EVALUATION OF TRAFFIC FORECASTING ACCURACY IN ROAD PROJECTS IN SRI LANKA

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Degree of Master of Engineering

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DECLARATION OF THE CANDIDATE AND SUPERVISOR

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ABSTRACT

Evaluation of traffic forecasting accuracy in road projects in Sri Lanka

Traffic forecasting is a significant process carried out in early stage of many transport development projects. To implement such project, it is inevitable to have benefits whilst been a feasible option. As this traffic forecast directly dealt with benefit calculations, the accuracy of forecast needs to be in high standard.

There are various method and tools to forecast traffic according to past studies. Growth factors, Trend line and Time series analysis, Traffic demand Models and Simulation models are some of them. Even though models and other methods are calibrated in the design stage, very few studies carried out to evaluate the accuracy of forecast in post construction stages.

In this research traffic forecast accuracy of some national highways and Three Expressways in Sri Lanka are evaluated. Southern Expressway, Outer Circular Expressway and Colombo-Katunayake Expressway are the three expressways and those are analyzed separately. Difference between forecast traffic and actual traffic is calculated w.r.t actual traffic and inaccuracy for each road sections was obtained. Forecasted traffic data was obtained by feasibility reports of highways and expressways which are gathered from Road Development Authority and University of Moratuwa. Actual traffic data was found from traffic counts done by University of Moratuwa and available data in RDA.

Furthermore, factors that influence mostly on forecast accuracy are discussed. In Sri Lanka the utmost reason for Over/Under estimation is difference between estimated and actual road network considered in forecast method. Change of forecast accuracy with respect to forecast method and forecast years were plotted.

Key words: Traffic forecast, Forecast accuracy, Models, Expressways

ACKNOWLEDGEMENTS

Foremost all, I would like to express my deep and sincere gratitude to my research supervisor Dr. H. R. Pasindu, in Department of Civil Engineering for giving me the opportunity to do the research and confer invaluable guidance throughout this research. His motivation, vision and sincerity have greatly evoked me. He has shown me the procedure to do the research and taught me to exhibit the research confidently. It was a great privilege and honor to work and study under his supervision.

I would also wish to express my gratitude to all Mangers, Engineers and staff members of Road Development Authority and all Staff members, Research students and Non-academic staff members of Civil Engineering department, University of Moratuwa for arranging relevant data and other materials to outmatch my research. Without their cooperate support this would not be successfully completed.

I am extending my thanks to research colleagues and friends those who have helped me and gave me immense support to complete this research

Last but not least I would like to thank my beloved family who have always behind me and hearten me in every single step of my life.

Thank You.

TABLE OF CONTENT

DECLARATION OF THE CANDIDATE AND SUPERVISOR i

ABSTRACT ii

ACKNOWLEDGEMENTS iii

TABLE OF CONTENT iv

LIST OF FIGURES vi

LIST OF TABLES vii

LIST OF ABBREVIATIONS viii

1. INTRODUCTION 1

1.1 Background 1

1.1.1 Traffic forecast 1

1.1.2 When we need Traffic forecast 1

1.1.3 Need of accurate Traffic forecast 2

1.2 Research overview 3

1.2.1 Research scope 3

1.2.2 Research importance 3

1.3 Objective 4

2. LITERATURE REVIEW 5

2.1 Traffic forecasting Methods & Tools 5

2.1.1 Traffic Forecast Models use in Sri Lanka 10

2.2 Traffic forecasting accuracy calculation methods 12

2.2.1 Traffic forecasting accuracy 12

2.2.2 Traffic forecasting accuracy calculation methods 13

2.3 Past studies on Traffic forecasting accuracy 16

2.4 Model Calibration and Validation 25

3. METHODOLOGY 28
3.1 Traffic data for National Highways 28
3.1.1 Details of selected road projects 28
3.1.2 Forecast details 29
3.1.3 Forecast traffic data 30
3.1.4 Actual traffic data 31
3.2 Traffic data for Expressways 33
3.2.1 Details of selected Expressway projects 33
3.2.2 Forecast details 34
3.2.3 Forecast traffic data 35
3.2.4 Actual traffic data 36
3.3 Calculation of Forecast inaccuracy 38
4. TEST RESULTS AND DISCUSSION 39
4.1 Analysis of forecast accuracy in Highways 39
4.1.1 Probable reasons for over estimations in A8, A10, AB10, AB29 40
4.1.2 Probable reason to underestimations in A19 and AB26 43
4.2 Analysis of forecast accuracy in Expressways 44
4.3 Outer Circular Expressway 46
4.3.1 Introduction 46
4.3.2 Probable Reasons for the overestimation 46
4.4 Colombo-Katunayaka Expressway 51
4.4.1 Introduction 51
4.4.2 Probable Reasons for Overestimation 52
4.5 Summary 54
4.6 Traffic forecasting accuracy w.r.t forecast years and forecast method in National Highways 55

5. CONCLUSIONS 57

6. RECOMMENDATIONS... 58

7. REFERENCES 59

LIST OF FIGURES

Figure 2-1: AADT vs Year - study of (Sliupas, 2006).. 5

Figure 2-2: Transport demand vs GNP - (Kartikeya Jha, 2013)................................. 6

Figure 2-3: Time series analysis of AADT vs Years - (Kartikeya Jha, 2013)............. 7

Figure 2-4: Average inaccuracies of road projects in Minnesota 16

Figure 2-5: Inaccuracy w.r.t Roadway functional classification 17

Figure 2-6: Inaccuracy w.r.t Volume ranges... 17

Figure 2-7: Distribution of PDFF (project level).. 21

Figure 2-8: Expected ranges of actual traffic (base model)...................................... 23

Figure 3-1: Selected Highways - Western Province 32

Figure 3-2: Selected Highways - Other Provinces.. 32

Figure 3-3: Traffic count in toll gates 36

Figure 4-1: Inaccuracies of traffic forecast in Highways.. 40

Figure 4-2: GDP growth rate 40

Figure 4-3: New vehicle registrations growth rate 41

Figure 4-4: Forecast growth rates vs Actual growth rates of Vehicle classes in AB10 42

Figure 4-5: Forecast growth rates vs Actual growth rates of Vehicle classes in A8, A10 and AB29 42

Figure 4-6: GDP growth rate from 2005 to 2015 43

Figure 4-7: Inaccuracies of Traffic forecast in Southern Expressway....................... 45

Figure 4-8: Inaccuracies of Traffic forecast in Outer Circular Expressway 45

Figure 4-9: Inaccuracies of Traffic forecast in Colombo-Katunayaka Expressway .. 45

Figure 4-10: Considered road developments in the model 47
Figure 4-11: Actual Expressway developments in analyze year 47
Figure 4-12: Urban centers 48
Figure 4-13: Trips from Urban centers through OCH and Normal highway............. 49
Figure 4-14: Proposed Expressway network 52
Figure 4-15: Route choice from Kandy, Kurunegala, Kegalle and Gampaha to BIA 53
Figure 4-16: Distance to different Town centers along A3 from Colombo............... 54
Figure 4-17: Forecast years vs MAPE – Growth Factor method (National Highways) 55
Figure 4-18: Forecast Method vs MAPE 56

LIST OF TABLES

Table 2-1: Results of trip generation model for Karachchi Transport Development Project 8
Table 2-2: Results of OLS regression model 18
Table 2-3: Summary statistics for forecast inaccuracies for toll roads 19
Table 2-4: Traffic-forecasting inaccuracies over time 19
Table 2-5: Forecast inaccuracy by forecast volume group (project level)................. 22
Table 2-6: Quantile regression results (actual count modeled as a function) 22
Table 2-7: Known sources of forecast inaccuracy for deep dives 24
Table 2-8: Validation checks for each step of modelling 26
Table 3-1: Details of selected road projects 28
Table 3-2: Details related to Forecast 29
Table 3-3: Forecast Traffic data of National Highways 30
Table 3-4: Actual traffic on selected National Highways.. 31
Table 3-5: Details of Expressways... 33

Table 3-6: Forecast traffic data of Expressways 35
Table 3-7: Actual traffic data of Expressways 37
Table 4-1: Inaccuracies of traffic forecast in Highways 39
Table 4-2: Corrected traffic volumes for A19 and A26 43
Table 4-3: Inaccuracies of traffic forecast in Expressways 44
Table 4-4: Distances to nearest interchanges from some Urban centers 50
Table 4-5: Summary of the analysis for Expressways and National Highways 54
Table 4-6: Analysis of Forecast error w.r.t. forecast duration 55
Table 4-7: Analysis of Forecast error w.r.t. Forecast method 56

LIST OF ABBREVIATIONS

AADT - Annual Average Daily Traffic

RDA - Road Development Authority

ARIMV - Auto-Regressive Integrated Moving Average

JICA - Japan International Cooperation Agency

STRADA - System for Traffic Demand Analysis

DTA - Dynamic Traffic Assignment

1. INTRODUCTION

1.1 Background

1.1.1 Traffic forecast

Traffic forecasting is an essential study carried out in various analytical decision-making stages. It characterized the traffic amount on a particular road section in a desired future year. It is required to have past traffic data and socioeconomic data to predict the future traffic flow.

1.1.2 When we need Traffic forecast

Traffic forecasting is mostly used in road development projects. In the early stage of the road projects to evaluate the feasibility it is needed to estimate number of vehicles that will use the particular road segment or proposed road.

In the design stage of the road projects traffic forecasting plays vital role as it is needed to evaluate ESAL values for Pavement designs and No of vehicles for Capacity designs.

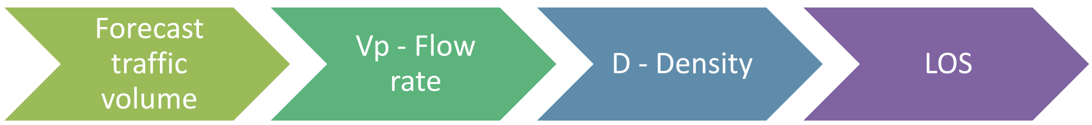
Instead of road projects for different types of Transport development projects use traffic forecast to analyze the situations. When introducing a new transport mode (LRT, MRT, etc.) the operating traffic should be estimated to evaluate the transport mode. And also, traffic forecast is used in Junction designing, Traffic planning and various transport management decision making stages.

Not only in the Transportation but also in Environmental studies, Economic studies and researches traffic forecast is a useful study. To predict the emissions from vehicles in desired year it is required to do a forecast the traffic. Economist use this forecast traffic for their calculations in socio-economic parameters.

1.1.3 Need of accurate Traffic forecast

Most of the road development projects implemented after evaluating the feasibility of the project. In other words, it is required to clarify whether the project provides necessary benefits for the spent amount. Main benefit from a road project is travel time saving and it is calculated estimating the vehicle population in the required year. So, if the forecast is not accurate then the benefit calculation may not explicit as it is. Sometimes an inaccurate forecast may result in huge waste of money as the expected outcomes would not be serve. Hence an accurate traffic forecast is much needed in feasibility studies of a road project.

Other main aspect of traffic forecast is in Capacity design and Pavement design of road. It may be a new road project or an upgrading project, however it is essential to carryout Capacity design and Pavement design. In the Capacity design most of the criteria depends on the operating vehicle volume. Forecast traffic volume is taken to determine LOS. And also, in the pavement design to determine the traffic class it is required to calculate ESAL value using estimated traffic.



Accuracy of forecast depends on various factors. Method of forecast, Parameters used, expected scenarios and Development patterns of towns are some of them. Unrealistic future conditions affect to the accuracy of forecast greatly.

1.2 Research overview

1.2.1 Research scope

In this research 17 number of National Highways and Three main Expressways are analyzed to observe traffic forecast inaccuracies. For national highways only “A” class roads are considered as it is difficult to find forecast data for lower grade roads. Southern Expressway, Outer Circular Expressway and Colombo Katunayake Expressways are the three expressways considered in this research.

Forecast traffic data for National highways and Expressways are gathered mostly from feasibility studies carried out prior to the implementation of road projects. For national highways some forecast traffic data was found from completion reports and analysis reports. Actual traffic data for desired years are collected from Road Development Authority and University of Moratuwa.

1.2.2 Research importance

Even though several studies were done regarding the Traffic forecast accuracy in other countries, it is hard to find a study for Sri Lanka context. This research evaluates forecast inaccuracies for some National Highways and Three Expressways in Sri Lanka. This research will help to find what are road projects overestimate and underestimate most. Further here discussed about the probable reasons for forecast inaccuracies. This will help to mitigate or eliminate the errors and uncertainties those are led to forecast inaccuracy.

Most of the developed countries keep descriptive data records regarding the transport related parameters like Vehicle ownership, Trip distribution and etc. Those will greatly help to forecast future traffic more accurately. Lack of necessary data also a reason to inaccuracy in traffic forecast as shown in the research study. So, it is recommended to record data that will be useful for planning purposes.

An accurate forecast will produce feasible output for road projects without underutilizing the allocated money.

1.3 Objective

The main objective of this research is to find out traffic forecast accuracy of some Highway and Expressway roads in Sri Lanka. And also, to analyze the accuracy of forecast with respect to forecast method and forecast period.

2.1 Traffic forecasting Methods & Tools

There are so many methods and tools available to predict the traffic forecasts. Among those, the most suitable method should be choose considering factors such as the size and scale of the project, the desired time period and the parameters and data available to determine the forecasts. Following methods and tools are used in routinely:

- Growth rates
- Time-series analyses
- Trend line analyses
- Travel demand models
- Traffic simulation models

1. Growth rates

Growth rate analysis is the basic and simple method of calculating the traffic in future year. Here past year's traffic data was analyzed and calculate the traffic growth. Sometimes additional parameters also used to calculate the growth factor such as growth of vehicle registration and growth of population etc.

E: g – In the study of (Sliupas, 2006) several methods are performed to obtain AADT for future years. The graph plotted to observe the growth rate and equation derived is shown below.

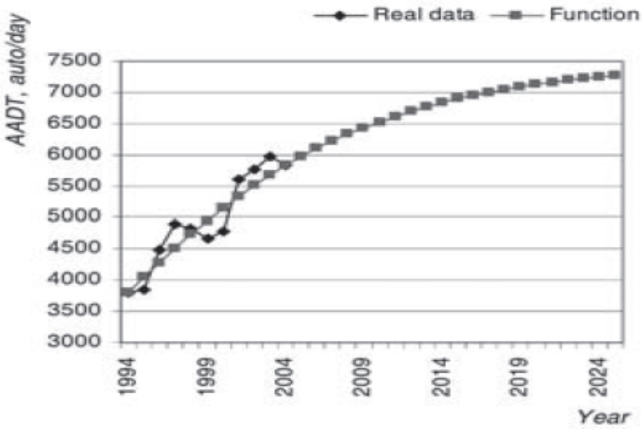


Figure 2-1: AADT vs Year - study of (Sliupas, 2006)

Derived equation - $\ln(E_t) = a + b * e^{\frac{-t}{10}}$ **2-1**

Growth rate - $\frac{-b}{10} * e^{\frac{-t}{10}}$ **2-2**

(Sliupas, 2006)

2. Trend line analyses

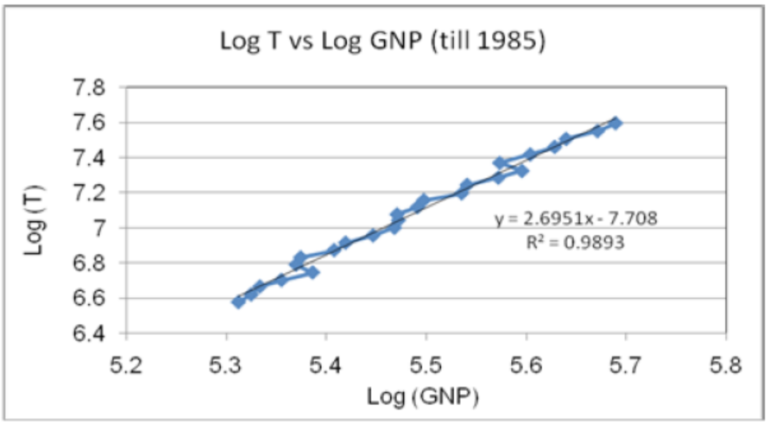
Relationship with traffic and the other different parameters is used in Trend line analyses. An equation is formed by analyzing the graph of traffic drafted with respect to different parameters.

e: g – $\log(T) = a + b * \log(GNP)$ **2-3**

Here, T - Transport demand

GNP - Gross domestic product

a & b - coefficients derived emphatically



(Kartikeya Jha, 2013)

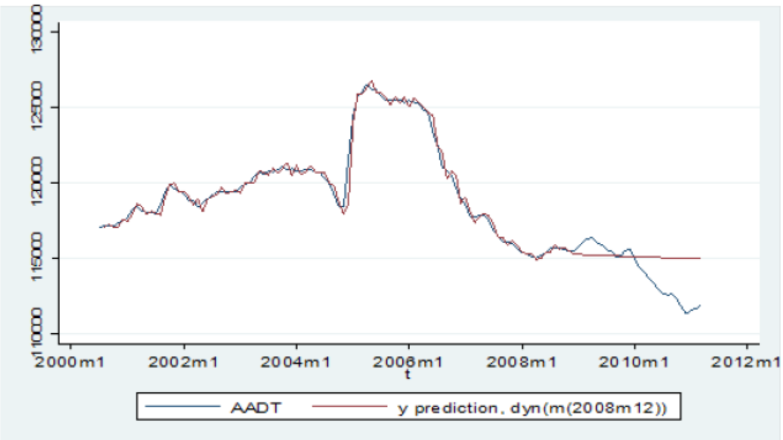
Figure 2-2: Transport demand vs GNP - (Kartikeya Jha, 2013)

3. Time-series analyses

A set of observations which are ordered in time is called as Time series. Observations are collected over equally spaced discrete time intervals. Ideally at least 50 observations are required for performing appropriate time series analysis (George E. P. Box, 2016). In the study conducted by (Kartikeya Jha, 2013), they have used Box and Jenkins methodology and analysis has been done using Auto-Regressive Integrated Moving Average (ARIMA) approach. Box and Jenkins method produce relatively high accurate forecast.

There are five steps in Box and Jenkins method

a. Checking for stationarity
b. Identification of parameter of the model
c. Estimation of parameters
d. Performing diagnostic checks
e. Forecasting



(Kartikeya Jha, 2013)

Figure 2-3: Time series analysis of AADT vs Years - (Kartikeya Jha, 2013)

4. Travel demand models

Travel demand models are sophisticated analyzing tool which is used in present context. There are many travels demand models available in different countries. A model requires many parameters to perform a forecast. So, depend on the data available to feed, models can be developed and calibrated.

The basic principle of modeling is four step modeling.

Those are:

- Trip generation /Attraction model
- Trip distribution model

- Model split model
- Trip Assignment model

Trip generation /Attraction model: - Trips which are generated and attracted when considering the relevant road section or transportation infrastructure. To find this generated traffic several socioeconomic data to be collected such as Employment, Population, Vehicle ownership and income etc. Relationship is developed w.r.t gathered socioeconomic parameters and total trips generated/attracted are quantified. Below show the results made from trip generation model done by JICA study team for Karachchi Transport Development Project report

Table 2-1: Results of trip generation model for Karachchi Transport Development Project

Model	Purpose	Population	Workers at resident place	Employees at work place	Students at resident place	Students at school place	Constant	Correlation Coefficient
Production	To Work		0.8133				2,574.4	0.907
	To School	0.0919			0.6065		1,559.2	0.864
	Business			0.0144			433.3	0.691
	Private	0.1115					1,542.3	0.684
	To Home	0.1691		0.0400		2.0038	5,263.5	0.860
Attraction	To Work	0.0188		1.2077			1,404.5	0.825
	To School					1.3441	910.0	0.927
	Business	0.0089		0.0043			820.9	0.545
	Private	0.1009		0.0105			2,995.6	0.510
	To Home	0.6061					4,916.8	0.874

Source: Prepared by the JICA Study Team

Trip Distribution model: - In this step, generated trips are distributed in specific zones. Origin-Destination matrix is produced and hence produces the trip distribution between selected zones by iterative method.

Modal Split model: - After obtaining Origin Destination trips from trip distribution model, those volumes are distributed in to several travel modes. Structure of modal choice, Transport modes to be selected and criteria for selection of modes are the key factors considered in this model share model.

e: g – For Karachchi Transport Development Project, JICA study team has considered following modal choices and obtain relationship for each mode.

Mode 01 $$R_{ij}^{Walk} = \frac{1}{e^{a \cdot d_{ij} + K}} \tag{2-4}$$

Mode 02 $$R_{ij}^{Public} = \frac{1}{1 + e^{a \cdot D_{ij} + b \cdot \left(\frac{t_{ijt}^{public}}{t_{ij}^{car}} \right) + c \cdot NCO_i + d \cdot NCO_j + K}} \tag{2-5}$$

Mode 03 $$R_{ij}^{Car} = \frac{1}{1 + e^{aD_{ij} + b \cdot \left(\frac{t_{ijt}^{car}}{t_{ij}^{motorcycle}} \right) + c \cdot CO_i + d \cdot CO_j + K}} \tag{2-6}$$

Trip Assignment model: - This is the last step of four step modeling. Here trips are assigned to each links depending on relevant assignment model. JICA STRADA model which is developed by JICA has two different models to assign the trips to links. Those are Incremental assignment and User equilibrium assignment.

5. Traffic simulation models

Traffic simulation models are the latest modeling tool for analyze traffic behavior and predict traffic patterns. Using these simulation models, it is easy to analyze and made decisions on transport planning according with the travel pattern specific for required region. There are three basic simulation models namely, Microscopic modeling, Macroscopic modeling and Mesoscopic modeling.

- **Microscopic modeling** – In Microscopic modeling, characteristics of various vehicle movements such as motorcycles, buses, cars and other vehicles are considered. This scale models can collect parameters like, Speed, Density, Flow, Travel and delay time, Shock waves, Stops, Pollution, Long queues and Fuel consumption. Different Types of

Microscopic models are lane-changing models, car-following model and gaps of the individual drivers.

- **Macroscopic modeling** - In macroscopic model, traffic stream is represented as whole and measured using characteristics like flow, density and speed.
- **Mesoscopic modeling** – Mesoscopic models are aggregation of both Microscopic and Macroscopic models. Platoon dispersion and vehicle platoon behavior are the two main Mesoscopic models. DTA (Dynamic Traffic Assignment) is a Mesoscopic simulation model use to forecast future traffic. Study carried out by (Mingqiao Zou, 2013) introduce DTPO (Dynamic Transportation Planning and Operations) which is also a DTA that has improved to temporal changes of traffic flow and optimizing integrated strategies. DTPO is applicable in recurrent and non-recurrent situations.

2.1.1 Traffic Forecast Models use in Sri Lanka

1. RDA Model (JICA STRADA package)

STRADA is abbreviation of "The System for Traffic Demand Analysis". JICA STADA package was used and a model is prepared by RDA that suits for National Road Network. Future traffic of the network is forecasted in this model according to the trip generation and attraction considering the socio-economic parameters of the area. This method is based on Four Step Modeling. That is

- Trip generation and Attraction
- Trip distribution
- Modal split
- Trip assignment

Normally future trip demand is estimated by Trip generation and attraction models. Those are typically a liner regression equation consists with some socio-economic parameters that are depending on the project and the area considered.

2. TRANSPLAN Model

TRANSPLAN model is developed by University of Moratuwa to analyze various features to develop better transportation network. TRANSPLAN produces several features such as:

- Physical road condition by links and nodes
- Socioeconomic data on DS division
- Traffic flow estimates by link for any present or future scenario
- Network efficiency parameters to investigate contribution of road improvements

TRANSPLAN calculated the future traffic estimates on three basic parameters.

1. Socioeconomic parameters
2. Transport policy
3. Highway network

In the traffic forecasting of Colombo – Katunayake Expressway this TRANSPLAN model were used. Socioeconomic parameters used in this study were

- Population
- Household
- Numbers of jobs in various categories
- Vehicle population etc.

Expressways considered in this study were

- Colombo – Katunayake Expressway
- Outer Circular Highway to city of Colombo and connected to CKE
- Southern Highway
- Colombo Kandy Alternate Highway up to Ambepussa

2.2 Traffic forecasting accuracy calculation methods

2.2.1 Traffic forecasting accuracy

Traffic Forecast is an uncertainty made in the basis of past patterns and available parameters. This forecast directly dealt with project implementation as feasibility of project depends on benefits in future that project serves. So, it is an obligatory requirement to perform the forecast in accurate manner.

There are several factors affecting the forecast accuracy

- Mismatching between the real future and predicted future
- Insufficient theory
- Inaccurate application of theory
- Calibration data
- Inadequate model specification
- Input variables
- Lack of spatial or temporal resolution
- Enumerate

The main reason for inaccuracies in forecast is difference between actual future and assumed future. If the road network assumed in modelling is not in the actual future road network, huge underestimations or over estimation will occur. Even the developments in land use predicted in the model will not be actually developed. In that case also trip generations and attractions may vary drastically.

Other main reason is lack of input data. In the modelling several parameters considered to produce traffic forecast. For each parameter different types of data need to be collected. Data unavailability or lack of data directly affect to the parameters considered in model.

2.2.2 Traffic forecasting accuracy calculation methods

After reviewing most of the researches done to evaluate the forecast accuracy, it can be concluded that there exist two systems to evaluate the accuracy of the traffic forecasts. In the Traffic Forecasting Accuracy Assessment Research (NCHRP report 934) that has been conducted under the National Cooperative Highway Research Programme (Greg Erhardt, 2020) it is descriptively discuss about these two types of Forecast accuracy evaluating methods.

First approach is based on large number of data sets with forecast data and actual traffic data for corresponding forecast years. From this approach it is possible to compare the forecast traffic with respect to the actual traffic. And also, by analysing the data set it is possible to find the corelation of forecast accuracy with the data inputs, road facility type, method of forecast and forecast period. In the NCHRP report this approach is referred as Large-N analysis.

- **Large-N analysis**

  This analysis compares the forecast volume with the actual traffic count in the project operation. Previous studies define the forecast error between forecast traffic and the actual traffic in many ways.

  Some studies measure the error as forecast volume minus actual volume and positive values implies an overestimation. Other studies define the error as actual traffic volume minus forecast traffic volume and positive value implies an underestimation.

  Forecast error = Actual traffic volume – Forecast traffic volume; or

  Forecast error = Forecast traffic volume – Actual traffic volume

  A popular metric used to evaluate forecast accuracy is the Half-a-lane criteria. According to the Half-a-lane criteria, accurate forecast can be defined as the difference between forecast volume and the actual volume is less than half lane's capacity. If forecast volume is less than the road capacity by more than half lane capacity then the road would have been consisted with one fewer lane. And if forecast volume is greater than the road capacity by more than half lane capacity then the road needs an additional lane.

Forecast error may be represent as either the percentage of actual traffic or the percentage of forecast traffic. This is referred as Percent Difference from Forecast.

$$PDFF = \frac{Actual\ volume - Forecast\ volume}{Forecast\ volume} * 100\% \qquad \textbf{2-7}$$

Positive values of PDFF indicate underestimations and negative values indicate overestimation. Despite it is positive or negative some researches express the size of error by taking the mean absolute value of PDFF. It is called Mean Absolute Percentage Difference from Forecast (MAPDFF).

$$MAPDFF = \frac{1}{n}\sum_{i=1}^{n}|PDFF_i| * 100\% \qquad \textbf{2-8}$$

n – Number of projects

In a road project there may be different segments itself. So those segments may have different characteristics. It is better to analyse the forecast error of these segments separately other than having an aggregate result for entire project. Past studies have used Ordinary Least Square regression to examine the biases of forecast accuracy. In Ordinary Least Square regression the actual traffic volume is regressing as a function of forecast traffic volume.

Actual traffic volume = fn (Forecast traffic volume, descriptive variables)

Not only the biases but also the association of variables to the forecast accuracy distribution can be examined. As the forecast error is measured by MAPE in OLS regression, NCHRP research team propose Quantile regression as a substitution to OLS regression to assess the error for specific percentiles.

Second approach is a detailed analysis of particular transport project after reviewing related documents, surveys for before and after road project, detailed data collection and interviews with professional who involving in early stage of the project. It is kind of a case study which is particular for that project. Through this type of analysis researches can find out causes of forecast accuracy such as input errors, model errors, assumption errors, changes in project scope and etc. Advantages of this approach is researches and planners can have idea about assumptions made in the models and their reliability. And also, it reveals the strengths and weaknesses of that particular model. The main disadvantage of this approach is it is impractical to generalize the findings of the particular case study to other cases or analyses.

- **Deep dives**

NCHRP research team referred this approach as Deep dives. The deep dives accommodate to assess which elements of forecasts could be identified clearly as impacts for errors. In some traffic forecasts, growth rate of traffic was estimated using population growth rates and employment forecasts. But in actual scenario the population growth rate may not be grown as expected or employment distribution may be changed with some infrastructure development. In such cases this approach keenly looking at the causes to forecast error. Another main causes or forecast error is change in project scope or operational changes. Sometimes the part of the project would not be completed by the time of analysis. Then the estimated scenarios have been violated resulting huge inaccuracies with the traffic forecast. So, the Deep dives enable to these root cause findings of forecast inaccuracies. Unavailability of sufficient data narrows the possibility of carryout a Deep dive analysis.

2.3 Past studies on Traffic forecasting accuracy

- **"Post-construction evaluation of traffic forecast accuracy"** (Pavithra Parthasarathi, 2010)

  This study was carried out to evaluates the traffic forecast accuracy of recently completed road projects in Minnesota and identify the causes of inaccuracy in forecast.

  Forecast traffic data has been collected from Transportation Analysis Reports (TAR), Environmental Impact Statements (EIS) and other forecast reports produced by the Minnesota Department of Transportation (Mn/DOT) and Actual traffic data has been gathered from the Office of Traffic Forecasting & Analysis Section at Mn/DOT using the traffic count database. 76 numbers of projects were considered counting 3500 roadway points. Actual traffic data was gathered for 1765 numbers of roadway points out of these 3500 points. Analysis was done in three approaches namely Illustrative analysis, Quantitative analysis and Qualitative analysis.

  <u>Illustrative Analysis</u>

  Based on Bain and Plantagie (2004), traffic forecast inaccuracy was estimated as a ratio of the forecast traffic to the actual traffic. Actual traffic data was collocated for the forecast year. If ratio is less than zero it indicates Underestimation and if ratio is greater than zero it indicates Overestimation.

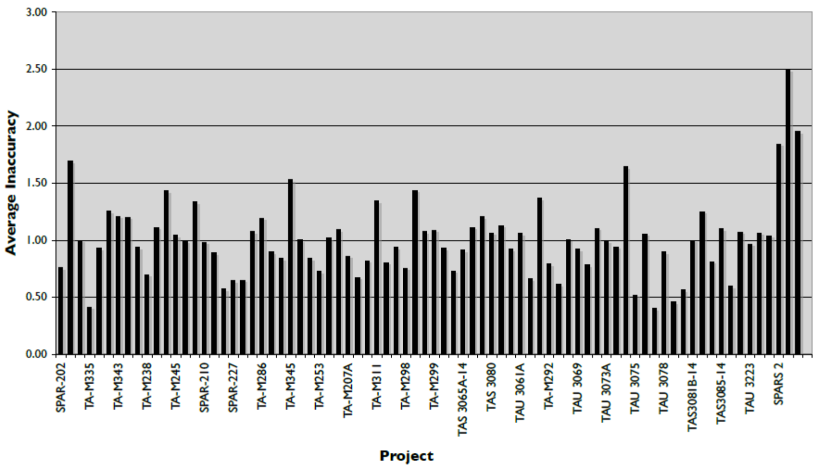


Figure 2-4: Average inaccuracies of road projects in Minnesota

50% of the roads have shown inaccuracy less than 1.0 which means underestimation and 45% of the roads have shown inaccuracy more than 1.0 implying overestimation. When considering the frequency distribution, it has shown 56% underestimation trend and 44% overestimation trend. Highest frequency of 46% is lied between the -0.5 to 0.0.

The average inaccuracy was analyzed with respect to five functional classification of roadway segments. Those are Freeway, Divided arterial, Undivided arterial, Expressways and Collectors.

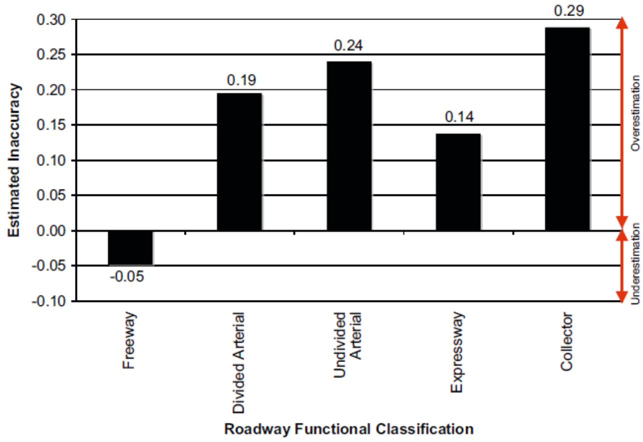


Figure 2-5: Inaccuracy w.r.t Roadway functional classification

It is clearly shown that only freeways show underestimation whilst other functional classification of roadways show overestimation. And also, volume base classification was done analyze how accurate are the lower volume roadways and higher volume roadways. Higher volume roadways were underestimated and lower volume roadways were overestimated according to the histogram drawn.

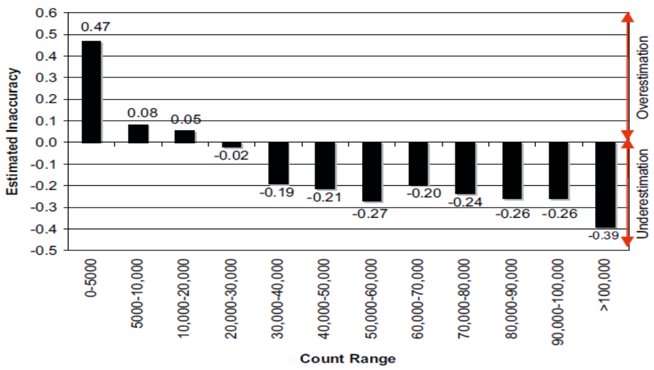


Figure 2-6: Inaccuracy w.r.t Volume ranges

Quantitative Analysis

In the Quantitative analysis forecast inaccuracy of roadways was formulated by a function of relevant independent variables namely;

- N - No of years between the report year and forecast year
- V - Vehicle kilometers travelled
- H - Type of the roadway
- F - Functional classification
- D - Decade of report prepared
- S - Status of project – Existing facility or New facility

I = f (N, V, H, F, D, S)

Simple Ordinary Least Square regression model was estimated and conclusions are made based in the results. Functional classification and status of the roadway did not influence much on forecast inaccuracy. Increase in no of years between report year and forecast year results in underestimation. And also, Radial roadways were more underestimated than Lateral roadways.

Table 2-2: Results of OLS regression model

Variable	Model 1-Entire dataset			Model 2-Freeways			Model 3-Undivided Arterials			Model 4-Other		
	Coefficient	t	Sig	Coefficient	t	Sig	Coefficient	t	Sig	Coefficient	t	Sig
Dependent variable: inaccuracy in roadway forecasts												
Number of years	−3.39E−02	−9.56	***	−2.57E−02	−6.95	***	−5.72E−02	−3.92	***	−7.30E−02	−8.35	***
Project VKT	−7.47E−09	−1.43		−5.54E−09	−0.23		−1.30E−08	−0.02		−1.22E−08	−2.25	*
Radial highway type	−1.08E−01	−3.33	**	−2.10E−01	−5.07	***	4.57E−01	2.88	**	−8.23E−02	−1.16	
Collector	−1.12E−01	−0.50										
Divided arterial	4.69E−02	0.83										
Expressway	9.70E−02	2.27	*									
Undivided arterial	3.11E−02	0.64										
East	2.64E−01	3.23	**	3.47E−01	4.01	***	2.19E−01	0.12		2.77E−01	1.70	+
Middle north	−3.61E−02	−0.49		1.51E−01	1.76	+	3.19E−01	0.78		−4.79E−02	−0.43	
Middle south	−3.48E−01	−3.32	**	4.44E−02	0.37		−9.54E−01	−3.09	**	−8.12E−01	−2.29	*
North	−1.13E−01	−1.56		1.53E−01	1.90	+	1.21E+00	3.15	**	−5.13E−01	−3.73	***
Northeast	5.52E−01	7.20	***	3.68E−01	2.73	**	6.57E−01	2.41	*	7.23E−01	6.06	***
Northwest	−1.93E−01	−2.22	*	−5.36E−03	−0.06		1.32E+00	3.19	**	−6.78E−01	−4.08	***
South	−5.58E−02	−0.78		1.86E−01	2.24	*	4.80E−01	2.07	*	−4.06E−01	−2.56	*
Southeast	3.58E−01	5.14	***	8.47E−01	8.18	***	1.63E−01	0.80		3.27E−01	3.11	**
Southwest	−1.62E−01	−2.05	*	1.41E−01	1.37		3.51E−01	1.15		−3.05E−01	−2.56	*
West	−1.54E−01	−1.86	+	4.92E−02	0.55					1.26E−02	0.07	
Report year between 1970 and 1980	1.11E−01	2.61	**	−1.04E−01	−1.87	+	1.15E+00	6.02	***	1.16E−01	1.44	
Report year between 1980 and 1990	6.38E−02	1.35		−2.12E−01	−3.32	**	−2.37E−02	−0.16		3.54E−01	3.60	***
Report year after 1990	2.78E−01	1.26					9.54E−01	0.52				
New facilities	−1.25E−01	−3.22	**	−1.18E−01	−3.11	**	−5.27E−01	−0.30		−2.38E−01	−2.10	*
Constant	1.64E+00	18.63	***	5.35E−01	5.17	***	3.28E−01	0.95		1.41E+00	8.16	***
Number of observations	1275			745			185			345		
F(x,x)	19.96			24.13			6.01			11.91		
Prob > *F*	0.0000			0.0000			0.0000			0.0000		
Adj. *R*-squared	0.2381			0.3322			0.3034			0.3366		

- **"Accuracy of travel demand forecasting in Norway".** (Morten Welde, 2011) Here Toll roads and Toll-free roads are analyzed for the forecast accuracy. 25 toll road sections and 25 toll free road sections in Norway were considered. Difference between forecast and actual traffic is calculated w.r.t forecast traffic.

$$U = ((X_a - X_f) \times 100) / X_f \qquad \textbf{2-9}$$

U - Percent accuracy, X_a - Actual traffic, X_f - Forecast traffic

Ministry of Transport and Communications in Norway accept plus or minus 10% range for construction cost estimates. Hence this study also takes plus or minus of 10% as the acceptable level of forecast accuracy.

Table 2-3: Summary statistics for forecast inaccuracies for toll roads

	Toll roads	Toll free roads
Number of cases	25	25
Mean	-2.5	19.0
Std. error of mean	4.4	4.1
Standard deviation	22.0	20.5
Minimum	-35.2	-14.6
Maximum	45.0	79.1

From this study it is concluded that Toll road's traffic forecast is more accurate than Toll free road's traffic forecast. When considered the road projects with their implemented years it is observe that there is no much improvement in accuracy of forecast over time.

Table 2-4: Traffic-forecasting inaccuracies over time

Road category/opened for traffic	*Mean inaccuracy*
Toll roads 1990–2000	-2.7%
Toll roads 2001–2007	-2.2%
Toll free roads 2001–2004	18.6%
Toll free roads 2005–2007	19.4%

- **National Cooperative Highway Research Programme (NCHRP)** discuss about the forecast accuracy considering several research studies in their report of Traffic Forecasting Accuracy Assessment Research (2020).

According to the previous studies there are two ways to present the Error.

1. Percent over the actual traffic

$$PE = \frac{Forecast\ volume - Counted\ volume}{Counted\ volume} * 100\% \qquad \textbf{2-10}$$

Where PE – Percent error

2. Percent over the forecast traffic

$$PDFF = \frac{Counted\ volume - Forecast\ volume}{Forecast\ volume} * 100\% \qquad \textbf{2-11}$$

Where PDFF – Percent difference from forecast

With both method accurate forecast will produce the value 0%. PDFF has more advantage as accuracy can measured even though the actual value is unknown. Using that equation negative values indicate over estimation and positive value indicate the under estimation. As for expressing the error over the dataset Mean percentage error (MPE) or mean absolute percentage error (MAPE) can be used. MAPE allow researchers to better understanding about the size of the error.

$$MAPE = \frac{1}{n} * \sum_{i=1}^{n} |PDFF| \qquad \textbf{2-12}$$

In this NCHRP report, analysis has made in two different approaches as discussed in Traffic forecast accuracy evaluating methods in this thesis. Under the Large-N analysis approach they have considered 1300 project in six states of USA (Florida, Massachusetts (one project), Michigan, Minnesota, Ohio, and Wisconsin) and four countries in Europe (Denmark, Norway, Sweden and the United Kingdom). As there exist several segments with different characteristic within a particular project, project team analyse the forecast accuracy in both

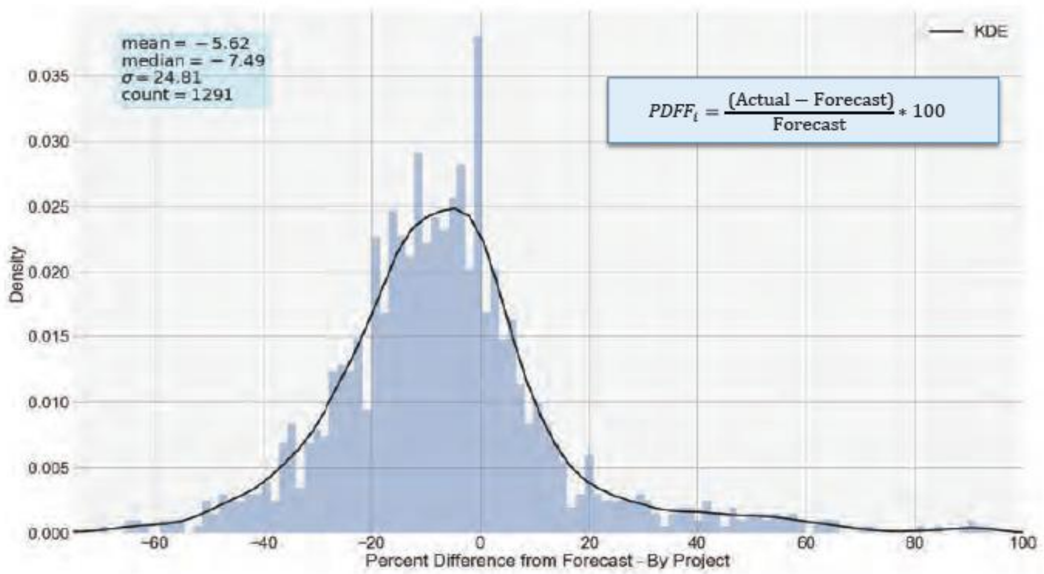
Project level and segment level. In the project level analysis aggregated characteristic from all segments was used as variable of particular project. Some variables are;

- ✓ Improvement type
- ✓ Functional class
- ✓ Forecast method
- ✓ Forecast horizon

Research team have used the regression model proposed by Odeck and Welde (2017). They have modified the regression model to as scaled by forecast value to consider the multiplicative effects.

$$y_i = \alpha + \beta \hat{y}_i + \gamma X_i \hat{y}_i + \varepsilon_i \qquad \textbf{2-13}$$

Results of the large-N analysis is as below.



	Observations	MAPDFF	Mean	Median	Standard Deviation	5th Percentile	95th Percentile
Project Level	1,291	17.29	-5.62	-7.49	24.81	-37.56	36.96

Figure 2-7: Distribution of PDFF (project level)

Mean value of -5.62 imply that generally traffic forecasts are overpredicted. It is seen that MAPDFF is 17.29% and standard deviation is 24.81. On average traffic forecast was deviated with 3500 vehicles per day.

Further the study extended to analyse PDFF by volume group. As the forecast volume increases MAPDFF value getting smaller and spread seems to be less.

Table 2-5: Forecast inaccuracy by forecast volume group (project level)

Traffic Forecast Range (ADT)	Observations	MAPDFF	Mean	Median	Standard Deviation	5th Percentile	95th Percentile
0–3000	133	24.59	-1.85	-5.75	42.15	-45.01	75.17
3001–6000	142	20.53	-0.37	-4.64	29.74	-36.50	50.33
6001–9000	125	16.75	-5.68	-8.80	21.94	-35.29	36.67
9001–13000	145	15.59	-4.66	-7.29	19.99	-31.34	34.45
13001–17000	143	17.41	-6.20	-6.53	21.61	-37.76	30.65
17001–22000	113	17.98	-5.65	-8.31	25.47	-41.62	37.85
22001–30000	133	19.54	-5.65	-8.47	25.36	-40.31	41.75
30001–40000	115	15.56	-9.78	-10.26	18.23	-39.54	12.26
40001–60000	137	13.18	-8.95	-7.68	16.01	-34.44	7.49
60000+	105	10.20	-8.96	-7.90	9.90	-24.50	3.68

Quantile regression analysis estimates the required quantile of the response variable by changing the predictor variable. This allows to compare some percentile of actual traffic be more affected by forecast volume than other percentiles. As the first model they have regressed actual traffic on the forecast volume. The results were as follows.

Table 2-6: Quantile regression results (actual count modeled as a function)

	5th Percentile		20th Percentile		50th Percentile		80th Percentile		95th Percentile	
Pseudo R-Squared	0.433		0.619		0.723		0.750		0.748	
	Coef.	t value	Coef.	t value	Coef.	t value	Coef.	t value	Coef.	t value
Intercept	-826.73	-10.55	-434.03	-5.06	37.15	0.54	1395.74	6.59	2940.45	6.50
Forecast Volume	0.62	30.68	0.81	89.56	0.94	148.10	1.05	76.12	1.42	42.26

For median, t value is not much differing from the 0 but the forecast volume coefficient is significantly varied from one. This implies there is a detectable bias. Instead of bias, regression model can be used to illustrate an uncertainty window for forecast. Median estimate be like,

Actual volume = 37.15 + 0.94*Forecast volume

Likewise, they have constructed ranges of actual traffic and PDF for differing forecast volumes by applying the coefficients as an equation.

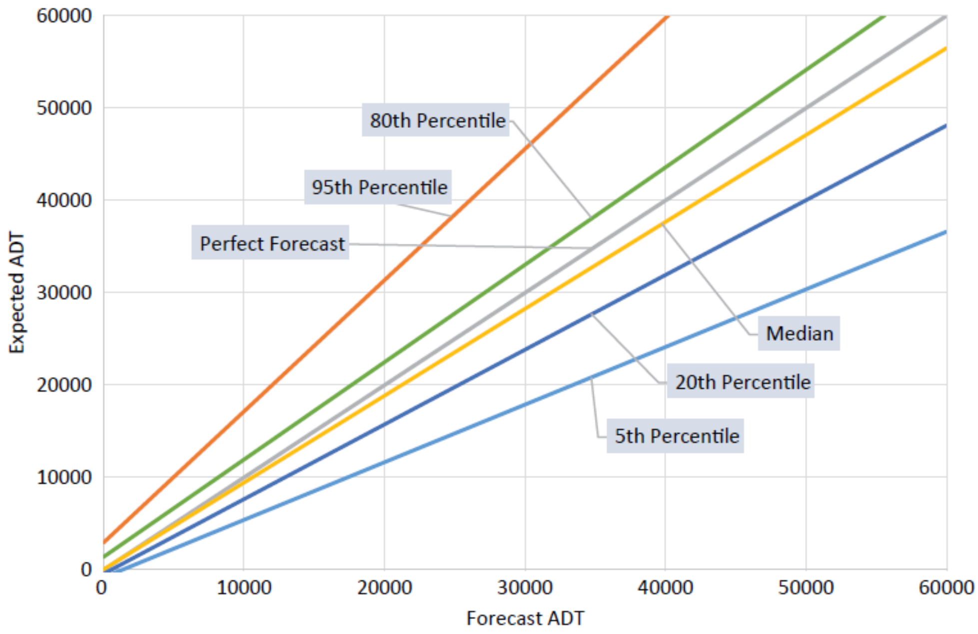


Figure 2-8: Expected ranges of actual traffic (base model)

Large-N analysis does not provide answer to the question why forecast error occurs but Deep dive approach does. As Deep dive approach needs more details to analyse the project in a wider angle only six numbers of project were selected in NCHRP research. Those are,

- Eastown Road Extension, Lima, Ohio
- Indian Street Bridge, Palm City, Florida Construction
- Central Artery Tunnel, Boston, Massachusetts
- Cynthiana Bypass, Cynthiana, Kentucky
- South Bay Expressway, San Diego, California
- US 41 (later renamed as I-41), Brown County, Wisconsin

NCHRP research team has identified several factors affecting forecast accuracy through detail study of literature. GDP or GDP growth, Employment, Short term economic fluctuations, Travel characteristics, Land use changes, Population projections, Fuel price, Car ownership, Time saving by proposed project, Toll culture and Forecast duration are some of them. Ultimate goal of the Deep dive study was to quantify the forecast error and quantify the relative importance of above mention factors to the accurate forecast.

Effect on forecast by each factor was obtain exponentiating an elasticity of the common source errors, and a natural-log of the change rate in forecast value.

$$Change\ in\ foorecsat\ value = \frac{Actual\ value - Forecast\ value}{Forecast\ value} \quad \textbf{2-14}$$

$$Effect\ on\ forecst = \ e^{(Elasticity * \ln(1+change\ in\ value))} - 1 \quad \textbf{2-15}$$

Adjusted forecast was generated as

$$Adjusted\ forecast = (1 + effect\ on\ forecast) * Actual\ forecast\ volume \quad \textbf{2-16}$$

Results obtain from Deep dive approach is displayed below.

Table 2-7: Known sources of forecast inaccuracy for deep dives

Project	Original PDFF	Remaining PDFF After Adjusting for Errors in:		Remaining PDFF After all Adjustments
Eastown Road Extension, Lima, Ohio	-43%	Employment	-39%	-28%
		Population/Household	-38%	
		Car Ownership	-37%	
		Fuel Price/Efficiency	-34%	
		Travel Time/Speed	-28%	
Indian Street Bridge, Palm City, Florida	-60%	Employment	-59%	-56%
		Population	-61%	
		Fuel Price	-56%	
Central Artery Tunnel, Boston, Massachusetts	-16%	Employment	-10%	-10%
		Population	-14%	
		Fuel Price	-10%	
Cynthiana Bypass, Cynthiana, Kentucky	-27%	Employment	-25%	-8%
		Population	-25%	
		External Trips Only	7%	
US-41 (later renamed as I-41), Brown County, Wisconsin	-5%	Population	-4%	-6%
		Fuel Price	-6%	
South Bay Expressway, San Diego, California	Revenue less than projected, leading to bankruptcy of P3	Socioeconomic Growth	The available documentation did not allow the effect of these factors on traffic volume to be quantified	
		Border Crossing		
		Toll Rates		

2.4 Model Calibration and Validation

Model calibration and validation is an essential step for each travel demand models to assess the developed model. Reliability and consistency of the forecast values depend on how far the model is calibrated and validated. Most of the time incomplete calibration and validation results in forecast errors. Normally forecast models consist with four steps as discussed earlier. It is needed to perform the calibration and validation after each step of Trip Generation, Trip Distribution, Mode choice and Trip Assignment. If the calibration and validation have done only at the end, it would cause to error propagation in each step. (Dr. Fred Wegmenn, 2016)

In the FHWA Model Validation and Reasonableness Checking manual (Barton Aschman Associates, 1997) it clearly discusses the basics for perform a model calibration and validation.

Calibration adjusts the parameter values until the estimated values match the observed values within the region for the base year. For example, calibration of the mode-specific constants in a mode choice model ensures that the estimated shares match the observed shares by mode.

Validation tests the ability of model to predict the future behaviour. It requires comparing the model predictions with information other than that used in estimating the model. There are two major validation checks namely Reasonableness checks and Sensitivity checks.

Reasonableness checks include comparison of rates and parameters, regional and subregional values, logic test etc. The models should be evaluated in terms of acceptable level of error, Consistency of model results, ability to perform as per the theoretical & logical expectations.

Sensitivity checks include response to transportation system, socioeconomic or policy changes. Sometimes it expresses as an elasticity of the variable. As an example, it examines how travel demand behave after doubling the parking tolls. This sensitivity analysis would be much important as projected policies and conditions may not abide in the base year.

There are four approaches to evaluate the model prediction over observed values. Those are

1. Absolute difference
2. Relative difference
3. Correlation
4. Variance

Calibration procedure can be differentiated as aggregate and disaggregate models. Aggregate models are zone based and calibration is done by trial-and-error adjustment of parameters. Disaggregate models are individual based choice models and calibration is done looking at the parameters & the confidence limits of the estimated values. Accordingly, validation procedure also consists with aggregate model and disaggregate model.

Validation checks need to be performed for each step of Trip generation, Trip distribution, Model split and Trip assignment are summarized below.

Table 2-8: Validation checks for each step of modelling

Modelling step	**Validation Checks**
Trip Generation	Socioeconomic disaggregation • Compare observed & estimated household by socioeconomic sub groups • Calculate correlation of shares of observed & estimated household by sub group • Calculate correlation & plot the relationship between the observed & estimated house hold for each household size group at the district or census tract level Trip production • Calculate the total person trip production per household per capita. • Calculate the total person trips by purpose. Trip attraction

	• Home based work person trip attraction per total employment • Home based school trips per school enrolment • Home based shop trips per total employment
Trip Distribution	• Compare average trip lengths by purpose • Compare trip lengths for trips produced versus trips attracted by purpose by area type • Plot trip length frequency distributions by purpose • Plot normalized friction factors
Model split	• Average auto occupancies by trip purpose • Percentage single occupant vehicles by trip purpose • Home based work transit trips as a percentage of total transit trips • Mode shares from area types or major districts • Average auto occupancies to/from area type or major districts
Trip Assignment	• Check VMT values for the region, per household, per person • Compare observed and estimated traffic volume • Compare observed versus estimated volumes for all links with counts • Calculate R^2 (Coefficient of determination) compare regionwide observed traffic counts verses estimated volumes • Calculate percent RMSE

3. METHODOLOGY

3.1 Traffic data for National Highways

3.1.1 Details of selected road projects

Traffic forecasting accuracy is calculated using forecast traffic data and the actual traffic data in the same year. In this research seventeen numbers of highways and three Expressways were analyzed. Expressways were analyzed separately as their operational conditions are tremendously depend on presume road network.

Table 3-1: Details of selected road projects

Road ID	Road section	Forecast traffic data collected Report	Feasibility report	Completion report/post analysis report	Report Year	No of lanes	Type of Rehabilitation	Surface type
A001	Kiribathgoda - Nittabuwa	National Highways Development Project Final Report Volume 2	✓		2005	4 lane	Reconstruction and widening	Asphalt
A002	Maliban Jn. Rathmalana - Nalluruwa Jn. Panadura	Feasibility study for the Improvement of A002 road from Maliban Jn. Rathmalana to Nalluruwa Jn. Panadura	✓		2012	6 lane and 4 lane	Reconstruction and widening	Asphalt
A002	Nupe junction - Wellawaya (Batheegama)	National Highways Development Project Final Report Volume 2	✓		2005	2 lane	Maintain and widening where necessary	Asphalt
A002	Nupe junction - Wellawaya (Ambalantota)	National Highways Development Project Final Report Volume 2	✓		2005	2 lane	Maintain and widening where necessary	Asphalt
A003	Nawaloka Jn. Peliyagoda - Seeduwa jn.	Feasibility study for the Improvement of A003 road from Nawaloka Jn. Peliyagoda to Seeduwa jn.	✓		2012	4 lane	Widening	Asphalt
A004	Kirulapona - Godagama	National Highways Development Project Final Report Volume 2	✓		2005	4 lane and 2 lane	Widening	Asphalt
A005	Nuwara Eliya - Badulla	National Highways Development Project Final Report Volume 2	✓		2005	2 lane	Reconstruction and widening	DBST
A006	Ambepussa - Dambulla	Feasibility study of Ambepussa - Kurunegala - Trincomalee (A06) road from Ambepussa to Dambulla	✓		2010	4 lane and 2 lane	Reconstruction and widening	Asphalt
A007	Hatton - Nuwara Eliya	National Highways Development Project Final Report Volume 2	✓		2005	2 lane	Widening	DBST
A008	Panadura - Ingiriya	Road Network Improvement Project		✓	2009	2 lane	Improving	
A010	Katugastota - Kurunegala	Road Network Improvement Project		✓	2009	2 lane	Improving	
A012	Nochchiyagama - Trincomalee	Feasibility study of Puthalam - Trincomalee road (A12) from Mochchiyagama to Trincomalee	✓		2010	2 lane	Reconstruction and widening	Asphalt
A018	Embilipitiya - New Japanese road	Road Network Improvement Project		✓	2009	2 lane	Rehabilitation	
A019	Polgahawela - Kegalle	National Highways Development Project Final Report Volume 2	✓		2005	2 lane	Widening	Asphalt
A026	Udatenna - Mahiyangana	National Highways Development Project Final Report Volume 2	✓		2005	2 lane	Widening and some part reconstruction	DBST
AB010	Ambatale - Kaduwela	Road Network Improvement Project		✓	2009	2 lane	Improving	
AB029	Pasyala - Meerigama	Road Network Improvement Project		✓	2009	2 lane	Improving	

3.1.2 Forecast details

It is important to gather information related to Traffic Forecast to analyze the forecast accuracy with reference to several factors like forecast horizon, forecast method and etc. From the feasibility reports and appraisal reports forecast related information were gathered.

Table 3-2: Details related to Forecast

Road ID	Road section	Forecast period	Forecast method	Location
A001	Kiribathgoda - Nittabuwa	10	Growth Factors	24 km
A002	Maliban Jn. Rathmalana to Nalluruwa Jn. Panadura	4	RDA model	Airport jn
A002	Nupe junction - Wellawaya (Batheegama)	2	Growth Factors	180 km
A002	Nupe junction - Wellawaya (Ambalantota)	2	Growth Factors	225 km
A003	Nawaloka Jn. Peliyagoda to Seeduwa jn.	5	RDA model	2 km
A004	Kirulapona - Godagama	6	Growth Factors	16 km
A005	Nuwara Eliya - Badulla	6	Growth Factors	82 km
A006	Ambepussa to Dambulla	5	TRANSPLAN	57 km
A007	Hatton - Nuwara Eliya	9	Growth Factors	91km
A008	Panadura - Ingiriya	11	Growth Factors	road section
A010	Katugastota - Kurunegala	11	Growth Factors	road section
A012	Mochchiyagama to Trincomalee	5	TRANSPLAN	82 km
A018	Embilipitiya - New Japanese road	11	Growth Factors	road section
A019	Polgahawela - Kegalle	10	Growth Factors	1km
A026	Udatenna - Mahiyangana	6	Growth Factors	38 km
AB010	Ambatale - Kaduwela	11	Growth Factors	road section
AB029	Pasyala - Meerigama	11	Growth Factors	road section

3.1.3 Forecast traffic data

Forecasted traffic was obtained mostly by feasibility studies carried out before construction of particular road section. Analysis reports also considered to obtain forecasted traffic data. Obtained forecast data of main arterial highways is listed as follows.

Table 3-3: Forecast Traffic data of National Highways

No	Road ID	Name	Forecast AADT
1	A001	Kiribathgoda - Nittabuwa	24846
2	A002	Maliban Jn. Rathmalana - Nalluruwa Jn. Panadura	67203
3	A002	Nupe junction - Wellawaya (Batheegama)	6415
4	A002	Nupe junction - Wellawaya (Ambalantota)	5835
5	A003	Nawaloka Jn. Peliyagoda - Seeduwa jn.	64533
6	A004	Kirulapona - Godagama	34184
7	A005	Nuwara Eliya - Badulla	2933
8	A006	Ambepussa - Dambulla	12905
9	A007	Hatton - Nuwara Eliya	3027
10	A008	Panadura - Ingiriya	17529
11	A010	Katugastota - Kurunegala	16612
12	A012	Nochchiyagama - Trincomalee	14722
13	A018	Embilipitiya - New Japanese road	4782
14	A019	Polgahawela - Kegalle	6800
15	A026	Udatenna - Mahiyangana	2430
16	AB010	Ambatale - Kaduwela	30199
17	AB029	Pasyala - Meerigama	14121

3.1.4 Actual traffic data

Actual traffic in each road section at the forecasted year and at the nearest location to forecast location was obtained by traffic data available at University of Moratuwa-Transportation division, Road Development Authority and Feasibility reports. Some available traffic data was needed to convert to AADT as the records available as traffic data on particular day. Basic norms and reliable estimations were made during the conversion of traffic data to AADT.

Table 3-4: Actual traffic on selected National Highways

No	Road ID	Name	Actual AADT
1	A001	Kiribathgoda - Nittabuwa	22056
2	A002	Maliban Jn. Rathmalana - Nalluruwa Jn. Panadura	70062
3	A002	Nupe junction - Wellawaya (Batheegama)	6643
4	A002	Nupe junction - Wellawaya (Ambalantota)	5201
5	A003	Nawaloka Jn. Peliyagoda - Seeduwa jn.	59209
6	A004	Kirulapona - Godagama	28728
7	A005	Nuwara Eliya - Badulla	2800
8	A006	Ambepussa - Dambulla	11714
9	A007	Hatton - Nuwara Eliya	3179
10	A008	Panadura - Ingiriya	11600
11	A010	Katugastota - Kurunegala	8630
12	A012	Nochchiyagama - Trincomalee	15044
13	A018	Embilipitiya - New Japanese road	4380
14	A019	Polgahawela - Kegalle	15996
15	A026	Udatenna - Mahiyangana	6144
16	AB010	Ambatale - Kaduwela	15600
17	AB029	Pasyala - Meerigama	6540

Figure 3-1: Selected Highways - Western Province

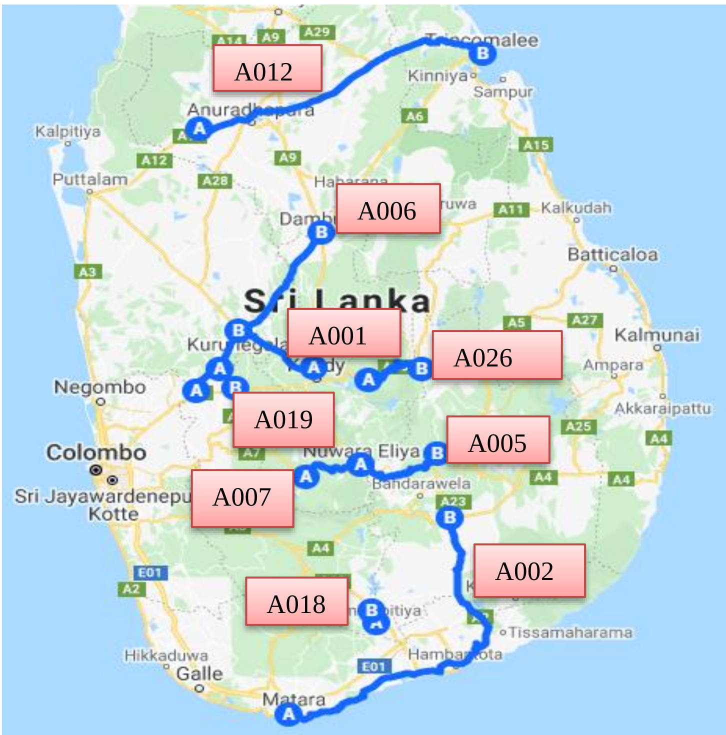


Figure 3-2: Selected Highways - Other Provinces

3.2 Traffic data for Expressways

3.2.1 Details of selected Expressway projects

Three expressways namely Southern Expressway, Outer Circular Expressway and Colombo – Katunayake Expressway were selected to analysed the forecast accuracy.

Pre-feasibility studies for Southern Expressway was carried out in 1991 and construction work began in 2003. Long time spent on land acquisition delayed the start of construction works and whole section from Kottawa to Godagama was opened to traffic in 2014. Extension of Southern Expressway to Mattala from Gadagama is not take in to analysis in this research which was opened in February, 2020. Outer Circular Expressway was started to construction in 2009. Even though from Kottawa to Kadawatha section was opened to traffic on 2015 still it has not connected to Colombo – Katunayake Expressway. Colombo – Katunayake Expressway construction works also started parallel to the Outer Circular Expressway in 2009 and completed in 2013.

Table 3-5: Details of Expressways

Road ID	Road Project	Start	End	Total length	No of Interchanges	Commenced year	Completion year
E01	Southern Expressway	Godagama, Matara	Kottawa	126 km	9	2003	2014
E02	Outer Circular Expressway	Kottawa	Kerawalapitiya	29 km	4	2009	2015
E03	Colombo - Katunayake Expressway	Peliyagoda	Katunayake	26 km	3	2009	2013

3.2.2 Forecast details

In Southern Expressway traffic forecast was done considering the evaluated growth rates. As traffic growth is related to Economic growth, elasticity between traffic growth and economic growth was calculated and hence evaluate the traffic growth rate. Other than the growth of existing traffic, generated and diverted traffic also taken into consider. Using origin destination surveys clear idea was taken to evaluate generated and diverted traffic. When estimating the demand buses, goods vehicles and private vehicles were computed separately. As the forecast was made in 1997 and analysis is done for 2016, forecast horizon for Southern Expressway can be taken as 19 years. Three scenarios were evaluated as Project without OCH, Project with OCH and Project with OCH & generated traffic. Project with OCH scenario was selected to analysis.

For Outer Circular Expressway, forecast was made in 1999 and analysis is done for 2016. Typical four step modelling was used to forecast the traffic. The model is developed by RDA using JICA STRADA package. Study area is western province and it consist with 31 zones. Correlation between several socioeconomic factors and vehicle trip generation and attraction by vehicle type and trip purpose was evaluated to construct the model. Socioeconomic factors such as Employment, Population, Vehicle ownership and Income were considered. For trip distribution model is based on the ease of travel formulated by cost and time. Total of eleven types of models were constructed for trip types such as Bus trips, Truck trips, Home-based work trips, non-home-based work trips and etc. For the traffic assignment model, incremental traffic assignment technique was used as the ease of checking route and link assignments. Further equal travel time principle was used. Analysis was done for both with OCH and without OCH scenarios for reference purpose.

Traffic forecast for Colombo Katunayake Expressway was done using TRANSPLAN model. Trip generation and trip attraction was evaluated relating to the socio-economic parameters such as population, household, number of jobs and vehicle population. Forecast was carried out for both with toll and without toll options. Forecast was carried out in three scenarios namely Only CKE without toll, CKE and other expressways without toll and CKE & other expressways with toll. For this research analysis CKE with other expressways with toll scenario was selected. All-or-nothing assignment technique was used for the traffic assignment model.

3.2.3 Forecast traffic data

Three Expressways was selected to analyze the forecast accuracy.

1. Southern Expressway (E01)
2. Outer Circular Expressway (E02)
3. Central Expressway (E03)

Southern expressway initial feasibility report (1997) is taken into obtain forecast traffic data. There exist eleven interchanges and forecasted traffic amount between each inter changes are obtained. Similarly forecasted traffic amount is obtained for Outer circular Expressway and Central Expressway from feasibilities carried out in 1999 and 2008 respectively.

Table 3-6: Forecast traffic data of Expressways

Road ID	Name	Forecast AADT
E01	Kottawa–Kahathuduwa	8193
	Kahathuduwa–Gelanigama	14963
	Gelanigama–Dodangoda	17442
	Dodangoda–Welipenna	14615
	Welipenna–Kurundugahahethekma	12775
	Kurundugahahethekma–Baddegama	13734
	Baddegama–Pinnaduwa	12996
	Pinnaduwa–Imaduwa	10504
	Imaduwa-Kokmaduwa	10133

	Kokmaduwa-Godagama	9761
E02	Kadawatha - Kaduwela	35240
	Kaduwela - Kothalawala	37275
	Kothalawala - Athurugiriya	39842
	Athurugiriya - Kottawa	44390
E03	Pelliyagoda - Ja ela	99343
	Ja ela - Katunayake	65843

3.2.4 Actual traffic data

Actual traffic amounts of three expressways are gathered from Road Development Authority. AADT is calculated from the data available at each month between each interchange.

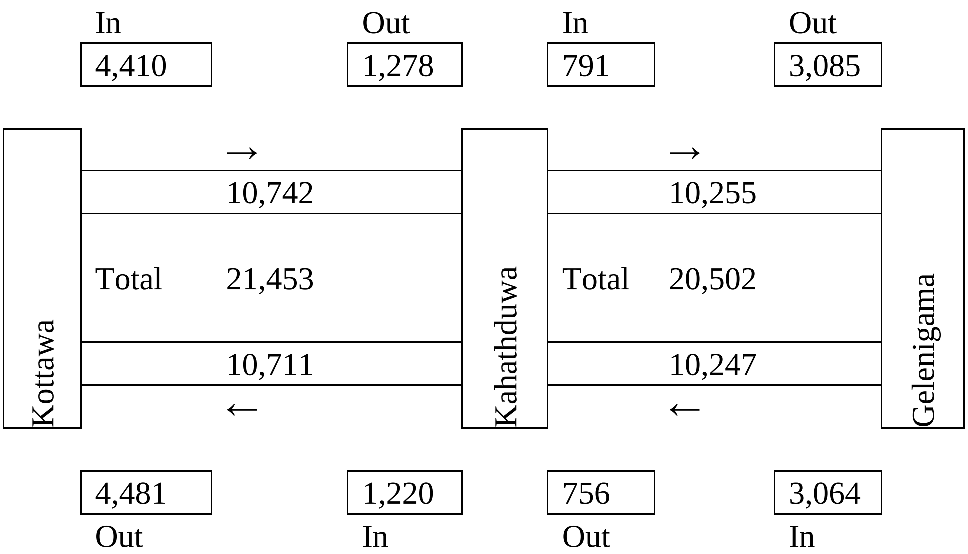


Figure 3-3: Traffic count in toll gates

Table 3-7: Actual traffic data of Expressways

Road ID	Name	Actual AADT
E01	Kottawa–Kahathuduwa	23158
	Kahathuduwa–Gelanigama	21906
	Gelanigama–Dodangoda	17142
	Dodangoda–Welipenna	15040
	Welipenna–Kurundugahahethekma	13420
	Kurundugahahethekma–Baddegama	12333
	Baddegama–Pinnaduwa	11125
	Pinnaduwa–Imaduwa	8538
	Imaduwa-Kokmaduwa	7672
	Kokmaduwa-Godagama	6993
E02	Kadawatha - Kaduwela	13109
	Kaduwela - Kothalawala	15791
	Kothalawala - Athurugiriya	19172
	Athurugiriya - Kottawa	25163
E03	Pelliyagoda - Ja ela	23489
	Ja ela - Katunayake	18246

3.3 Calculation of Forecast inaccuracy

Deviation with the accurate forecast is calculated as it clearly represents the over estimations and under estimations. Forecast inaccuracy is calculated as a proportion of deviation to the actual traffic.

$$\text{Forecast inaccuracy } i = \frac{Forecast\ traffic - Actual\ traffic}{Actual\ traffic} * 100 \qquad \textbf{3-1}$$

Here i > 0 - Over estimation

i < 0 - Under estimation

For analyze the forecast inaccuracy with respect to some variables such as forecast period or forecast method, inaccuracy should be represented as a value irrespective from positive or negative. So absolute value was taken from calculated inaccuracies as MAPE.

$$MAPE = \left|\frac{Forecast\ traffic - Actual\ traffic}{Actual\ traffic} * 100\right| \qquad \textbf{3-2}$$

4. TEST RESULTS AND DISCUSSION

4.1 Analysis of forecast accuracy in Highways

As discussed in chapter 3 inaccuracy is calculated with respect to the actual traffic.

Table 4-1: Inaccuracies of traffic forecast in Highways

No	Road ID	Name	Forecast AADT	Actual AADT	Inaccuracy	%
1	A001	Kiribathgoda - Nittabuwa	24846	22056	0.126	12.6
2	A002	Maliban Jn. Rathmalana - Nalluruwa Jn. Panadura	67203	70062	-0.041	-4.1
3	A002	Nupe junction - Wellawaya (Batheegama)	6415	6643	-0.034	-3.4
4	A002	Nupe junction - Wellawaya (Ambalantota)	5835	5201	0.122	12.2
5	A003	Nawaloka Jn. Peliyagoda - Seeduwa jn.	64533	59209	0.09	9.0
6	A004	Kirulapona - Godagama	34184	28728	0.190	19.0
7	A005	Nuwara Eliya - Badulla	2933	2800	0.048	4.8
8	A006	Ambepussa - Dambulla	12905	11714	0.102	10.2
9	A007	Hatton - Nuwara Eliya	3027	3179	-0.048	-4.8
10	A008	Panadura - Ingiriya	17529	11600	0.511	51.1
11	A010	Katugastota - Kurunegala	16612	8630	0.925	92.5
12	A012	Nochchiyagama - Trincomalee	14722	15044	-0.021	-2.1
13	A018	Embilipitiya - New Japanese road	4782	4380	0.092	9.2
14	A019	Polgahawela - Kegalle	6800	15996	-0.575	-57.5
15	A026	Udatenna - Mahiyangana	2430	6144	-0.604	-60.4
16	AB010	Ambatale - Kaduwela	30199	15600	0.936	93.6
17	AB029	Pasyala - Meerigama	14121	6540	1.159	115.9

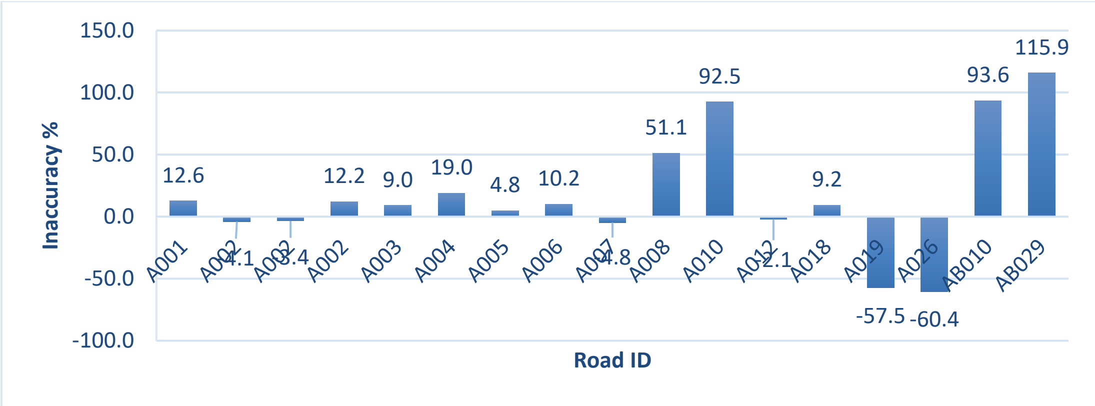


Figure 4-1: Inaccuracies of traffic forecast in Highways

By looking at the graph it can be seen that some of the highways show under estimations whilst others show overestimation.

4.1.1 Probable reasons for over estimations in A8, A10, AB10, AB29

For A8, A10, AB10 and AB029 roads forecast and actual traffic data was gathered from completion report of "The Road Network Improvement Project (RNIP)" that was financed with ADB. According to that report most of the roads were overestimated at the appraisal including pre-mentioned roads. Estimations were carried out considering the regional economic growth and on the increase in traffic flow relative to the rate of increase in future gross domestic product (GDP). When we consider the GDP growth rate and New vehicle registration growth according to the Central Bank reports, it can be clearly seen that GDP growth rate and New vehicle registrations growth have decreased in recent years back from 2009.

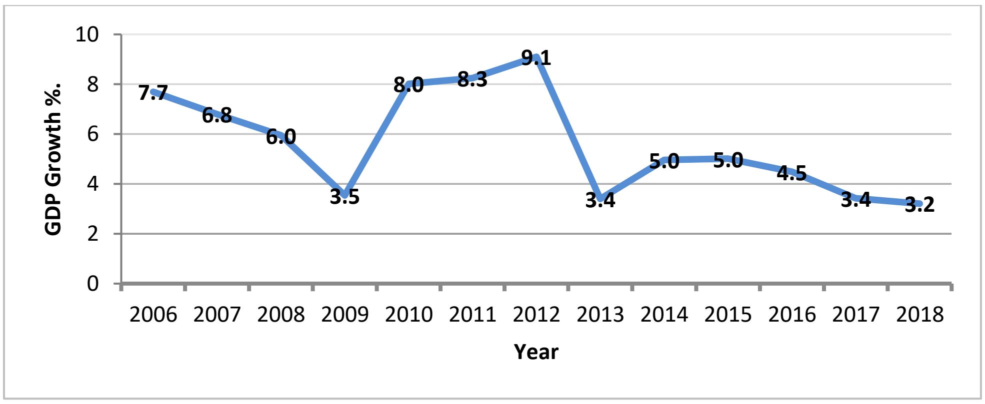


Figure 4-2: GDP growth rate

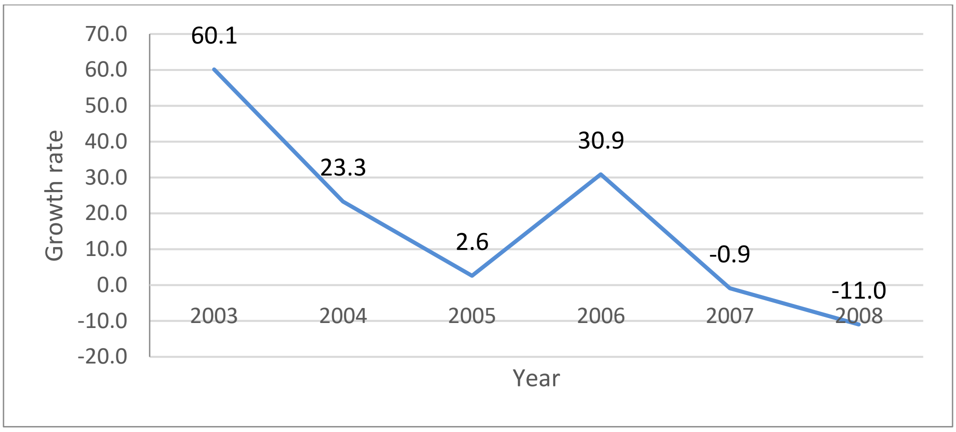


Figure 4-3: New vehicle registrations growth rate

So, over estimation of GDP growth rates may be a reason for over estimation of traffic growth rates.

And other main reason to over estimations may be Token estimation for generated traffic according to their design options. Two main design options were considered in the appraisal

- Option 01 – Upgrade to standard of new national roads and having 20 years pavement life
- Option 02 – Necessary improvements of the existing carriageway pavement, while keeping the present right-of-way to provide a 20-year pavement life.

At the completion report it was analyzed that only 63% of the road lengths have been improved to Option 01 from the planned road lengths. So, token estimations of 5% for traffic generation not account for remaining 37% of road lengths and that token estimations may be much higher with the road improvements existed in 1997 to 2008. Further the estimated growth rates for smaller private vehicles were much higher than the actual situation.

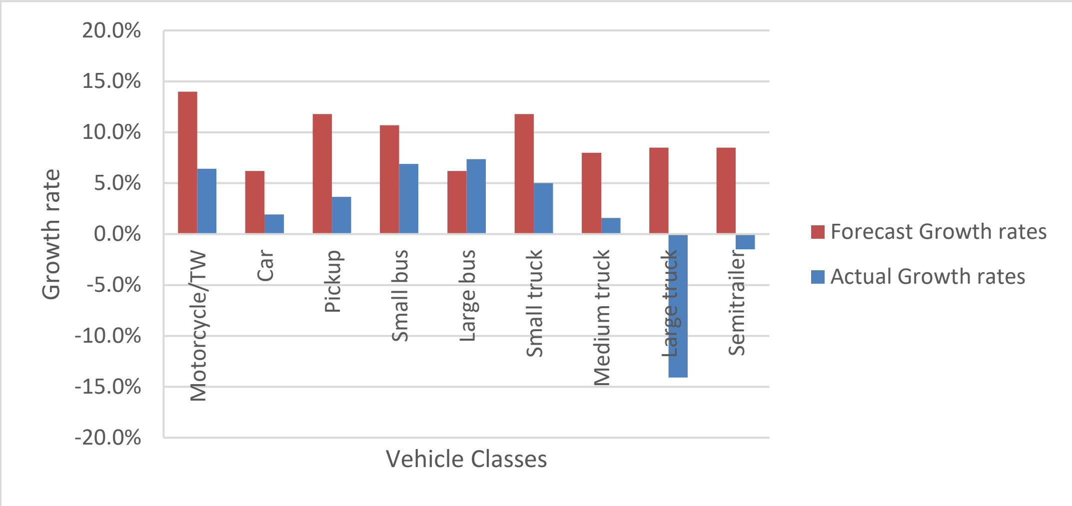


Figure 4-4: Forecast growth rates vs Actual growth rates of Vehicle classes in AB10

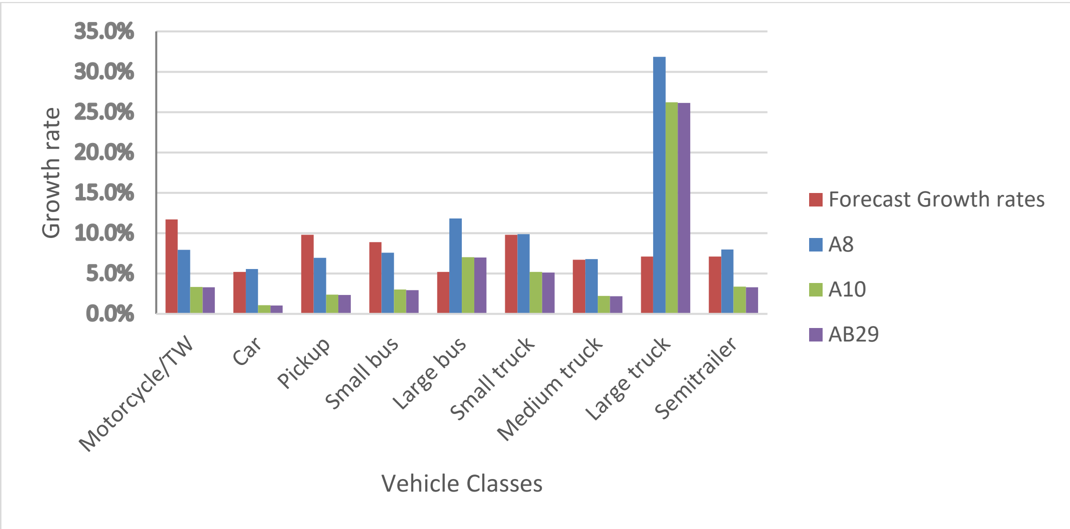


Figure 4-5: Forecast growth rates vs Actual growth rates of Vehicle classes in A8, A10 and AB29

It can be concluded that there were high estimations for AB10 and AB29 in almost all vehicle classes except large bus and large truck in AB29. This also may be cause to high over estimations in AB10 and AB29. Growth rate forecast for A8 and A10 is not much overestimated. But forecast growth rates of Motorcycle and Three-wheeler were high for A8 and A10 also. Because of having large share for Motorcycle and Three-wheeler from overall traffic forecast ultimate traffic forecast would have been overestimated.

4.1.2 Probable reason to underestimations in A19 and AB26

For A19 and AB26 Forecast traffic was gathered from ADB report "Sri Lanka: National Highways Development Project Final Report Volume 2: Main Report". In this study they have estimated the future traffic dividing in to three main sections namely, Normal traffic, Diverted traffic and Generated traffic. The normal traffic was forecasted analyzing the GDP growth pattern.

Equivalent compound traffic growth rate for 10-year period was estimated from the linear growth rate that has been calculated from historic data. Then this traffic growth rate was amplified in proportion to the projected future growth in real GDP compared to average GDP growth of 4.6% for 1990 to 2003 period. According to the Central Bank record Average GDP growth rate for the period 2005 to 2015 is around 6.3%.

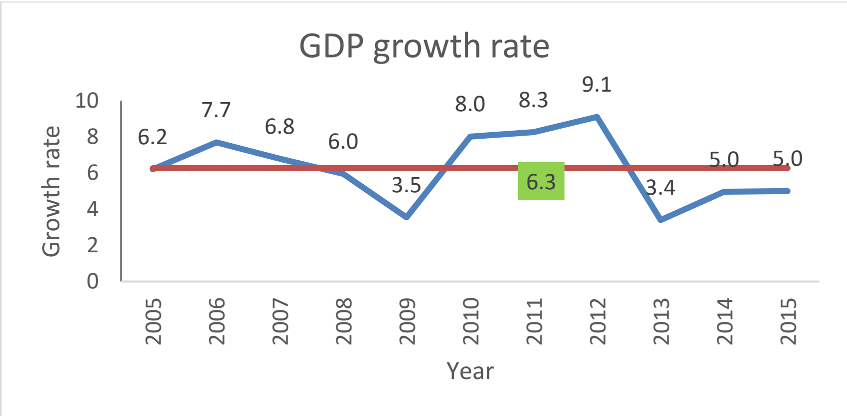


Figure 4-6: GDP growth rate from 2005 to 2015

Table 4-2: Corrected traffic volumes for A19 and A26

Road	2005 Traffic	Compound growth rate	Historic GDP growth rate	Estimated GDP	Traffic growth (A)	Estimated Traffic (A)	Actual GDP	Traffic growth (B)	Estimated Traffic (B)
A19	5000	2.9	4.6	5.0	3.2	6800	6.3	4.0	7381
A26	2000	3.3	4.6	5.0	3.6	2430	6.3	4.5	2607

And if directly calculate the forecast traffic for A19 and A26 it will be 7381 and 2607 respectively. Those values are somewhat higher than the forecasted value in the report.

4.2 Analysis of forecast accuracy in Expressways

Table 4-3: Inaccuracies of traffic forecast in Expressways

No	**Road ID**	**Name**	**Forecast AADT**	**Actual AADT**	**Inaccuracy %**
01	E01	Kottawa–Kahathuduwa	8193	23158	-65
		Kahathuduwa–Gelanigama	14963	21906	-32
		Gelanigama–Dodangoda	17442	17142	2
		Dodangoda–Welipenna	14615	15040	-3
		Welipenna–Kurundugahahethekma	12775	13420	-5
		Kurundugahahethekma–Baddegama	13734	12333	11
		Baddegama–Pinnaduwa	12996	11125	17
		Pinnaduwa–Imaduwa	10504	8538	23
		Imaduwa-Kokmaduwa	10133	7672	32
		Kokmaduwa-Godagama	9761	6993	40
02	E02	Kadawatha - Kaduwela	35240	13109	169
		Kaduwela - Kothalawala	37275	15791	136
		Kothalawala - Athurugiriya	39842	19172	108
		Athurugiriya - Kottawa	44390	25163	76
03	E03	Pelliyagoda - Ja ela	99343	23489	323
		Ja ela - Katunayake	65843	18246	261

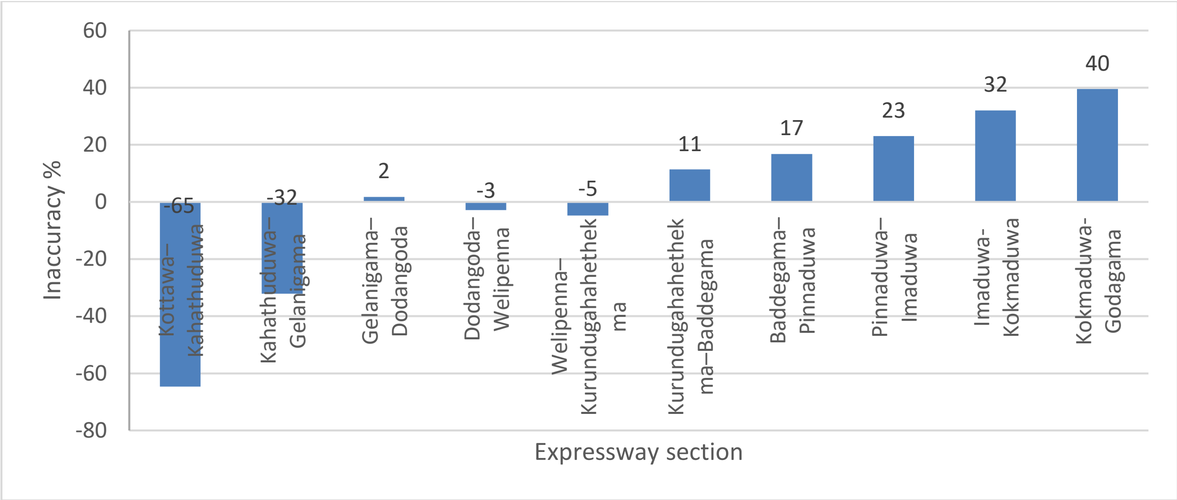


Figure 4-7: Inaccuracies of Traffic forecast in Southern Expressway

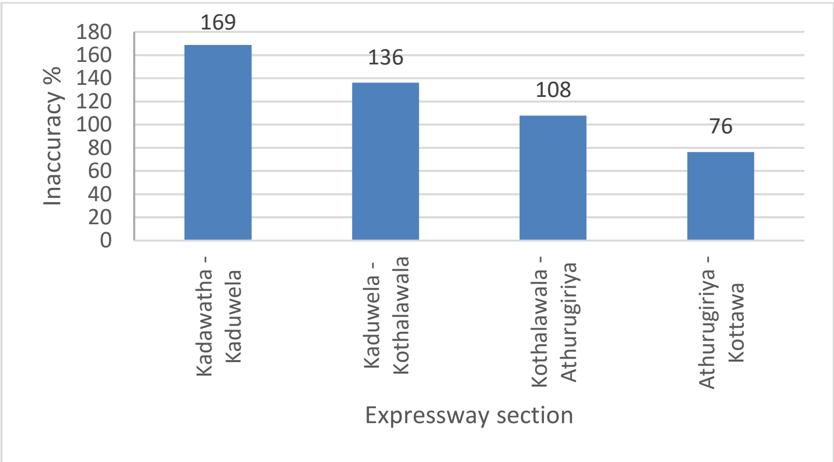


Figure 4-8: Inaccuracies of Traffic forecast in Outer Circular Expressway

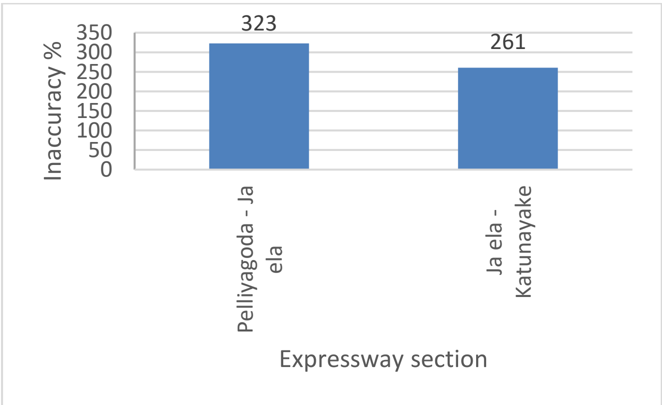


Figure 4-9: Inaccuracies of Traffic forecast in Colombo-Katunayaka Expressway

Outer circular expressway and Colombo Katunayake Expressway show comparatively high overestimations than Southern Expressway. There are several reasons for that huge over estimation. Possible reasons for overestimations in Outer circular expressway and Colombo Katunayake expressway are discussed below.

4.3 Outer Circular Expressway

4.3.1 Introduction

Feasibility studies for the Outer Circular Expressway were carried out in 1998 as an orbital road to encourage the development of existing and future growth centres, to connect radial routes, to divert the through traffic from the centre of the city.

RDA model using JICA STRADA package was used to forecast the traffic. It consists of four step modelling such as Trip Generation/Attraction, Trip Distribution, Model split and Trip Assignment. For each numerical model was prepared.

4.3.2 Probable Reasons for the overestimation

1. Road projects considered to be operated by the time of forecast years are not fully operated

This is the main reason for over estimation. Because when implementing the Traffic assignment model some new road sections were considered in the model for forecast traffic in OCH. Those proposed new road sections are

1. Katunayake - Padeniya Highway
2. Colombo - Katunayake Expressway
3. Northeast highway to Kandy
4. Southeast Highway to Rathnapura
5. Base line road extension

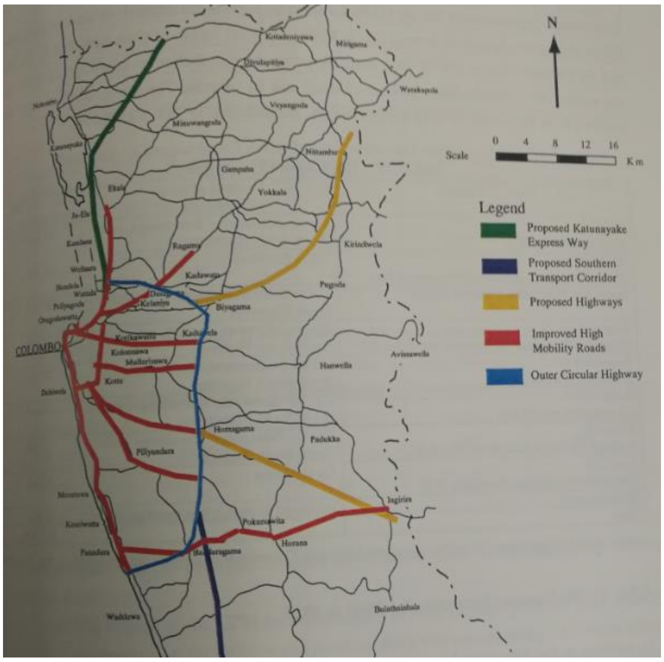


Figure 4-10: Considered road developments in the model

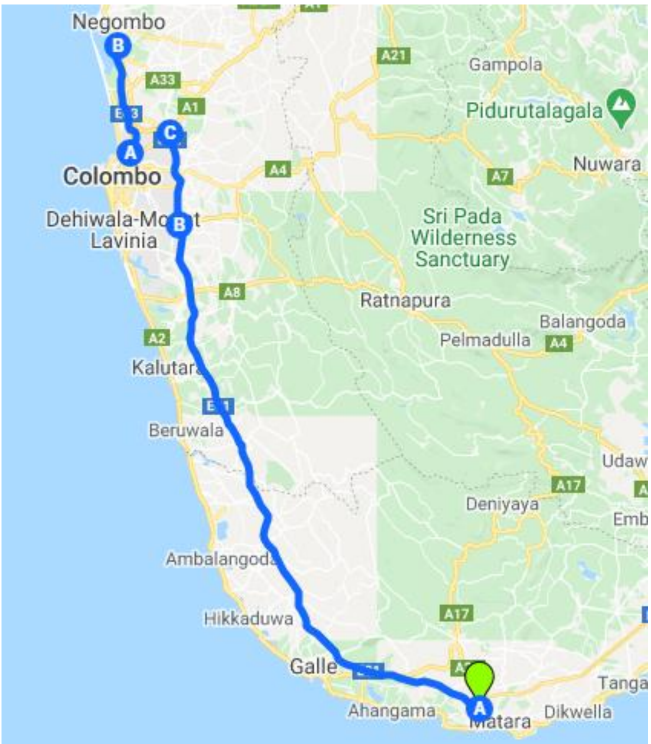


Figure 4-11: Actual Expressway developments in analyze year

Among those new road sections only Colombo – Katunayake Expressway was completed. Even though CKE is completed it is not connected to OCH by the time of analysis. Hence large amount of traffic introduce to OCH was cleared off.

2. And also, some road sections expected to be improved by the time of analysis as show in figure 4-13. The considered road sections are
    1. Colombo – Kandy road (A01) up to Kadawatha Interchange
    2. Colombo – wellawaya road (A02) up to Panadura
    3. Paliyagoda – Puttalam road (A03) up to Ja-Ela Interchange
    4. Colombo – Batticolow road (A04) up to Kottawa Interchange
    5. Colombo – Horana road (B84) up to Polgasowita Interchange
    6. Colombo – Hanwella road (A110) up to Kaduwela Interchange
    7. Kollupitiya – Sri Jayawaranpura (A0) up to Thalangama Interchange
    8. Panadura – Rathnapura Upton Ingiriya
    9. Base line road improved to dual-3 lane carriageway

Most of the road sections were improved as expected. But those improvements not meet the required level of service as most of the roads are reach their capacity in peak hours.

3. Demotivation to use expressway for intra traffic within Colombo

According to final report of "Urban Transport System Development Project for Colombo Metropolitan Region and Suburbs" by JICA, they have identified following urban centres as most traffic generated points.

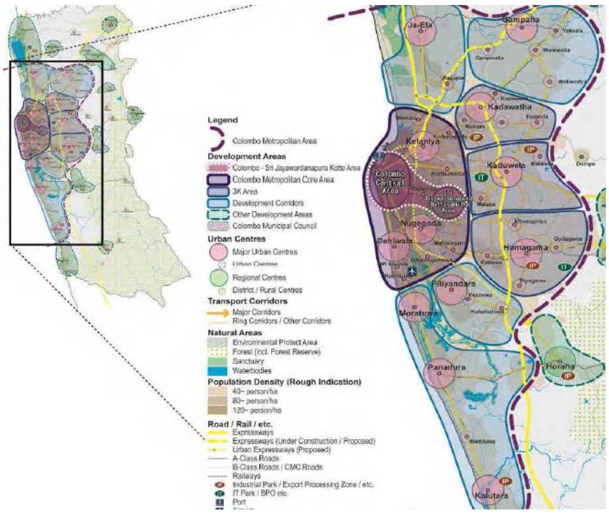


Figure 4-12: Urban centers

Source: CoMTrans Study Team

Considering these Urban centers, it is required to analyze trips from those Urban centers to destinations where traffic needs to use Outer Circular Expressway.

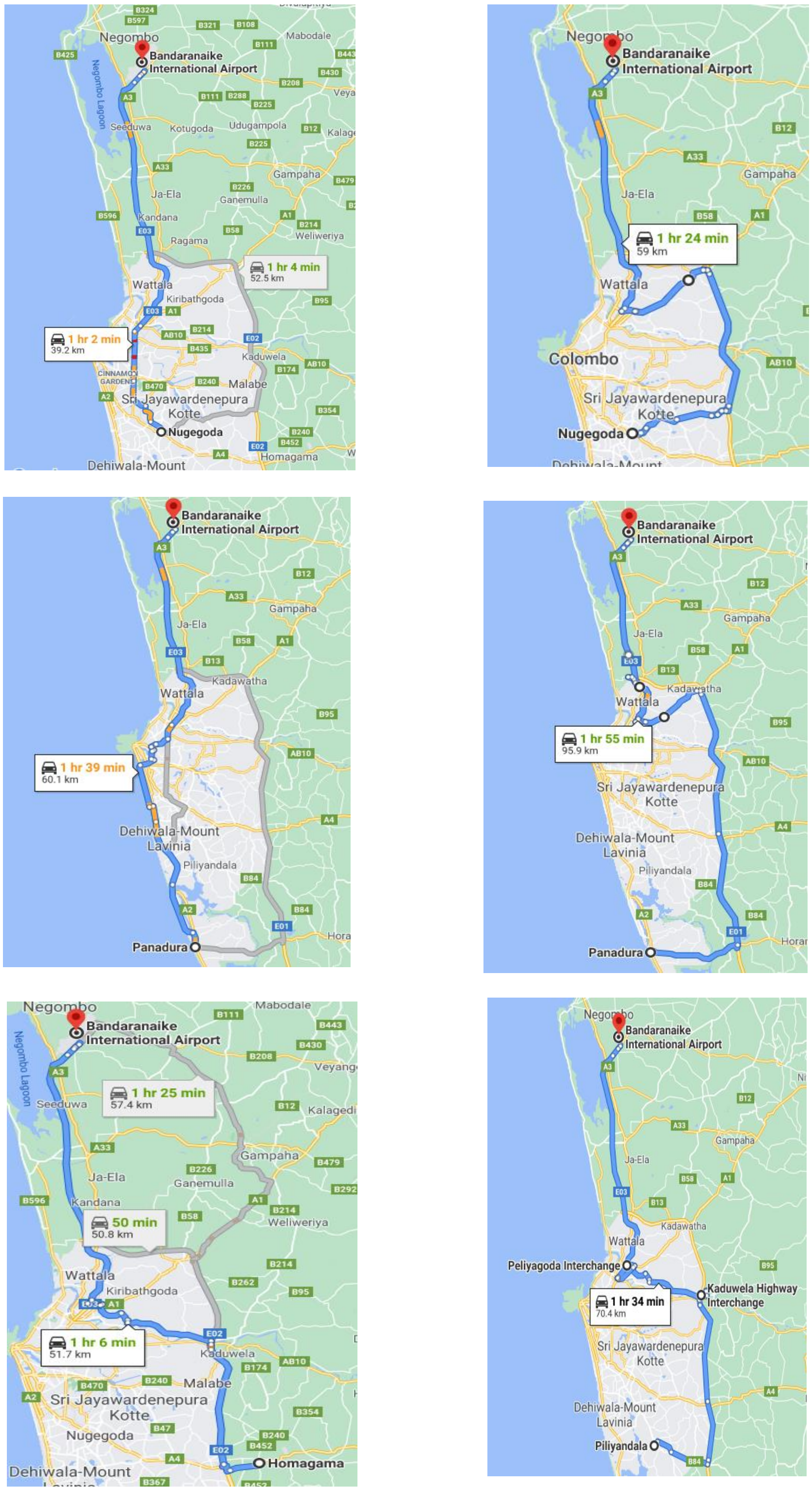


Figure 4-13: Trips from Urban centers through OCH and Normal highway

According to the above Figure 4-16 it can be conclude that trips from some urban centres tend to use normal highway rather than using Outer Circular Expressway. Even though the trips starting from Homagama and Piliyandala through OCH they have to use normal roads from Kaduwela or Kadawatha as Kadawatha to Kerawalapitiya section (OCH phase iii) was not opened by the time of analysis. Those types of trips that have to use normal roads because of not connecting the E02 and E03 may result in high overestimation of 1.688 within the Kaduwela to Kadawatha section.

And also, distance to Expressway interchanges from those Urban centres are considerably high. This tends people to use normal routes with their day today activities rather than using long distance paths. Distances to nearest Expressway interchange from some Urban centres are given below.

Table 4-4: Distances to nearest interchanges from some Urban centers

Urban Centre	**Nearest Interchange**	**Distance**
Colombo central area	Kaduwela	17.3 km
Sri jayawardanapura Kotte/ Baththaramulla	Athurugiriya	21.0 km
Gampaha	Kadawatha	12.8 km
Ja-ela	Kadawatha	12.6 km
Kadawatha	Kadawatha	1.5 km
Kelaniya	Kadawatha	6.6 km
Kaduwela	Kaduwela	2.8 km
Nugegoda	Kottawa	10.6 km
Dehiwala	Kottawa	16.0 km
Piliyandala	Kahathuduwa	7.6 km
Homagama	Kottawa	3.7 km

Moratuwa	Kahathuduwa	12.0 km
Panadura	Gelanigama	11.9 km
Kaluthara	Dodangoda	13.0 km

4. Some parameters used in modelling was taken according to the Japan and American standards

For traffic assignment model an incremental traffic assignment model was selected. The equal travel time principal was used and it means traffic will switch to another route with minimal travel time. Travel time is depending on Capacity, Design speed and Speed flow. Design information from Japan used as a reference for setting the Maximum daily design capacity. For the Sri Lankan context it would be deferent than the Japan design capacities.

4.4 Colombo-Katunayaka Expressway

4.4.1 Introduction

Previously CKE project was started in 2000 and it was mutually terminated in 2004 with RDA taking over the site. After that, in 2006 feasibility studies were carried out again with new trace. Transport division of University of Moratuwa had implemented the TRANSPLAN model to forecast the future traffic. The TRANSPLAN model predicts the future traffic of the considered network according to the trip generation and attraction by referring to the socio-economic parameters of the area such as Population, Household, Number of jobs in various categories and Vehicle population etc.

4.4.2 Probable Reasons for Overestimation

1. Road projects considered to be operated by the time of forecast years are not fully operated

Same as the OCH, for CKE also the main reason for over estimation is non-operation of the assumed road sections those are considered in modelling. The expressways considered to be operated were,

a) Colombo – Katnayake Expressway
b) Outer Circular Highway and connected to CKE
c) Southern Highway
d) Colombo Kandy Alternate Highway up to Ambepussa

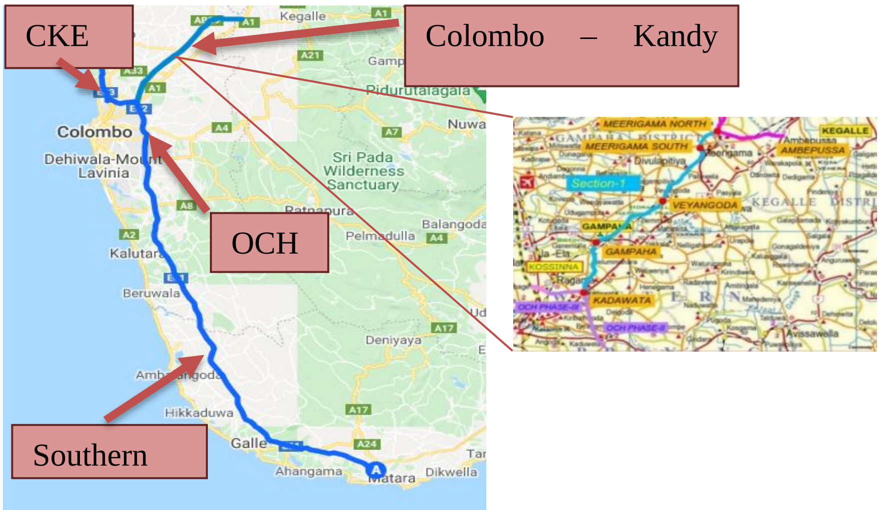


Figure 4-14: Proposed Expressway network

But in the analysis year (2017), only southern highway was completed and OCH was not connected to Colombo Katunayake Expressway. Colombo Kandy highway up to Ambepussa also not completed by the time of analysis. The road network is more similar to the Figure 4-14.

Because of that huge traffic amount was not operated in the Colombo – Katunayake Expressway. Trip generated from the major town centres like Kandy, Kurunegala, Kegalle and Gampaha to Katunayake area have chosen the normal roads because of the less distance and less travel time.

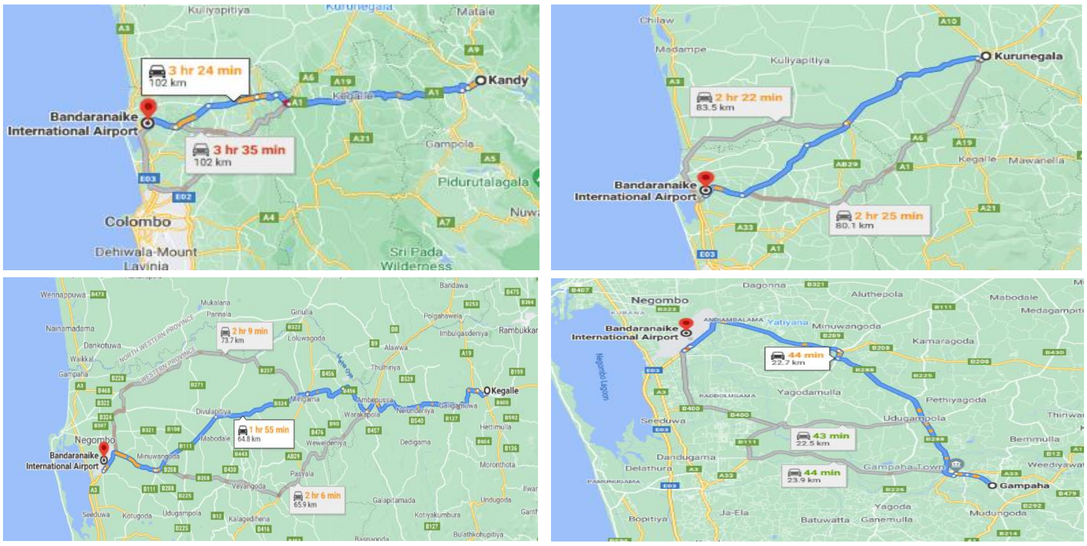
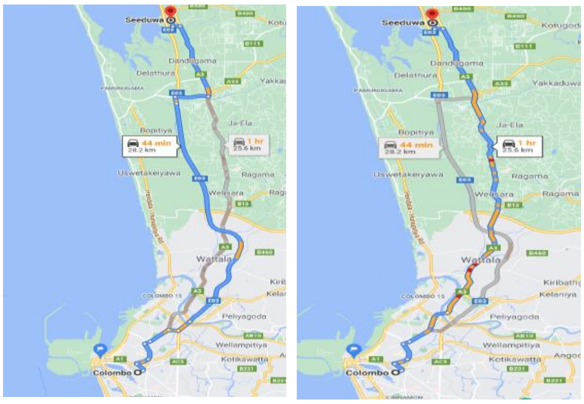


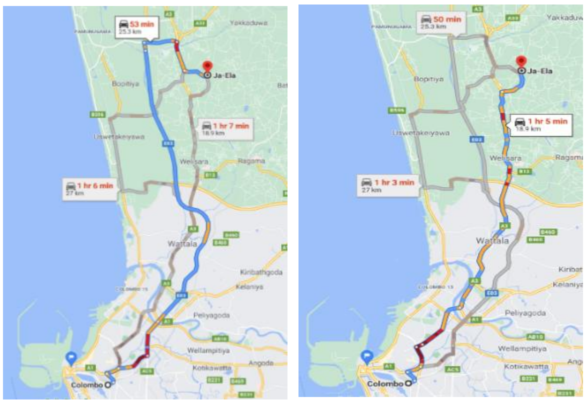
Figure 4-15: Route choice from Kandy, Kurunegala, Kegalle and Gampaha to BIA

Because of not having the Colombo Kandy Highway even up to Ambepussa most of the traffic not travel through CKE resulting probable overestimation in traffic forecasting model. And generated traffic also can reduce such as Taxi services to BIA, Passenger services to Katunayake Industrial Zone and etc.

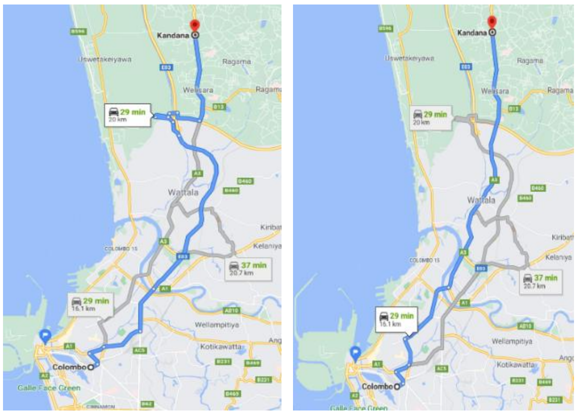
2. Reduction in Intra traffic using CKE from Colombo to Town centres along A3

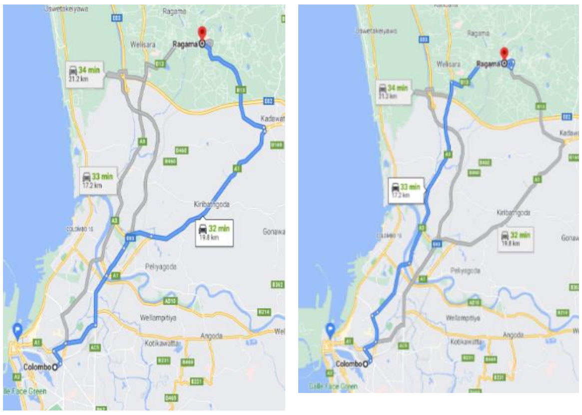
More likely the scenario in OCH, due to the distance through the CKE is considerably higher than the along A3 traffic shifted to A3 road mostly in off peak times. Below figures show the difference in time and distance when travelling from Colombo to Town centres along A3 road.





Colombo to Seeduwa Colombo to Ja-ela





Colombo to Kandana Colombo to Ragama

Figure 4-16: Distance to different Town centers along A3 from Colombo

4.5 Summary

Here Absolute inaccuracies were considered to calculate the mean inaccuracy and variance.

Table 4-5: Summary of the analysis for Expressways and National Highways

	Mean	Var	RMSE	MIN	MAX
E01	0.229	0.039	6323	-0.646	0.396
E02	0.933	0.118	18217	0.534	1.337
E03	2.919	0.193	63321	2.609	3.229
Highways	0.328	0.144	5522	-0.604	1.159

4.6 Traffic forecasting accuracy w.r.t forecast years and forecast method in National Highways

As described in chapter 2 forecast method and forecast period also directly affecting the accuracy of forecast. Here only National Highways selected to check the accuracy w.r.t forecast years and forecast method. Because when considering expressways, Outer Circular Expressway and Colombo Katunayaka Expressway are not operating as the expected scenarios. For National Highways, most of the road's feasibility studies carried out before 2010. So, most of the traffic forecasts are done using traditional growth factor method.

Here Mean Absolute Percent Error (MAPE) and Correlation coefficient are used to analyse the inaccuracy w.r.t forecast years and forecast method.

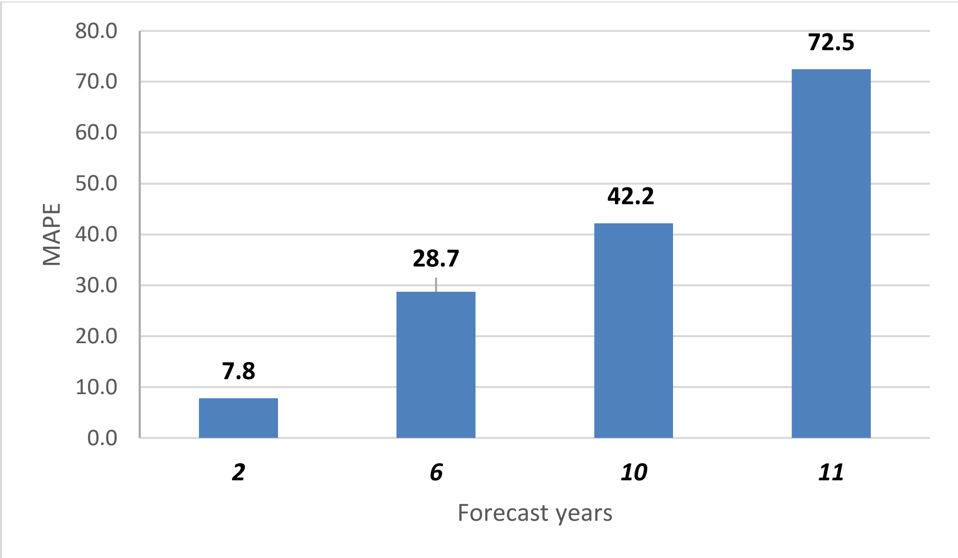


Figure 4-17: Forecast years vs MAPE – Growth Factor method (National Highways)

Table 4-6: Analysis of Forecast error w.r.t. forecast duration

Year	MAPE	Mean	SD	5th percentile	95th percentile
2	7.8	0.0	6.2	3.9	11.8
6	28.7	-0.1	30.0	6.2	58.1
10	42.2	-0.3	41.8	15.6	68.8
11	72.5	0.7	42.4	17.6	111.4

According to the figure 4-20 it can be seen that higher the forecast duration, MAPDF also getting large. That means forecast error is getting higher with the increase of forecast duration. And also, Table 4-5 indicates that with the increase of forecast duration forecast error have a wider spread (90% of the data will fall within 17.6% to 111.4%). And also, correlation coefficient is 0.93 which implies a high relation between forecast duration and MAPE.

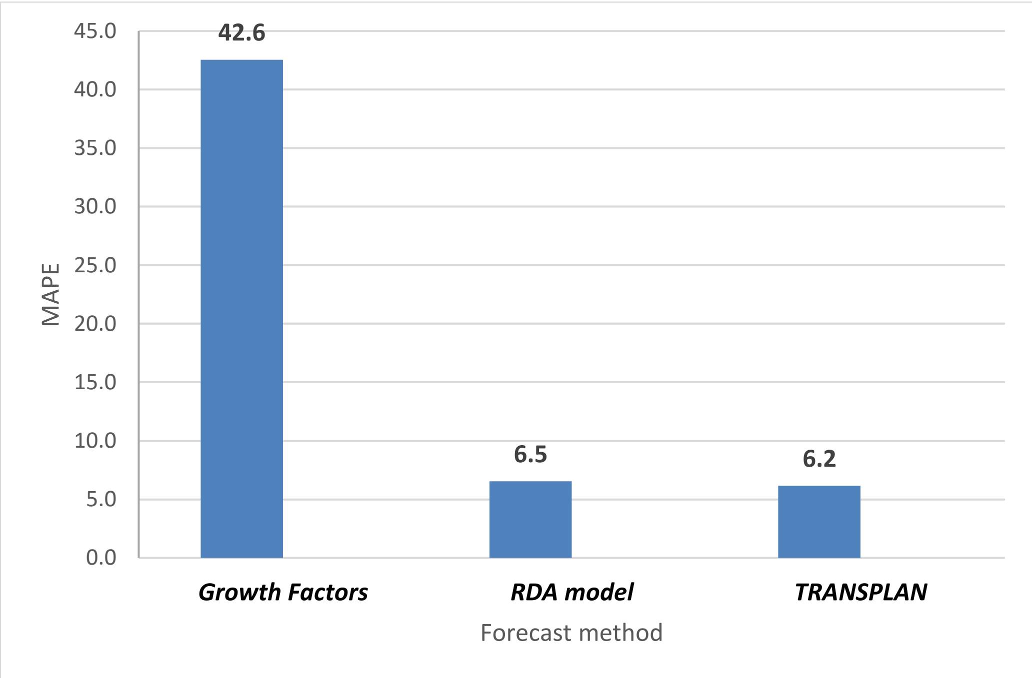


Figure 4-18: Forecast Method vs MAPE

Table 4-7: Analysis of Forecast error w.r.t. Forecast method

Forecast method	MAPE	Mean	SD	5th percentile	95th percentile
Growth factor	42.6	0.2	40.5	4.2	102.5
JICA STRADA	6.5	0.0	3.5	4.3	8.8
TRANSPLAN	6.2	0.0	5.7	2.5	9.8

Looking at the distribution of error by forecast method (Figure 4-21), Growth factor method exhibit large MAPDF value compare to RDA model and TRANSPLAN model. And also, standard deviation of Growth factor method is 40.5 which implies huge variation of results.

5. CONCLUSIONS

According to the analysis of data following conclusions can be made

National Highways:

- National Highways show overestimation than under estimation. Most of the overestimated highway's feasibilities are done before 2010.
- For Growth factor method, forecast accuracy is higher when the forecast period (years) is shorter in the national highways.
- When forecast accuracy is compared with the forecast method, RDA model and TRANSPLAN method exhibit more accuracy than the Growth factor method.

Expressways:

- According to the results Southern Expressway shows least inaccuracy whilst Outer Circular Expressway and Colombo-Katunayake Expressway demonstrate huge overestimations.
- In Southern Expressway, northern part shows under estimation and southern part shows over estimation.

6. RECOMMENDATIONS

- Some more Forecast traffic data and relevant Actual traffic data should be analyzed for National Highways to analyze Forecast accuracy with respect to Forecast method.
- Expressways should be analyzed after connecting the Outer Circular Expressway and Colombo - Katunayaka Expressway.
- Factors affecting the overestimations and underestimations should be evaluated in detail with extensive data collection.
- Traffic forecasting methods should be analyzed separately to find issues in forecasting parameters and models.
- To have a broader picture about how diverted traffic hit the forecast volume it is needed to have traffic data for pre and post opening project.
- Other than AADT, Peak hour traffic, Average speed and Truck volumes should be considered from the forecast.
- It is advisable to increase accuracy of forecasting models for socio-economic parameters rather than improving travel model.
- It is highly recommended to compile forecast data and traffic count data made available to public for researchers.

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