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# Prediction of Travel Time on Undivided Rural Roads

Akhil Lal
PG Student,
Department of Civil Engineering
Rajiv Gandhi Institute of Technology,
Kottayam, India

Jomy Thomas
Assistant Professor
Department of Civil Engineering
Rajiv Gandhi Institute of Technology,
Kottayam, India

***Abstract*— A heterogeneous traffic stream consists of vehicles that have different static and dynamic characteristics sharing the same road space. Lack of lane discipline and complex interactions among vehicle classes make modelling heterogeneous traffic very difficult. On undivided rural road stretches, traffic operations are influenced by vehicles moving in the same as well as opposing directions. Geometric features of the road are also important parameters which have an impact on travel time on a rural road stretch. Literature on study of traffic parameters on undivided roads is relatively sparse. This study therefore attempts to model travel time on rural roads as a function of roadway and traffic flow characteristics. Roadway characteristics considered are deviation angle, grades, etc. For predicting the travel time multiple linear regression models were developed for different modes based on empirical data collected over a wide range of conditions. The study was conducted on a 9 km stretch on NH 183(Kollam-Theni Highway) in Kottayam district in Kerala. The stretch was divided into 3 segments and travel time data were collected using video graphic surveying at peak and off peak hours. The geometric features of road stretch like deviation angle of curves and gradient were obtained by conducting total station surveying. The models developed for smaller vehicles depicted that their travel time was significantly affected by heavy vehicles and three wheelers in the same direction. The maximum impedance by opposite flow as well as rise in the segment was for the travel time for heavy vehicles. The models developed will be useful for various traffic and transportation planning applications.**

***Key words: Travel time, Traffic flow, Geometric features***

## I. INTRODUCTION

A heterogeneous traffic stream consists of vehicles that have varying static and dynamic characteristics. It is difficult to model heterogeneous traffic conditions due to these variations as well as lack of lane discipline. A commonly used performance measure of traffic flow is travel time. It is defined as the time required for travelling along a route between any two points within a traffic network. It is well known that travel time or speed is influenced by the traffic flow on the road. On an undivided road stretch, traffic characteristics are influenced by traffic in same as well as opposing directions. There are models correlating travel time and traffic parameters. But geometric features like curves, gradients, carriageway width etc are also important parameters which have an impact on travel time. This study therefore identifies roadway characteristics affecting travel times on rural roads, and subsequently develops the models for predicting travel times on a rural road, based upon road characteristics identified. In order to manage the traffic operations smoothly and efficiently, it is necessary to model different traffic characteristics associated with transportation network. Travel time is an important parameter that can measure the service provided, hence it is an important attribute considered when a traveller selects a route from various other options. Travel time can be used as a measure for the effectiveness of improvement schemes. Economic analysis of transportation projects, road user cost estimation etc have a direct relation with the travel time. Travel time on a particular road stretch is a function of various traffic as well as the geometric features of the road under consideration. Out of the geometric parameters gradient and curvature have significant effect on the journey time. Along rural highways in Kerala, these features vary widely even over short stretches. The main aim of the study is to develop new models to predict travel time in the heterogeneous undivided traffic conditions based on vehicular composition and geometric features.

## II. LITERATURE REVIEW

Vanichkobchinda and Siriprasert (2012) developed a roadway-characteristics-and-Level-of-Service-dependent Travel times on rural roads in Thailand for both freight as well as passenger traffic. The variables used for the prediction are roadway environment (type of adjacent land use), roadway characteristics (presence of horizontal curvature and bridges along the road), road width, IRI etc. The parameters were correlated by using multiple linear regression method. They found that the influence of the modelling parameters depends on the Level-of-Service. Friesz et al. (1993) proposed whole link travel time model for urban roads in which the link travel time was treated as a linear function of the number of vehicles on the link. But they fail to give a solution procedure for the function. Another drawback of the study is that it follows first-in-first-out (FIFO) condition for all continuous inflow patterns. Rodenas et al. (2005) developed a whole link travel time model with occupancy constraint. The reformulate link travel time model in which travel time for traffic entering a time t, is a function of the number of vehicles on link and they also developed a solution procedure for the model. Speciality with this formulation is that here it is not necessary to satisfy the first-in-first out (FIFO) condition.

## III. DATA COLLECTION AND ANALYSIS

The stretch chosen for this study is a part of NH 183. The NH 183 connects Kollam in Kerala with Theni in Tamilnadu and the en route tourist destinations of Thekkady and Kuttikanam, as well as the agricultural towns of Kanjirapally and Mundakayam. The stretch is a two lane road having traffic in both the directions. From the selected part of the highway, three segments of road each of 3 km length as shown in Fig. 1were selected for the study.

The three segments identified are

1 Manarcadu to Sanjose
2 Sanjose to 9th mile and
3 Alampally to 13th mile

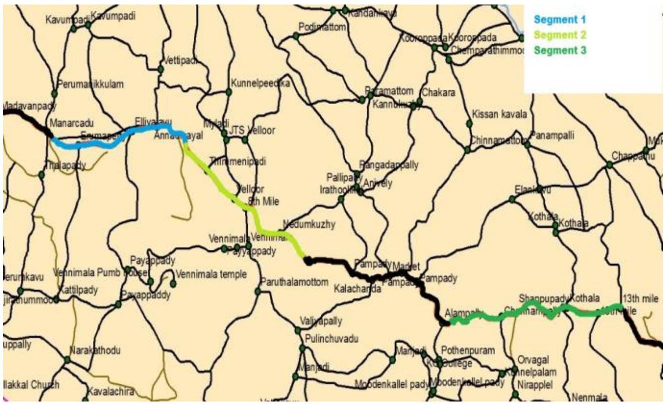


Fig 1. Study Stretch (Source Natpac)

### A. Geometric Data

The horizontal and vertical alignment was obtained by total station surveying. After the survey, the data collected which was stored in the memory of total station equipment were transferred to the computer. The output includes an excel sheet showing co ordinates of all the station points and staff points and an AutoCAD file showing all station as well as staff points. All the co ordinates include latitude longitude and altitude of every station point on one side of the segment obtained from the total station output were used to draw the longitudinal profile of every stretches. From the profile the rises and falls of the stretch were estimated and added separately. From the value of total rise and fall in each segment, rise and fall in metre per kilometre were found out and are shown in Table 1

TABLE 1. Rise and fall in study segments

| Segment | Total rise in m | Total fall in m | Rise (m per km) | Fall (m per km) |
|---|---|---|---|---|
| 1 | 48.54 | 42.27 | 16.18 | 14.09 |
| 2 | 50.84 | 45.24 | 16.96 | 15.08 |
| 3 | 82.74 | 67.62 | 27.58 | 22.54 |

All the deviation angles were measured from the AutoCAD output by drawing tangents. By adding the entire deviation angle for a section total deviation in degrees for that segment was obtained. Deviation angle per kilometre for a stretch was obtained by dividing total deviation angle of the segment by the length of the segment.Deviation angle in all the segments per kilometre as shown in Table 2 obtained by adding the deviation angles of each curves in the segment.

TABLE 2 Deviation angle in study segments

| Segment | Total Deviation angle (Degrees) | Deviation angle per km (Degree per km) |
|---|---|---|
| 1 | 759 | 253 |
| 2 | 414 | 138 |
| 3 | 826 | 276 |

### B. Traffic Data

Traffic data is obtained by conducting video graphic survey at the entry and exit points of each segment. Totally five days (Monday-Friday) data collection was conducted. Every day 10 hours of video graphic data were taken by using synchronized video cameras which was started at the same time.

Traffic flow is obtained by conducting classified count of vehicles travelling in both directions through the every data collection point for every fifteen minute interval. Traffic volume for one hour was obtained by multiplying the fifteen minute data with four.

Travel time measurement was done by vehicle identification method .The identification was done by noting the model of vehicle as well as the colour by playing the video data input and output of the stretch simultaneously. Each vehicle was identified at entry and exit points of the segment and the travel time was obtained by taking the difference in the arrival times. Travel time per kilometre for all the segments in both directions was obtained by dividing the segment travel time with the length of segment. It was done for an interval of 15 minutes and average travel time of vehicles was obtained by taking mean of that 15 minutes data. Total 40 travel time values were obtained for each class of vehicle from one day survey in one direction.

The analysis of the various parameters including deviation angle, rise, fall, traffic flow, travel time etc were conducted and their inter relationships have been brought out. Patterns of various relationships between travel time and traffic flow, Travel time and the geometry were identified. Rise and fall are significantly higher in segment three when travelling towards Kumly direction. Travel times of various classes of vehicles at third segment are higher than those at all other segments, which shows the impact of geometry on vehicle in a that segment.



## IV. MODEL CALIBRATION AND VALIDATION

Travel time models for three classes of vehicles are developed with the class wise flows in the same and opposite direction of flow, geometric features like rise, fall and degree of curve as independent variables by using multi linear regression. BPR type models were developed using aggregate flow in both directions and geometric features as independent. The models are calibrated using 70 percent of collected data, selected randomly and validation is done by the held out 30 percent. Mean absolute percentage error (MAPE) is used as a measure of performance of the models.

Travel time prediction models were developed for buses, cars and two wheelers by regressing the travel time of various class of vehicle as dependent variable with independent variables such as class wise flow in both directions, rise, fall, deviation angle etc. Sample size for the calibration of the model is 840. Table 3 shows the model summary in which the values in the bracket indicate t-statistic of that variable.

TABLE 3. Model summary multiple linear regression

| Vehicle class | Bus | Car | Two wheeler |
|---|---|---|---|
| Sample size | 840 | 840 | 840 |
| Constant | 1.162 | 0.779 | 0.832 |
| Shv | - | 0.0019 (3.82) | 0.0015 (4.76) |
| Stw | 0.0010 (8.06) | - | - |
| Scr | - | 0.0002 (2.96) | 0.0001 (2.92) |
| Sth | 0.0007 (2.75) | 0.0009 (3.51) | 0.0007 (3.83) |
| Ocr | 0.0006 (4.89) | 0.0007 (7.09) | 0.0006 (7.42) |
| Otw | 0.0006 (5.08) | - | - |
| R | 0.0383 (21.62) | 0.0312 (20.01) | 0.0338 (22.85) |
| F | -0.0167 (-12.9) | -0.0123 (-10.36) | -0.0146 (-12.67) |
| **D** | **0.0003** (3.13) | **0.0002** (4.26) | **0.0003** (5.13) |

Where,
Shv =Volume of heavy vehicles in same direction (vehicle/hr)
Stw =Volume of two wheelers in the same direction (vehicle/hr)
Sth =Volume of three wheelers in the same direction (vehicle/hr)
Scr =Volume of cars in the same direction (vehicle/hr)
Otw = Volume of two wheelers in the opposite direction (vehicle/hr)
Ocr = Volume of cars in the opposite direction (vehicle/hr)
R =Rise in the segment m/km
F =Fall in the segment m/km
D =Deviation angle in the segment degrees/km

The Travel time prediction model for bus which predicts the time required by bus to traverse unit length is calibrated using the class wise volume data collected as well as the geometric features of road. The model form is shown below.

$$T_{Bus}= 1.162+0.001\times Stw+0.0007\times Sth + 0.0006\times Ocr +0.0006\times Otw+0.0383\times R-0.0167\times F+0.0003\times D \quad (1)$$

$R^2$ value is obtained as 0.799 which implies 79.9 % of the variance of the dependent variable can be explained by the model. The MAPE of calibrated model is 6.01%. From the model obtained it can be concluded that the travel time of buses is influenced by traffic in same and opposite direction. Among the traffic along the stream, auto rickshaws moving at comparatively low speeds affect the travel time of bus most significantly. Two wheelers in the same direction are also affecting the travel time of buses which may be due to the frequent changing of their relative position on the road. Cars and two wheelers in opposite direction constituting nearly 80% of the flow are the most significant among variables. Two wheelers and cars in opposite direction offer the same impedance to bus, the coefficients of both flows being almost equal at 0.0006. Among the geometric parameters rising gradient in m/km is found to be with a coefficient of 0.038. The increase in travel time that is caused by a rise of one metre per kilometre is greater than the decrease in travel time caused by fall of 1m per kilometre (coefficient = -0.0167). As the deviation angle in m/km increases also the travel time got increased.

Travel time of cars to cover a kilometre of road in any direction is modelled with various parameters like flow of various classes of traffic and geometric features.

The obtained model is shown below.

$$T_{Car}=0.779+0.0019\times Shv+0.0002\times Scr_{+}0.0009\times Sth+0.0007\times Ocr +0.0312\times R-0.0123\times F+0.0002\times D \quad (2)$$

$R^2$ value is obtained as .764 which means 76.4 % of the variance of the dependent variables can be explained by the model and the MAPE value of calibrated model is 4.78%. Flow of heavy vehicles in the direction of cars influence the travel time of cars most significantly. 80 % of heavy vehicle is composed by buses due to this reason the light vehicles that follows a bus has to stop on the back of the buses when they are dwelling on the stops. Also the cars and the three wheelers moving in the same direction have influence on the travel time of cars. Even though cars are the vehicle class which has the highest speed there are some slow moving cars which reduce the speed of cars. Three wheelers in the same direction which travels in much lower speed increases travel time of cars.



The model which predicts the travel time of bikes is obtained by combining the various effects traffic and geometric parameters which is then

$$T_{2w}=0.8322+0.0015\times Shv+0.0007\times Sth+0.0001\times Scr+0.0006\times Ocr+0.0338\times R-0.0146\times F+0.0003\times D \quad (3)$$

$R^2$ value is obtained as .791 which means 79.1 % of the variance of the dependent variables can be explained by the model and the MAPE value of calibrated model is 3.29%. Travel time of a two wheeler moving in a direction mostly influenced by the presence of heavy vehicle in the same direction. In a rural undivided road it takes more time to overtake a heavy vehicle due to the presence of opposing traffic. Also the presence of curves as well as steep gradients makes the overtaking difficult. The three wheelers in the same direction which is moving in slower speed is also a significant parameter that affects travel time of car. Car in the same direction and opposite direction also affects the travel time. Cars in the opposing direction have more significance than that in same direction.

Travel time prediction models obtained show that the travel time of any vehicle in an undivided road affected by vehicles in both directions. By analysing the obtained models for predicting the travel time of two wheelers and cars the variables influencing are the same but the coefficients are different. By comparing coefficients of the rising gradient increase the travel time of bus per unit increase in rising gradient is the highest. There is an 18% and 11.3% reduction in increase of travel time of cars and two wheelers when comparing with increase of travel time of bus. Reduction in travel time due to falling gradient is highest for bus followed by two wheeler and car. Deviation angle have same coefficient in the case of two wheeler and bus.

Validation of the models developed was done by using the randomly selected 30 % data. The calibrated model is used to predict the travel time in the validation data. The MAPE value was calculated by considering the observed and predicted values of travel time for various classes of vehicles.

TABLE 4 . MAPE Values for calibration and Validation

| Model | Calibration | | Validation | |
|---|---|---|---|---|
| | Sample size | MAPE | Sample size | MAPE |
| Bus | 840 | 5.73 | 360 | 5.79 |
| Car | 840 | 6.96 | 360 | 6.11 |
| Two wheeler | 840 | 5.53 | 360 | 5.72 |

The MAPEs obtained for all the models during calibration and validation are less than 10%. Hence the result obtained was accurate. Hence the overall model is acceptable.

## V. CONCLUSIONS

Traffic and geometric features of the selected stretches were collected and analysed. Models were formulated to predict travel times of three classes of vehicles namely buses, cars and two wheelers based on the traffic and geometric features. For predicting travel time in the selected undivided road, class wise flow of different classes of vehicles in both directions and geometric features of the road stretch like gradient and deviation angle were considered as independent variables. MAPE is used as the measure of performance of the models developed. Validation of the formulated model was done using randomly selected sample from the collected data. Travel times were found to be primarily influenced by roadway features such as deviation angle, rise and fall for all classes of vehicles. Travel time is also a function of the traffic flow in the same and opposite directions on undivided roads. Travel time of bus is affected by cars and two wheelers in the same and opposite direction affect the model. But models for two wheelers and cars depicts that the impact of opposing flow is less for them.

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