Travel time Reliability under Heterogeneous Traffic Conditions and Improvising it Using ITS

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ABSTRACT

Traffic congestion is an increasingly serious problem faced by travellers throughout the world. Congestion can be defined in simple terms as the traffic demand exceeding the roadway capacity. Traffic congestion is becoming a serious problem in most Indian cities too. The rapid pace of economic growth and the resulting growth in vehicular population is one of the main reasons for this problem. There is a limit on how much additional roadway infrastructure can be added to meet the growing vehicle population. City planners are doing the best they can to cope with the increasing demand for transportation infrastructure. . For this, in recent years, transportation engineers and planners have increasingly embraced strategies that deal with better management of existing roadways, including Intelligent Transportation Systems (ITS). ITS includes the application of advanced technologies using real-time information about roadway conditions to implement appropriate control strategies. Real-time control of roadway operations through a Transportation Management Centre (TMC) has become a major activity undertaken by transportation agencies. The present study falls in the latter category, where the general objective is to provide travellers with information about traffic conditions to help them in taking better travel decisions. The information that can be provided to the travellers includes expected travel times, traffic conditions such as congestion, availability of alternate routes, etc.

INTRODUCTION

Congestion, delay and unreliability are terms that most associate with present-day travel. Both individuals and companies suffer from economic losses due to lost time as well as additional vehicle operating and detour costs. For this reason, travel time has been a critical measure used to evaluate conditions on the road and assess improvement projects. Despite it being a popular statistic, until now travel time has been difficult to measure. For economic analyses the travel time is most commonly deduced from free-flow travel time. Other ways in which travel time is calculated is from floating car studies or by using speed obtained from loop detectors. While travel time has always been the most important measure associated with effectiveness of the transportation system, recently a single measure of travel time has become insufficient. Travel times can vary during the day or between days. During peak hours, the travel time can increase significantly as compared to other time periods. In addition, heavily travelled corridors at or near capacity suffer from large travel time variation due to even small perturbations in traffic. An average travel time cannot capture these changes and a reliability measure is necessary. Reliability of travel time has often been used interchangeably with variability and can refer to changes in travel time during the course of a day or changes from day to day. Seven sources of variability in travel times have been identified: incidents, work zones, weather, demand fluctuations, special events, traffic control devices and inadequate base capacity. Understanding travel time reliability is important to travellers in order for them to plan their trips effectively as well as shippers for them to plan and select routes appropriately. Furthermore, reliability needs to be taken into account during project assessment in order to capture all the benefits of an improvement project. The major problem is a "traffic jam" (as opposed to heavy, but smoothly flowing traffic) may suddenly occur.

It has been found that individual incidents (such as accidents or even a single car braking heavily in a previously smooth flow) may cause ripple effects (a cascading failure) which then spread out and create a sustained traffic jam when, otherwise, normal flow might have continued for some time longer.

LITERATURE REVIEW

For the past few decades much of the transportation research has been dedicated to development of performance measures that would enable congestions evaluation. Most agencies have focused on volume to capacity ratios and level of service measurements to describe the travel conditions (Highway Capacity Manual, 2000). These measurements compare the facility capacity to its utilization on a localized scale. On a larger spatial scale, hours of delay and vehicle miles travelled are used to assess the conditions. While effective at assessing the road's performance in comparison to the rest of the network, these measures do not easily translate well to the user experience. Recently a trend has emerged to develop performance indicators that express congestion and mobility in terms of something the system users can understand and appreciate. Two such measures include travel time and reliability (FHWA, 2005). Travel time is a main factor in drivers' route choice decisions and its value has been studied for many decades. In more recent years, researchers hypothesized that the value of travel time models may have been omitting important reliability considerations and a model that includes both reliability as well as travel time should be used. Value of reliability has been explored both using the stated preference and revealed preference approach. Abdel-Aty et al. (1995) conducted a phone survey and formulated a binary logit model to determine the importance of reliability in route choice decision. He found that travel time reliability was equally important as travel time. Liu et al. (2004) used the revealed preference approach to estimate the value of travel time and reliability on SR 91. They estimated a mixed logit model by finding coefficients of travel cost, travel time and reliability that minimized the differences between the predicted and observed traffic flows. The authors concluded that the value of travel time was $12.81/hour, while the value of reliability was $20.63/hour. From these and other studies it is clear that reliability is important to the roadway users. While there's pervasive evidence that both travel time and reliability are important considerations in travel decisions, these parameters are not easy to measure and predict.

Methods of Estimating Travel Time Travel time evaluation methods consist of direct measurements and estimations. The most popular method to measure travel time directly has been the floating car technique (Robertson, 1994). This method uses a probe vehicle travelling with the traffic flow. Travel time and location are recorded along the route. A similar technique uses a GPS device to record the vehicle trajectory along with time stamps. This method provides more frequent sampling along the route and avoids human error. It also allows for viewing of the results using a GIS interface (Quiroga & Bullock, 1998). However, both methods only provide travel time for the probe vehicle, making it difficult to collect a large dataset for various routes and times of day. Travel time estimation methods vary from simple estimation of average free flow travel time based on posted speed to complex algorithms based on combination of real-time 30-seconddual loop detector data and historical data. Some of the most widely used estimation methods are based on dual-loop detector data. One method to evaluate the highway segment's travel time is based on an upstream and downstream speed (also referred to as trajectory method). The simplest way to estimate travel time over a segment is by dividing the segment distance by the average travel speed at the upstream and downstream detectors. This method is particularly appealing due to its simplicity and is still frequently used for real-time prediction (Tufte & Kothuri, 2007). Alternatively, instead of assuming that the vehicle traverses half the segment at the downstream speed and half the segment at the upstream speed, Cortes et al. (2002) proposed using a linear combination of speeds at upstream detector when the vehicle enters the segment and speed at downstream detector when the vehicle exits the segment.

Initially the two parameters are set to 0.5 and are then calibrated for the given network. While this method allows one to capture network specific traffic effects, it requires travel time data for calibration. Another trajectory method used to estimate the travel time was proposed by Lint and is called piecewise linear speed based (PCSB) (Lint & Zijpp, 2007). Unlike the previous method discussed, the travel speeds over the segment are not assumed to be constant but rather have a linear shape. This allows the speeds to be continuous as section ends and models drivers adjusting their speed gradually in response to slower speeds ahead of them. Dual loop detector data can also be used to estimate the probability density function of segment travel times (Fan & Chen, 2009). The authors treat vehicle occurrence at the upstream and downstream station as time series and calculate the auto-correlations and cross-correlations between the two time series. The probability density function of travel times is then derived using the Fredholm integral equation. Another technology that measures travel time directly is the Automated Vehicle Identification (AVI) system consisting of an in-vehicle transponder and a roadside unit that receives the signal (Turner, 1996). This technology is most often integrated with tolling infrastructure. While this method provides good real-time travel time data it is expensive to implement.

Travel Time Reliability Travel time reliability has been a subject of many studies. It is commonly accepted to refer to the level of consistency in transportation service for a mode, trip, route or corridor for a time period (Lomax et al., 2003). In general travel time variability has been classified into recurrent and non-recurrent, where recurrent variability is a result of insufficient capacity, while the non-recurrent variability is caused by transient events. Sources of non-recurrent congestion include accidents, inclement weather, construction and special events. Separating the causes for travel time variability is important in assessing the benefits of improvement projects and coordinating efforts to improve reliability (Bremmer et al., 2004).Instead of classification by its source, variability can be categorized by its time frame. Bates et al. (1989) and Small et al. (1999) discussed variability as being inter-day, inter-period and inter-vehicle. Inter-day or day-to-day variability is caused by unexpected events such as construction or inclement weather. Inter-period or daily variation generally refers to the changes in travel time due to peak hour congestion. Meanwhile inter-vehicle variability is a result of individual driver behaviour including lane changes and speed. The existence of inter-period and inter-day variability has been long accepted. These are believed to arise due to variations in traffic resulting in delays the facility is at or near capacity. However, Mannering et al. (1990) empirically studied that the inter-vehicle variability that exists, which contradicts the assumption often made that everyone travels at the same speed within a given traffic flow.

Travel Time Reliability Measures Regardless of the source or the type of variability, most common measures include various indices suggested by the FHWA (2005). Indices of reliability are commonly divided into statistical, buffer measures and tardy trip indicators. Statistical methods include travel time window and percent variation shown in equations 2.1 and 2.2. Both measures focus on estimating standard deviation of travel times and comparing it to the average travel time. These statistical measures are effective in communicating the extent of unreliability to professionals, however, may not be meaningful to users because it is difficult for individuals to apply the concept of standard deviation to their individual travel time.

They are also unable to capture variation due to different events separately thus providing a very general measure of reliability for the roadway. The second category of methods is buffer measures, of which the most common is the buffer index. Buffer Index (BI) is a measure of trip reliability that expresses the amount of extra buffer time needed to be on time for 95 percent of the trips. This measure allows the traveller to estimate the extra percent of travel time that the trip may take due to varying congestion level. The buffer index and planning time index are measures that most users can relate to because when planning a trip one would like to arrive on time in a vast majority of situations. The 95th percentile travel time ensures the user is only late 1 out of every 20 trips. The buffer can be used to calculate a single value of reliability for the road segment or different values that depend on time of day and day of the week. Bremmer et al. (2004) calculated the 95thpercentile travel time for 12 commuter routes in Puget Sound by time of departure and provided a web-based tool for users to retrieve this information. Tardy trip indicators, which include percent of unreliable trips and misery index, are the third way to evaluate the variability in the travel time. Percent of unreliable trips is simply evaluated as the percent of trips with higher than acceptable travel times. The misery index is calculated as the average travel time subtracted from travel time from the top 20% of trips divided by average travel time. In addition to the statistical methods of estimating travel time reliability, Elefteriadou (2006)proposed econometric modelling. She developed linear regression models to estimate average travel time for scenarios with different combinations of weather, accidents, congestion and work zones

TECHNOLOGY USED

METHODOLOGY

Travel time information is a vital component of many intelligent transportation systems (ITS) applications. ITS are used to tackle some of the problems that have been found out in the corridor that are considered. Identified the problem, collected the necessary data and give suggestions for improving the traffic conditions in the corridor considered for study. Studied some more routes and then use GIS software to analyse the data.

Amity University	Sector 18 Turn	Noida Entry/Exit Red Light	Mayur Vihar Phase-1
Congestion	Non-Recurrent	Recurrent	Recurrent
Problem	Narrow Road (Bottle Neck)	1. Narrow Road 2. Ineffective Green Time 3. Improper Following Of Rules	1. On-going Construction 2. Narrow Road (Bottle Neck)
Suggestion	Construction Of 2 Stack Flyover	1. Wide Raised Medians 2. Integration Of ITS (Increasing Green Time According to the flow of traffic) 3. Free Signalized Intersection 4. Construction Of Flyover	1. Construction Of Flyover(Already Being Done)

Fig: Suggestions for problem on route to Akshardham

Amity University	Kalindi Kunj Bridge	Delhi Entry Toll Plaza
Congestion	Recurrent	Recurrent
Problem	1. Insufficient Road Capacity(Before and after Bridge) 2. Narrow Road(Funnel Effect) 3. Insufficient Capacity of Bridge(4 Lane)	1. Ineffective Green Time 2. Collection Of Toll leading to Delays
Suggestion	1. Widening Of road(Up to 10 lanes) 2. Widening Of Bridge(Up to 8 Lanes)	1. Toll Free Roadway 2. Free Signalized Intersection 3. Use Of ITS for Allotting proper green time in accordance with vehicle per hour

Fig: Suggestions for problem on way to Ashram

<u>Auto Regressive Model</u>

- RTMS (Remote Traffic Microwave Sensor) Detectors used one RTMS can provide coverage for up to eight lanes of traffic.
- RTMS Application:

1. Incident detection
2. Actuated intersections
3. Mid-block detection
4. Traveller information
5. Work zone safety
6. Counting

<u>Model Parameters</u>

Speed can be considered the single most important predictor of travel time. However, only point speed estimates are generally available from loop detectors. Furthermore, speeds are not available for individual vehicles but rather 30-second averages. Distance is another critical variable, since an increase in the length of the segment will obviously increase the vehicle travel time. These variables can be included in the model as linear terms. However, from a theoretical standpoint, vehicle travel time should be proportional to distance divided by speed and thus a term representing the average travel time on the segment was included instead of separate linear terms. Rush-hour parameter can have many different definitions because it is difficult to estimate its onset. In this study, rush hour was estimated between 9-10 am. This indicator variable is incorporated into the model in addition to the traffic data because it is possible that during the rush hour there is a breakdown in the traffic flow and average speed and volume data will be unable to capture the extent of increase in travel time.

<u>Model Selection</u>

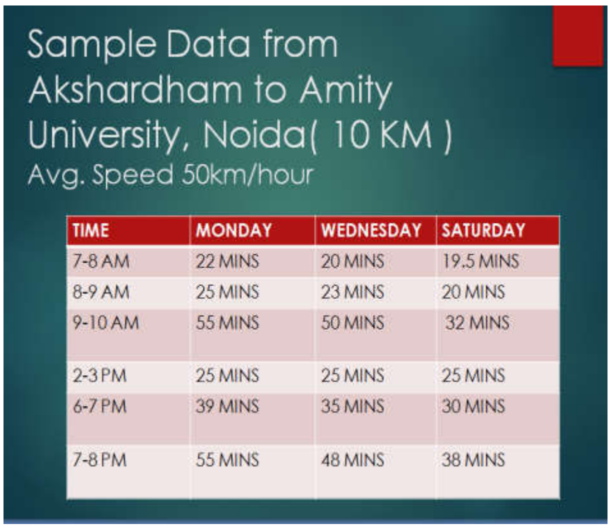
Linear regression analysis yielded reasonable parameter estimates and model fit. However, a check on the Durbin-Watson statistic, which was significantly different from two, indicated serial correlation between observations. Serial correlation violates the assumption that the error terms are independent between different observations and may result in parameter estimates being biased and inconsistent (Washington, Karlaftis, & Mannering, 2003).

In this study serial correlation is not unexpected since time-series data are being analyzed. One approach that allows to remove the correlation is regression incorporating lagged dependent variable terms. The first-order autoregressive model formis described as:

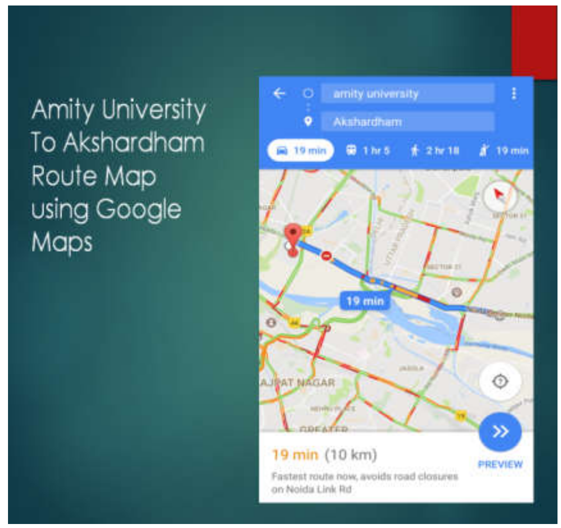
$Yi = \square\square Xi + \square\square Yi\text{-}1 + ei$

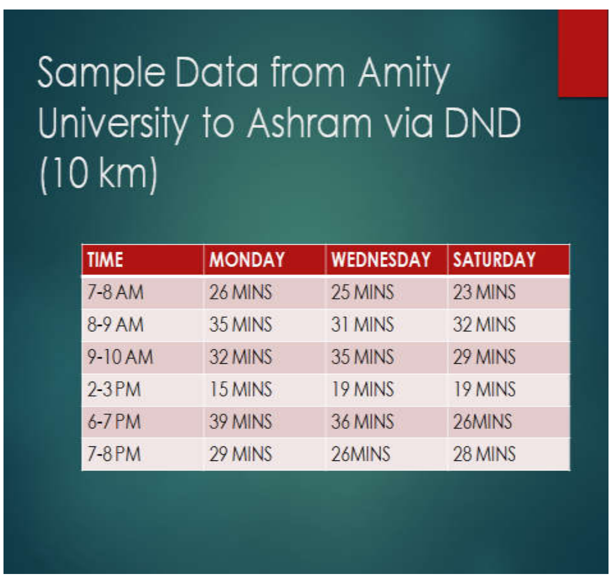
Where □□is a vector of estimated independent variable, Xi is the independent variable, □□is the coefficient of the lagged dependent variable, ei is the error term. Once this model is estimated, the Durbin Watson statistic is once again evaluated and additional lagged terms are added to meet the regression assumption.

DATA COLLECTED

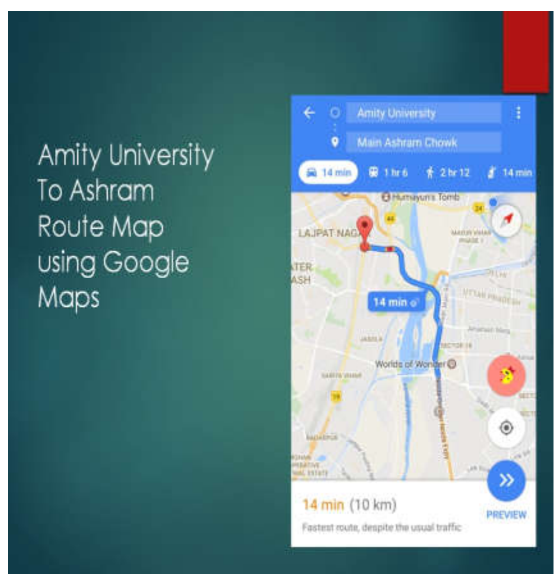


TIME	MONDAY	WEDNESDAY	SATURDAY
7-8 AM	22 MINS	20 MINS	19.5 MINS
8-9 AM	25 MINS	23 MINS	20 MINS
9-10 AM	55 MINS	50 MINS	32 MINS
2-3 PM	25 MINS	25 MINS	25 MINS
6-7 PM	39 MINS	35 MINS	30 MINS
7-8 PM	55 MINS	48 MINS	38 MINS



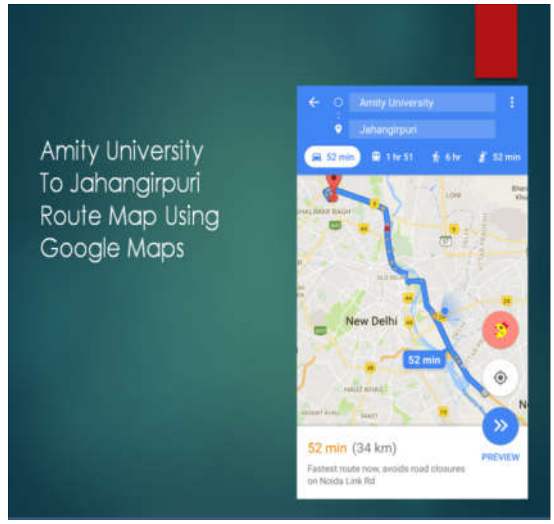


TIME	MONDAY	WEDNESDAY	SATURDAY
7-8 AM	26 MINS	25 MINS	23 MINS
8-9 AM	35 MINS	31 MINS	32 MINS
9-10 AM	32 MINS	35 MINS	29 MINS
2-3 PM	15 MINS	19 MINS	19 MINS
6-7 PM	39 MINS	36 MINS	26MINS
7-8 PM	29 MINS	26MINS	28 MINS



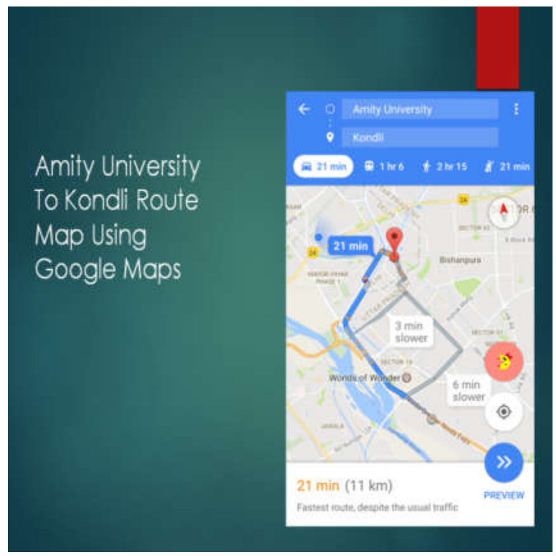
Sample Data from Jahangirpuri to to Amity University(34 km)

TIME	MONDAY	WEDNESDAY	SATURDAY
7-8 AM	40 MINS	45 MINS	40 MINS
9-10 AM	1.2 HOUR	1 HOUR	1 HOUR
1-2 AM	43 MINS	45 MINS	40 MINS
3-4 PM	40 MINS	45 MINS	40 MINS
5-6 PM	1 HOUR	50 MINS	45 MINS
7-8 PM	45 MINS	50 MINS	45 MINS



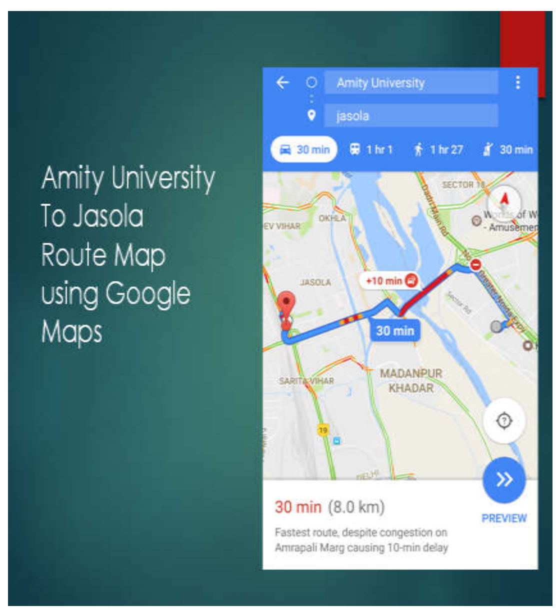
Sample Data from Amity University to Kondli (11 km)

TIME	MONDAY	WEDNESDAY	SATURDAY
7-8 AM	18 MINS	17 MINS	16 MINS
9-10 AM	31 MINS	38 MINS	30 MINS
1-2 PM	18 MINS	22 MINS	23 MINS
3-4 PM	21 MINS	16 MINS	25 MINS
5-6 PM	29 MINS	28 MINS	26 MINS
7-8 PM	38 MINS	37MINS	35 MINS



Sample Data from Jasola to Amity University(7 km)

TIME	MONDAY	WEDNESDAY	SATURDAY
7-8 AM	19 MINS	17 MINS	15 MINS
9-10 AM	35 MINS	40 MINS	25 MINS
1-2 AM	25 MINS	28 MINS	25 MINS
3-4 PM	25 MINS	28 MINS	25 MINS
5-6 PM	45 MINS	50 MINS	30 MINS
7-8 PM	55 MINS	45 MINS	30 MINS



PARAMETER	DESCRIPTION	VALUE	T-STATICS	P-VALUE
Travel Time	Estimated by distance divided by speed	0.374	19.23	<0.0001
Lagged Travel Time	Travel time of preceding vehicle	0.1733	19.85	<0.0001
Lagged Travel Time	Average Travel Time of preceding Vehicle 2 through 4	0.3464	0.0132	<0.0001
Lagged Travel Time	Average Travel Time of preceding Vehicle 5 through 7	0.1667	13.2	<0.0001
Rush Hour	Indicator Variable equal to 1 if vehicle is travelling between 8:30-10:00 am and 5:30-7:30pm	0.0462	5.28	<0.0001

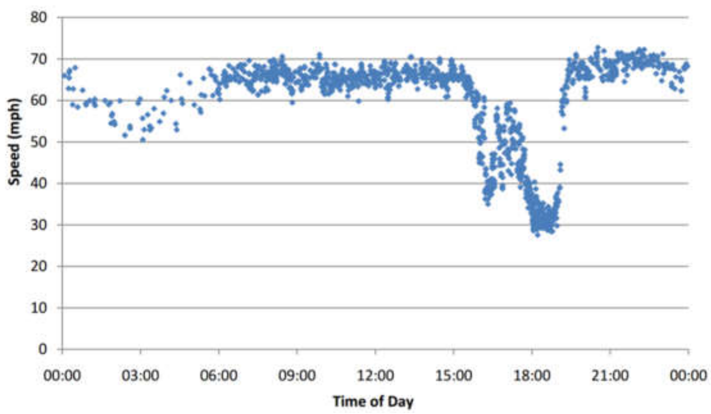


Fig: Daily Speed Profile For the Noida-Akshardham(Delhi) Route

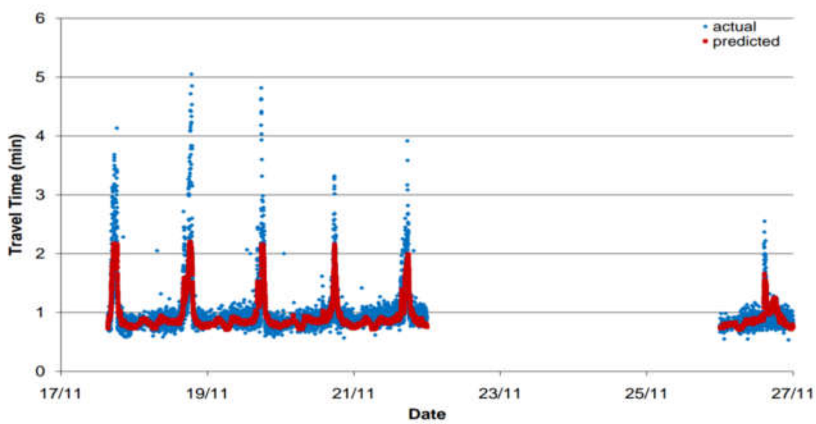


Fig: Travel time Estimated from Speed of a segment from Delhi Noida Route

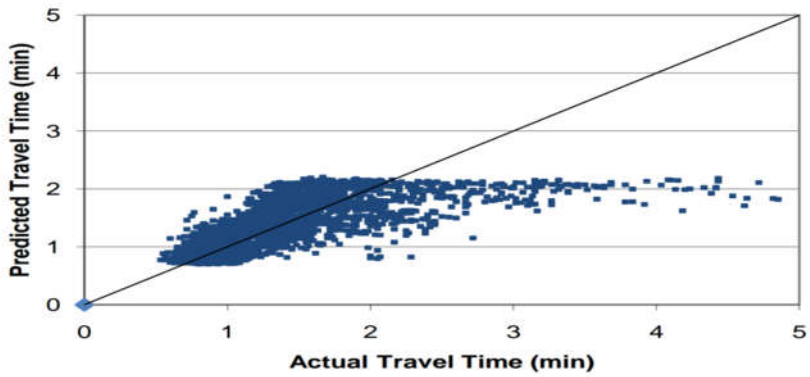


Fig: Scatter Plot of Predicted VS Actual Time

RESULTS AND DISCUSSION

- For route the speed model fails to predict the extent of the increase in travel times during the peak hour and under predicts travel times during the day.
- An objective comparison of the model can be performed using the root mean square error which corresponds to the distance between the predicted and actual estimate.

RMSE=√E(Yi-Y)²

The autoregressive model yields a RMSE of 0.30, while the RMSE of the model only based on the segment speeds and distances is 0.36

- It is evident that model performance is good for low travel times however appears to deteriorate for higher travel times.
- The estimated autoregressive model performs well compared to the simple model based only on speed and segment distance. As mentioned the predicted travel times deviate from the actual travel times during the night and peak hour.
- The model, estimated in this study can be used to replace the models used for real time travel time prediction

CONCLUSIONS

The model that have been worked on appears to capture the trends of the travel time of vehicles on different routes during the day time showing increasing travel time during the peak hours and fairly constant travel times during the day. There is fairly dropped in vehicle speeds resulting in the model over predicting the travel time. It is clear that the model performance is good for low travel times. This may be attributed to a higher travel times getting deteriorated results. It is important to assess the improvement that an auto regressive model yields over conventional ways of predicting travel times from travel speeds.

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