Future Traffic Prediction from Short Period Traffic Data

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Abstract. Prediction of future traffic is a complicated process which requires logical prediction methods and experience. The present study focused on the prediction of future traffic from the AADT data which is estimated from the one week continuous traffic data collected from the selected study area. State wise traffic contributions are estimated from the one-day number plate survey data and major states effecting the traffic in the study area are observed. The population data, vehicle registration data and economic data of the major states which are observed through number plate survey are used for the prediction of future traffic data. The vehicle growth rates were calculated using average vehicle registration growth rate method and nonlinear regression (power regression). Finally, the growth rates were decided according to the traffic design norms provided by NHAI. The year wise future traffic was predicted and presented in this paper from the year 2013 to 2040. The changes in Level of Service (LOS) of the NH 8A for four lane and six lane configuration is detailed for the future scenario.

1. Introduction

Roads are the major transport mode of any country’s transport system for both passenger and freight transport. The development of any country depends on the good connectivity of each and every corner of the country. India is a country where the 85% of total passenger traffic and more than 60% of freight traffic use road transport system [1]. As the country grows faster, a good strategic plan of developments in road systems are required. National and state high ways are the major corridors in Indian road transportation system. The growing countries like India, funding is a major problem in any development projects like high way construction. So, good statistical methods are required to predict the future traffic and to make development plans. Prediction of any natural phenomenon is not simple and straightforward. Even though prediction of future traffic though statistical methods is not an exact scientific process, many organizations are using the same methods with some adjustments in the growth rates of future traffic which requires proper experience and knowledge on the traffic flow of that particular corridor.

Generally, the future traffic can be estimated either from the past traffic record or by predicting the future traffic growth rates from the dependent parameter such as population, Per capita Income (PCI), Gross State Domestic Product (GSDP), Net State Domestic Product (NSDP) and growth of vehicle registration. Counting the continuous traffic data of number every year requires automatic counting systems, which is not economical and viable method for a wide country like India. So, prediction of future traffic from the limited traffic data is a better choice and economical.

Present study concentrated on prediction of future traffic from the AADT estimated from the one
week traffic data. The future traffic growth rates were estimated using growth rates of vehicle registration data and nonlinear regression process.

2. Study area and data collection
Revenue analysis is the ultimate study of any national development projects. The proposed development project should be in a position to generate the amount spent for the project. In the development of national high ways selection of toll plaza location is a key decision. The selected toll plaza location should have maximum toll-able traffic. In this present study, location nearer to the village named Rajoda, Ahmedabad district, Gujarat state, India which is 28 kilometers from Ahmedabad city on NH 8A (present NH 47), four lane National Highway was considered for the traffic analysis, presented in Fig. 1. Traffic volume count survey was conducted for a week and number plate survey was conducted for one working day of September month, year 2012. The collected traffic volume data was used to find out the AADT of the year 2012 and number plated survey data was used to find out the state wise traffic contribution. The estimated AADT data used as base input data for the present study.

3. Methods and analysis
The traffic growth of any nation depends on the economic and cultural development of the nation. The economic development can be assessed from SGDP, NSDP and PCI of the respective state or nation. The cultural development and population growth effect mainly the passenger traffic modes. The present analysis is concentrated on economic growth and population growth as main key parameter.
Massimiliano Gastaldi et. Al, [2] demonstrated method based on fuzzy theory that represents measures of uncertainty and road groups by fuzzy boundaries. Predefined road groups were assigned by road segment using Neural network methods. Study by Jung-Ah Ha and Ju-Sam Oh [3] estimated AADT from traffic volume data measured in short-term survey in a year using different methods and investigated more precise methods than previous studies which requires adjustment factors. The methods used can reduce error due to daily traffic variation while estimating AADT. Joe Flaherty [4] and Ha et al., [5] estimated AADT by clustering PTC points to apply adjustment factors. Ha et al., [5] proposed a method to assign them to the classified groups. The proposed method cannot reflect daily characteristics by group.
Lim et al., [6] analyzed different methods based on the same section, grouping of adjustment factors to estimate AADT of STC points and compared. The methods based on same section showed small error. Daily traffic variations cannot be reflected using this method even though
monthly factors and weekly factors applied. In addition to the method applying adjustment factors
AADT can be estimated using regression models, artificial neural networks and spatial statistics
models.
Xia et al., [7] and Zhao et al., [8] performed multi-variate regression analysis to estimate AADT
using spatial data. socio-economic variables and road characteristics were applied to the multi-
variate regression analysis and found that the applied variables affect AADT.
A spatial regression analysis was used by Eom et al., [9] and Heo et al., [10] to estimate AADT. Eom et al. [9] estimated the parameters of variogram using Euclidean distance in the application of spatial regression analysis (generalized kriging method). Instead of Euclidean distance Heo et al. [10] applied the shortest path to estimate the parameters of variogram which resulted improvement in accuracy of estimated AADT.
Spatial statistics models (kriging models) were used by Kim [11], Selby et al., [12] and Ha et al.,
[13] estimate AADT. Traffic volume of nearby roads and traffic volume of the previous year were
used as secondary variables in Kim's and Ha et al. studies respectively. These methods depends on the previous year traffic data, the present year data is not useful for estimation of AADT.
The estimated AADT data from the one week traffic data was considered as main input traffic data
to the present analysis. The population growth data, vehicle registration data, and economic growth
data of the states which were contributing the majorly are collected from the Open.
Government Data (OGD) Platform India. The collected data was used to calculate the future traffic
growth factors which are key factors in prediction of future traffic. The growth rates were analyzed
using vehicle registration growth rate method and regression analysis and the final decision of
growth rates were considered as per the norms given in manual of specifications and standards for
six laning of national highways, government of India, 2008. The detailed step wise procedure of prediction of future traffic is presented in the flow chart given in Fig. 2:

![Flow chart of the methodology for the present study](image)

**Fig. 2:** Flow chart of the methodology for the present study

### 3.1. Estimation of AADT

Estimation of AADT form the one week traffic volume requires seasonal traffic volume variation
data. The seasonal variations traffic volume can be found out by the past traffic volume data or
from the fuel sales data of the petrol stations nearer to the survey point. For the present study, the
seasonal variations were incorporated by finding the seasonal variation factors calculated from the petrol sales data. The month in which traffic volume surveys were conducted was considered as base month for calculating the monthly seasonal variation of traffic volume. The obtained AADT of individual vehicle was converted to passenger car units (PCU) and used to predict the future traffic volumes.

3.2. State contribution
Analysis of state wise contribution of traffic flowing through the study area is important to analyses the impact of state growth on the traffic growth. Gujarat, Rajasthan, Maharashtra and Haryana states are identified as the major traffic contributing states on the present study area from number plate survey. The percentage of state wise traffic contributions are calculated from the data collected by conducting one day number plate survey on working day of a week and the data is presented in Table 1. The major passenger and goods traffic were contributed by Gujarat state, Rajasthan and Maharashtra states goods traffic contribution was more compared to Haryana state contribution.

Table 1: State wise contributions of passenger and goods traffic

| State         | Motorbike | Auto | Car | Bus | 2 Axle | 3 Axle | M Axle | LCV | Mini LCV |
|---------------|-----------|------|-----|-----|--------|--------|--------|-----|---------|
| Gujarat       | 100       | 100  | 96  | 95  | 86     | 75     | 59     | 94  | 99      |
| Rajasthan     | 0         | 0    | 2   | 2   | 3      | 8      | 23     | 2   | 0       |
| Maharashtra   | 0         | 0    | 2   | 2   | 8      | 12     | 11     | 3   | 1       |
| Haryana       | 0         | 0    | 1   | 3   | 5      | 7      | 1      | 0   | 0       |

3.3. Growth rate analysis through vehicle registration data
Identifying the traffic growth rates from the vehicle registrations data is a direct method. Even though the analysis of traffic growth rates from the vehicle registrations data is straight forward method, it involves lots of uncertainties. From the observation of 11 years (from year 2001 to 2011) vehicle registration data, it was observed that the growth rates are not following the continuous increase in trend, the growth rates may follow negative trends for some period of years. Average growth rates were used for the present analysis to overcome the uncertainties in the vehicle registration data. The calculated average growth rates from the vehicle registration data of the major traffic contributing states are given in Table 2.

Table 2: Average growth rates obtained from vehicle registration data.

| State         | Average Growth Rate (%) |
|---------------|-------------------------|
|               | Motorbike | Auto | Car | Bus | Trucks |
| Gujarat       | 9.15       | 8.13 | 9.94 | 3.59 | 6.74   |
| Rajasthan     | 11.30      | 9.00 | 11.6 | 4.70 | 8.98   |
| Maharashtra   | 10.00      | 3.95 | 10.33| 1.88 | 7.13   |
| Haryana       | 11.50      | 14.25| 15.77| 26.50| 8.06   |
3.4. Regression model

The uncertainties in the average growth methods, some suitable methods are required to overcome the drawbacks of average growth methods and to predict the growth rates in a scientific way. Regression models are one of the most popular methods of analysis of complicated physical problems which involves lots of uncertainty. The regression models basically correlate the factors effecting the physical problem and estimates the effect of that particular factor or factors on the physical problems. Generally researchers tried linear regression, multiple linear regression and different nonlinear regression models to predict the growth rates of vehicles. The nonlinear regression models are better models when compared to linear regression models to analyze the natural physical phenomenon. The present study is followed the nonlinear regression (power regression) model to analyze the vehicle growth rates. The regression analysis basically needs proper understanding of the physical problem and the effecting parameters. In the present analysis population growth, PCI, NSDP and GSDP are considered as the basic parameters which are effecting the growth of vehicles, but the growth of truck vehicles does not depends on the population growth. So, population growth was not considered to calculate the truck vehicle growth through regression analysis. The following power regression model (equation 1) is considered to estimate the vehicle growth rates.

\[ V = a(x)^b \] \hspace{1cm} (1)

Here,

\( V \) = Vehicle type (dependent variable)
\( x \) = Population/ PCI/GSDP/NSDP (independent variable)
\( a \) = Constant
\( b \) = Elastic constant

The nonlinear models can be transformed to linear models by using simple transformation technics. The above equation 1 has transformed to linear model by introducing Ln on both sides of the equation as shown in equation 2.

\[ \text{Ln} (V) = \text{Ln} (a) + b \text{Ln} (x) \] \hspace{1cm} (2)

The elastic constants of the each vehicle type can be find out using the least square error method with respect to all the depending variables. The elastic constants of cars with respect to population, PCI and NSDP are plotted in Fig. 3.
The population, PCI, NSDP and GSDP data was collected for 11 years (from year 2001 to 2011) to calculate the average growth rates of respective data. The obtained average growth rates cannot be used directly to predict the vehicle growth rates due to the uncertainties in the population, PCI, NSDP and GSDP growth data. So the obtained growth rates should be corrected by multiplying the corresponding elastic constant obtained from the regression analysis. The obtained growth rated and the corresponding correlation coefficients of Gujarat state are given in Table 3. Similarly, the growth rates of different vehicle types were calculated for the each state which identified earlier state wise contribution analysis. The obtained growth factors of each state are used to calculate the effective growth factors of individual vehicle types.

Table 3: Growth rates form the regression analysis of Gujarat state

| Vehicle Type | Growth Rate | R² Value |
|--------------|-------------|----------|
|              | Population  | PCI      | NSDP    | Population | PCI | NSDP |
| Motorbike    | 9.29        | 9.10     | 9.15    | 0.99       | 1.00 | 1.00 |
| Auto         | 8.45        | 8.29     | 8.34    | 0.98       | 0.99 | 0.99 |
| Car          | 9.80        | 9.58     | 9.63    | 0.99       | 0.99 | 0.99 |
| Bus          | 4.76        | 4.86     | 4.86    | 0.73       | 0.80 | 0.98 |
| Trucks       | ---         | 6.20     | 6.25    | ---        | 0.97 | 0.98 |

4. Results
Selection of growth rates is a tricky process which involves the knowledge on vehicle type and economical and social parameters. In the present analysis vehicle growth rates were obtained from the population, PCI, NSDP and GSDP growth data. While selecting the obtained growth rates, the growth rate obtained from the PCI data was selected for both motorbike and car vehicle types because the personal transport modes always depends on per capita income. The growth of public transport depends mainly on population growth, the growth rates obtained from population data were used to find out growth rates of auto and bus vehicle types. The growth of any goods vehicles depends on the industrialization and economic development of any nation which impacts the NSDP and GSDP. The growth rates obtained from the NSDP and GSDP data were used to calculate the growth rates of truck vehicle types. Finally the average of growth rates obtained from the vehicle registration data and regression analysis are considered along with state wise traffic contribution factors. The final growth factors were used from Table 4 which were obtained from equation 3.

\[ FGFI = \sum_{i}^{n} S_i AGFI \]  

Here,
\( FGFI \) = final growth factor of \( i^{th} \) vehicle type
\( S_i \) = State wise traffic contribution factor (From Table 1) of \( i^{th} \) vehicle type
\( AGFI \) = Average growth rate obtained from vehicle registration data and regression analysis of \( i^{th} \) vehicle type
\( n \) = Number of vehicle types
Table 4: The final growth rates Obtained from the analysis using the data base from year 2001 to year 2011.

| Data Year | Motor bike | Auto | Car | Bus | 2 Axle | 3 Axle | M Axle | LCV | Mini LCV |
|-----------|------------|------|-----|-----|--------|--------|--------|-----|---------|
| 2001-2011 | 9.2        | 8.3  | 9.8 | 4.6 | 6.6    | 6.8    | 7.3    | 6.5 | 6.4     |

4.1. Growth rates adopted according to NHAI norms

Even though the growth rates were calculated from the analytical methods, the actual future growth rates never follow the analytical growth rates due to several reasons like transition of vehicle types from one mode to another mode, change of mode of transport from road to rail mode due to improvements in railway systems, new government policies, changes in fuel rates, changes in vehicle rates, developments in port systems etc. So, the prediction of future traffic requires some adjustments in future growth rates to overcome the uncertainties in future. The National Highway Authority of India has given some norms to design the traffic in manual of specifications and standards for six laning of national highways, government of India, 2008. According to the NHAI manual the growth rates obtained from the analysis can be used to the next five tears turn from the year of traffic data considered for the analysis. The future growth rates should reduce by 2% for all the vehicle types in every five years turn and the growth rates of any vehicle type should not be less than 5% in any year. By incorporating the NHAI traffic design norms, the future vehicle growth rates are adopted as given in Table 5.

Table 5: The modified future vehicle growth rates (%) as per NHAI norms.

| Year       | Motor bike | Auto | Car | Bus | 2 Axle | 3 Axle | M Axle | LCV | Mini LCV |
|------------|------------|------|-----|-----|--------|--------|--------|-----|---------|
| 2012-2015  | 9.2        | 8.3  | 9.8 | 5.2 | 6.6    | 6.8    | 7.3    | 6.5 | 6.4     |
| 2015-2020  | 7.2        | 6.3  | 7.7 | 5.2 | 5.1    | 5.3    | 5.6    | 5.1 | 5.0     |
| 2020-2025  | 5.2        | 5.0  | 5.7 | 5.1 | 5.0    | 5.0    | 5.0    | 5.0 | 5.0     |
| 2025-2030  | 5.0        | 5.0  | 5.0 | 5.0 | 5.0    | 5.0    | 5.0    | 5.0 | 5.0     |
| 2030-2035  | 5.0        | 5.0  | 5.0 | 5.0 | 5.0    | 5.0    | 5.0    | 5.0 | 5.0     |
| 2035-2040  | 5.0        | 5.0  | 5.0 | 5.0 | 5.0    | 5.0    | 5.0    | 5.0 | 5.0     |

4.2. The predicted future traffic

Prediction of future traffic is required to study the technical and financial viability of the national highway. Design of highways requires stage wise construction to save the economy. The predicted traffic will be used to develop the future construction plans and to estimate the revenue can generate through the project. In the present study, the estimated AADT of the year 2013 was used as base traffic data to predict the future traffic. The future traffic for each vehicle type in terms of passenger car units was calculated using the equation 4 and presented in Table 6.

\[ AADT_{ij} = GR_{ij} \times AADT_{ij-1} \ldots... (4) \]

Here,
AADT\(_{ij}\) = AADT of \(i^{th}\) vehicle type and \(j^{th}\) year (2014 ≤ \(j\) ≤ 2040)
GR\(_{ij}\) = Growth rates of \(i^{th}\) vehicle type and \(j^{th}\) year from Table 5
AADT\(_{ij}\) = AADT of \(i^{th}\) vehicle type and (\(j-1\)\(^{th}\) year
Table 6: The predicted future traffic for each vehicle type in PCUs.

| Year | Motorbike | Auto | Car | Bus | 2 Axle | 3 Axle | M Axle | LCV | Mini LCV | Total Traffic (PCU) |
|------|-----------|------|-----|------|--------|--------|--------|-----|---------|-------------------|
| 2012 | 2600      | 3936 | 7744| 3790 | 4039   | 3813   | 5646   | 1224| 788     | 33580             |
| 2013 | 2838      | 4263 | 8502| 3986 | 4306   | 4073   | 6055   | 1303| 839     | 36166             |
| 2014 | 3099      | 4616 | 9333| 4192 | 4591   | 4352   | 6495   | 1388| 892     | 38959             |
| 2015 | 3383      | 5000 | 10246| 4409 | 4895   | 4649   | 6966   | 1478| 949     | 41975             |
| 2016 | 3626      | 5315 | 10140| 4636 | 5147   | 4894   | 7356   | 1553| 997     | 44564             |
| 2017 | 3888      | 5649 | 11895| 4875 | 5411   | 5153   | 7767   | 1632| 1047    | 47317             |
| 2018 | 4167      | 6005 | 12817| 5126 | 5689   | 5425   | 8202   | 1714| 1099    | 50245             |
| 2019 | 4467      | 6384 | 13809| 5390 | 5981   | 5711   | 8662   | 1801| 1154    | 53360             |
| 2020 | 4789      | 6786 | 14879| 5667 | 6288   | 6013   | 9147   | 1892| 1212    | 56674             |
| 2021 | 5038      | 7125 | 15734| 5958 | 6603   | 6314   | 9604   | 1987| 1273    | 59635             |
| 2022 | 5300      | 7481 | 16638| 6264 | 6933   | 6629   | 10084  | 2086| 1336    | 62752             |
| 2023 | 5576      | 7856 | 17594| 6585 | 7280   | 6961   | 10588  | 2191| 1403    | 66033             |
| 2024 | 5866      | 8248 | 18605| 6923 | 7644   | 7309   | 11118  | 2300| 1473    | 69486             |
| 2025 | 6171      | 8661 | 19674| 7278 | 8026   | 7674   | 11674  | 2415| 1547    | 73119             |
| 2026 | 6479      | 9094 | 20660| 7650 | 8427   | 8058   | 12257  | 2536| 1624    | 76785             |
| 2027 | 6803      | 9548 | 21695| 8041 | 8848   | 8461   | 12870  | 2663| 1706    | 80635             |
| 2028 | 7143      | 10026| 22782| 8452 | 9291   | 8884   | 13514  | 2796| 1791    | 84678             |
| 2029 | 7501      | 10527| 23923| 8884 | 9755   | 9328   | 14189  | 2936| 1880    | 88923             |
| 2030 | 7876      | 11053| 25122| 9338 | 10243  | 9794   | 14899  | 3083| 1974    | 93382             |
| 2031 | 8269      | 11606| 26378| 9813 | 10755  | 10284  | 15644  | 3237| 2073    | 98059             |
| 2032 | 8683      | 12186| 27697| 10312| 11293  | 10798  | 16426  | 3399| 2177    | 102971            |
| 2033 | 9117      | 12796| 29081| 10837| 11858  | 11338  | 17247  | 3569| 2286    | 108129            |
| 2034 | 9573      | 13436| 30535| 11389| 12451  | 11905  | 18109  | 3747| 2400    | 113545            |
| 2035 | 10051     | 14107| 32062| 11969| 13073  | 12500  | 19015  | 3934| 2520    | 119232            |
| 2036 | 10554     | 14813| 33665| 12575| 13727  | 13125  | 19966  | 4131| 2646    | 125202            |
| 2037 | 11082     | 15553| 35349| 13213| 14413  | 13782  | 20964  | 4338| 2778    | 131471            |
| 2038 | 11636     | 16331| 37116| 13883| 15134  | 14471  | 22012  | 4554| 2917    | 138054            |
| 2039 | 12218     | 17148| 38972| 14587| 15891  | 15194  | 23113  | 4782| 3063    | 144966            |

4.3. The predicted traffic data by Gujarat infrastructure development board (GIDB)

Gujarat Infrastructure Development Board (GIDB) had conducted traffic surveys in the year 2003 to predict the future traffic in the National Highway (NH 8A). The GIDB conducted many locations on the NH 8A, the data provided for the location 15 km away (to words Rajkot, Gujarat) from the present study area is used to validate the present study. The vehicle growth rates were calculated using the Econometric Method, Trend Growth of past traffic data and Confusion Assessment Method (CAM). The results obtained by the present study are having good aggregation with the results obtained using Econometric Method provided by Gujarat Infrastructure Development Board. The comparison of the present study results and GIDB results are plotted in Fig. 4.
4.4. Volume study

The traffic volume studies are important to improve the stage wise capacity of the any highway. Stage wise development plan can be prepared because construction of any highways requires lot of money. Generally, the capacity of any highway can be improved by providing, earthen shoulders in first stage, paved shoulders in second stage and extra lane in final stage of construction. The stage wise development plans requires the future traffic data which is predicted from the present study. From the standards provided in Highway Capacity Manual, Transportation Research Board, Washington, D.C. (2016) [15], the existed four lane (NH 8A) with paved shoulders is having the maximum capacity of 79600 PCU/day. According to the NHAI standards any national highway should not cross the level of service ‘C’ (LOS-C) to maintain the free flow (100 km/h) traffic service. From the predicted traffic volume data, the changes in level of services and the requirement of six lane configuration in future scenario of the NH 8A is detailed in Table 8.

Table 7: Daily service volume and capacity table for two way highways [15]

| Area type | Terrain | AADT (PCUs/day/Lane) | LOS (A-C) | LOS (D) | Capacity / LOS - E |
|-----------|---------|----------------------|-----------|---------|--------------------|
| Urban     | Level   | 14,400               | 17,500    |         | 19900              |
| Urban     | Rolling | 13,700               | 16,700    |         | 19000              |
| Rural     | Level   | 12,100               | 14,800    |         | 16800              |
| Rural     | Rolling | 11,000               | 13,400    |         | 15200              |

Table 8: The predicted level of services of NH 8A (NH 47) at free flow condition.

| Level of service | Year of Reaching Level of service |
|------------------|----------------------------------|
|                  | 4 - Lane highway | 6 - Lane highway |
| LOS (C)          | 2021               | 2030              |
| LOS (D)          | 2015               | 2034              |
| Capacity / LOS - E | 2028            | 2036              |

Fig. 4: Comparison of predicted traffic from the present study and GIDB [14].
5. Conclusions
The following conclusions are drawn from the present study.

- The average growth rates estimated from the population data, PCI data and NSDP data are having good aggregation with each other for each individual vehicle type.
- The predicted future traffic volumes are having good aggregation with the data provided by Gujarat Infrastructure Development Board (GIDB).
- The existed NH 8A attains LOS - C in the year 2021 and reaches its full capacity in the year 2028. So transition of four lane to six lane is required in 2021 to maintain the free flow condition.
- The developed six lane NH 8A attains LOS - C in the year 2030 and reaches its full capacity in the year 2036. So transition of six lane to eight lane is required in 2030 to maintain the free flow condition.
- The predicted traffic volume can be used to estimate the financial viability development of four lane to six lane of NH 8A national highway.

Notations/abbreviations
AADT = Annual Average Daily Traffic
GIDB = Gujarat Infrastructure Development Board
GSDP = Gross State Domestic Product
LOS = Level of Service
NHAI = National Highway Authority of India
NSDP = Net State Domestic Product
Ln = Natural logarithm (log_e)
PCI = Per capita Income
PCU = Passenger Car Unit
R^2 = Correlation coefficient

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