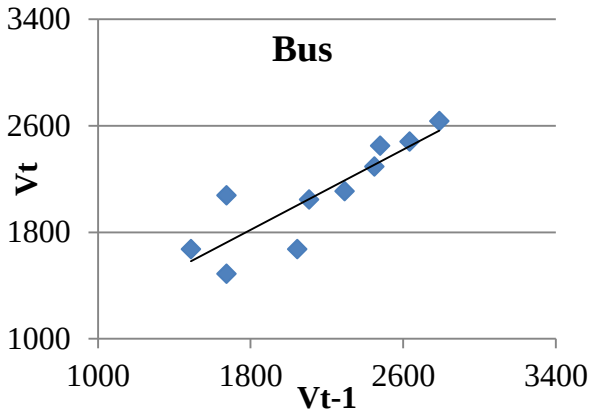
(e) 2-Axle Truck



(f) 3-Axle Truck



(g) Multi Axle Vehicle



(h) Bus

Figure 8. Scatter plot between predicted and observed traffic for OCTET model of each vehicle category (a) 2W, (b) 3W, (c) 4W, (d) LCV, (e) 2AT, (f) 3AT, (g) MAV and (h).Bus

Figure 7 and 8 show the scatter plots for all the APRIT and OCTET models of each vehicle category between V_t and V_{t-1}. The straight line in the plots are linear regression models tabulated in table 4 with the values of coefficient of regression and constant, the unexplained part. The data consist of outliers which could be seen in the plots.

Table 4. Models Summary

Time Series Model						
Vehicle	Constant	Coefficient	R^2	t-stat	p-value	MAPE (%)
APRIT Model						
2W	10298	1.1563	0.80	5.64	0.00	6.71
3W	1322	1.0608	0.78	5.34	0.00	13.47
4W	5226	0.9799	0.70	4.39	0.00	11.96
LCV	7489	0.9561	0.72	4.59	0.00	18.63
2-Axle Truck	7571	0.9688	0.76	5.03	0.00	19.45
3-Axle Truck	3693	1.0172	0.79	5.48	0.00	16.85
MAV	1156	1.3150	0.86	6.93	0.00	37.68
Bus	459	0.7548	0.86	6.92	0.00	2.81
OCTOT Model						
2W	913	1.1258	0.82	6.12	0.00	16.66
3W	2618	1.1038	0.83	6.25	0.00	22.88
4W	3490	1.0785	0.80	5.68	0.00	19.71
LCV	10874	0.9253	0.72	4.56	0.00	32.12
2-Axle Truck	10675	0.9368	0.74	4.78	0.00	31.25
3-Axle Truck	5766	0.9774	0.72	4.56	0.00	23.17
MAV	1569	1.3599	0.88	7.71	0.00	14.87
Bus	459	0.7548	0.76	4.98	0.00	4.27

As it could be seen from table 4 that ARPIT models are performing well in terms of MAPE, although APRIT model of MAV is showing highest MAPE value. High MAPE values are due to limited data points with vulnerability in data set. Lack of proper mechanism to collect and preserve traffic data in developing countries like India limits regress analysis for prediction.

The analysis shows high growth of LCV, truck and MAV by more than 200% in 10 years, and for 3W, car and 2AT by more than 130%. While bus shows negative growth rate of 27% which means passenger are transferring to private vehicle (2W and car) or intermediate public transport (IPT) like 3W. Thus the transport planners need to address this shift which could be helpful in reducing significant amount of vehicular traffic from highway. Traffic is predicted using these models up to horizon year of 2021 and later they are combined to get AADT in PCU. Thus the developed aggregate and disaggregate models could be applied for the predictions. Based on the forecast time series, traffic operating condition is analysed by evaluating hourly volume to capacity of the highway, as discussed in the nest section.

3.3 Volume to Capacity (V/C) Analysis

The concepts of capacity and level of service are important in planning, design and operation of highways. The operating condition for a highway is defined by a composite V/C ratio for the critical lane groups. An understanding of the highway capacity of roadway is highly important to a highway transportation engineer. By comparing the present traffic volume with capacity of existing highway, their adequacy or deficiency can be assessed. It is helpful to predict saturation point or year of existing highway so that it will help to plan widening of highway or a new alignment. The forecasted values of AADT are bidirectional values. So, as per Indian Road Congress (IRC) code, IRC-64-1990 the capacity of 6 lane divided road is 57500 PCU/day. By referring IRC 64-1990, the V/C and LOS values derived in the analysis are shown in table 3.

Table 5 LOS Thresholds by V/C

LOS	V/C
A	0 - 0.3
B	0.3 - 0.5
C	0.5 - 0.7
D	0.7 - 0.8
E	0.8 - 1.0

Forecasted traffic of INAD, EMPAD, APRIT, OCTOT and combined AADT model are used to perform V/C analysis to find out consequent level of service (LOS) pattern. Normal and pessimistic growth scenarios of INAD and EMPAD model are used for V/C analysis since optimistic growth is giving exaggerated results which is neither factual nor feasible. The capacity values given in IRC 64-1990 are 23 year old and does not meet the current condition due to which the Indonesian Highway Capacity Manual (IHCM) is also referred. The heterogeneous traffic pattern present in Indonesia is similar to Indian condition and thus capacity values of IHCM-Part II Interurban roads is used. Therefore for six lane divided road NH6 the estimated capacity is 11400 Light Vehicle Unit per hour (LVU/h). The LVU values of IHCM are used for calculating flow and Peak hour factor, K is assumed as 0.11 for calculating peak hour volume as per IHCM.

INAD and EMPAD model with NGR show high flow value due to which the highway is saturating in 2014 and 2018 as per IRC and IHCM guidelines respectively as shown in figure 9. While models with PGR show highway is saturating in 2016 and 2021 as per IRC and IHCM guidelines respectively. The forecast of INAD model are higher than EMPAD model due to high growth rate of investment than employment. Thus, these models will help

transport planners to get an insight of effect of economic development on existing transport infrastructure in region.

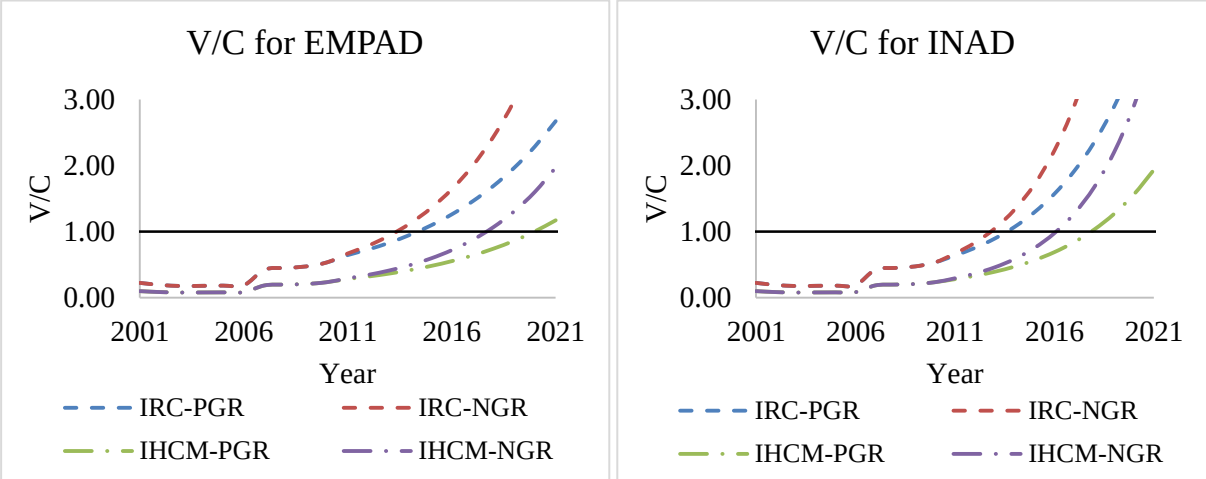


Figure 9. Graph displaying change in V/C pattern over analysis period for EMPAD & INAD model

The EMPAD and INAD models are giving very high traffic forecast which may not be the case in future and thus the growth rates are needed to be used judiciously. The high growth rates of employment and investment is mainly due to high investment in region since 2006 which has created lots of employment opportunity in region. This is the same time period when region experienced high decadal growth rate of 50%. Thus, growth in the region is likely to slow down relative to existing scenario.

APRIT, OCTOT and combined AADT model forecast are used for plotting LOS pattern as per IRC and IHCM guidelines. Traffic forecast of each model are converted into equivalent PCU and LVU values for V/C analysis and then plotted against time as show in figure 10.

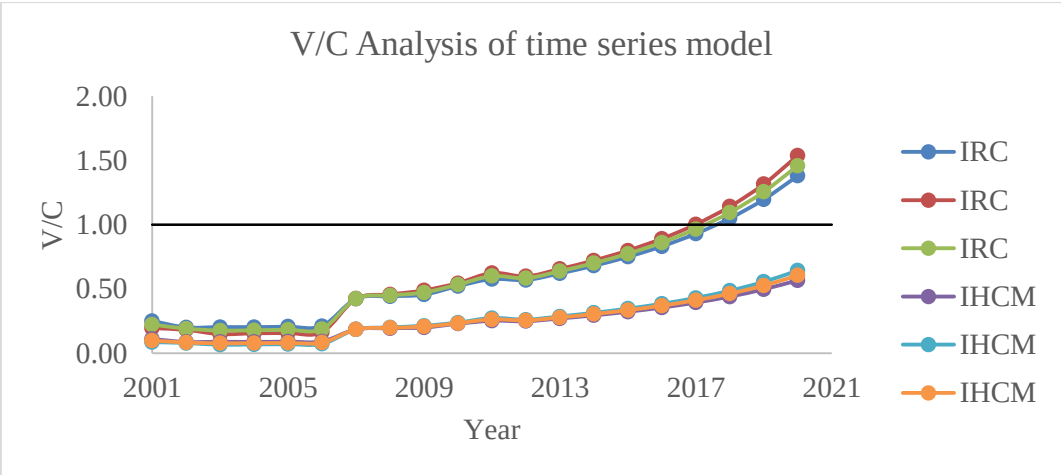


Figure 10. Graph displaying change in V/C pattern over analysis period for time series models

It could be clearly seen from figure 10, that IRC underestimate the capacity due to which highway is saturating in 2018 only, while IHCM shows highway in LOS C in horizon year 2021. This variation is due to capacity value proposed by IHCM which is high compared to IRC. The time series models forecast appear to be more rational compared to aggregate models in V/C analysis due to high growth values during the analysis period.

4. CONCLUSION

Socio-economic and demographic characteristics show high development and growth in region. Employment Multiplier worked out to find economic potential of region in terms of service employment generation shows high value. The employment multiplier of Surat district and Surat-Choryasi taluka is 2.33 and 3.04 respectively. This high value is mainly due to concentration of industries in the area. And INEMP model showed employment generation is dependent on investment in industrial sector of region and generates 20.6 employment opportunities with additional investment of each million INR.

This study has developed a methodology for assessing demand of rural road, national highway, for Indian conditions. The study is carried out on NH 6 which is originating in the study region and thus the traffic in the study section has one end of trip in study region (either production or attraction). Both Aggregate and disaggregate analysis is performed to quantify effect of socio-economic and demographic variables as well as individual growth of different vehicle type. The models developed are simple, understandable and easy to use.

Aggregate analysis shows that employment and investment models are performing better than other models. Employment and investment data is absolute and easy to procure than GDSP and GDP. Thus policy makers can use different scenarios of investment to find its effect on employment and traffic in region. To show policy change, 3 growth rates are taken PGR, NGR and OGR for both INAD and EMPAD model. The growth rates should be adopted wisely as it could lead to over or under estimation of future traffic as in our case. Disaggregate analysis is done using time series model of AR1 for each vehicle category for each month. The analysis shows high growth of LCV, truck and MAV than 2W, 3W, car and 2AT. While bus shows negative growth rate. Thus policy makers need to focus on high growth of LCV, truck and MAV and find out their root cause. The negative growth of bus should also be addressed to help in reducing private vehicle traffic on highway.

Finally, volume to capacity analysis was performed for forecasted traffic using aggregate and disaggregate models to quantify deterioration in level of service of the subject study section for horizon period. The results of V/C analysis holds promise to transportation planners for developing rational transport infrastructure development policies.

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