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Travel Time Management some Myths and Realities

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ABSTRACT

Travel time can be defined as the total time required for a vehicle to travel from one point to another over a specified route under prevailing conditions. Its calculation depends on vehicle speed, traffic flew and occupancy, which are highly sensitive to weather conditions and traffic incidents. Nonetheless, daily, weekly and seasonal patterns can be still observed at large scale. For instance, daily patterns distinguish rush hour and late night traffic, weekly patterns distinguish weekday and weekend traffic, while seasonal patterns distinguish winter and summer traffic. It has been increasingly recognized (Chien & Kuchipudi, 2003} that for many transportation applications, estimates of the mean and variance of travel times affect the accuracy of prediction significantly.

INTRODUCTION

Travel time data can be obtained through various surveillance devices, such as loop detectors, microwave detectors, and radars, though it is not realistic to have the road network completely covered by detectors. With the development of mobile and positioning technologies, the data can be more reliably collected and transmitted. More importantly, these devices can be set up on vehicles with minimal hardware using non-sophisticated communication and installation. However, travel time estimation is not so straightforward because it depends not only from the surveillance devices, but also on the prediction technique that is being used for data processing, Figure 2.3 presents the basic components for travel time estimation.

The following sections review the most common surveillance devices as well as the most well-known methods that are being used for travel time prediction and traffic forecasting.

Surveillance devices for travel time prediction

Various surveillance devices have emerged with the incorporation of portable computers and other electronic technology. According to Turner (1996) these emerging techniques include:

- Electronic Distance-Measuring Instruments
- Licence Plate Matching (via portable computer or video)
- Cellular Phone Tracking
- Automatic Vehicle Identification (AVI)
- Automatic Vehicle Location (AVL)
- Loop detectors

Electronic Distance-Measuring Instruments

The integration of an electronic distance-measuring instrument (DMI) with the floating car technique provides an easier, safer way to collect detailed travel time information. The sensor of the electronic DMI is attached to the test vehicle's transmission and the DMI typically can provide instantaneous speeds up to every 0.5 seconds (Thurgood, 1994). This detailed travel time information can be automatically downloaded to a portable computer in an easy-to-use data format. An electronic DM! coupled with a portable computer allows travel time runs to be safely performed with only a driver. This technique provides detailed travel time and delay information that is particularly valuable for bottleneck identification and intersection evaluation,

Licence Plate Matching {via portable computer or video)

License plate matching was used as early as the 1950's for travel time studies, but has more commonly been used for tracking or identifying vehicles in origin-destination surveys (Turner, 1996). Early methods relied on observers to note the license plates of passing vehicles and corresponding times on paper or into a tape recorder. License plates were manually matched later in the office, and travel times computed. Recent advances have substantially improved the ease and accuracy of this technique {Liu, 1994). Portable computers can now be used to record and match licence plates, significantly decreasing the data reduction time. Video cameras are also used to collect license plates, with image processing and computer algorithms used for automatic reading of licence plates.

Cellular Phone Tracking

With the increasing popularity of cellular phones among motorists, their application for traffic monitoring and travel time prediction is becoming more widely utilized (Robinson et al.t 1993). In some areas there are dedicated numbers for cellular phone users to report emergencies or accidents. Cellular phones can also be used by motorists to report their position at designated checkpoints, allowing a traffic operations centre to estimate travel times based on several cellular phone reports. Cellular phones in use can also be tracked using geolocating techniques (Levine et al., 1993).

Automatic Vehicle Identification (AVI)

Automatic Vehicle identification (AVI) is a technology that has emerged recently in various traffic management and toll collection applications. An AVI system basically consists of an in-vehicle transponder (tag), a roadside reading unit, and a central computer system (Boyce et al., 1991), When a vehicle containing a transponder passes a roadside reader unit, the information on the transponder is transferred o the reader unit. The transferable information can range from a simple vehicle identification number to toll account balances or trip information. For the purposes of computing travel times, the central computer monitors several consecutive reader units and matches transponder identification numbers (Hallenbeck et al., 1992).

Automatic Vehicle Location (AVL) is another technology that is finding several applications in transportation management. AVL permits the location of a vehicle to be known automatically, made possible through transmitters that are carried in a vehicle (i.e. on-board telematic devices). The transmitters allow the vehicle's location to be determined at frequent intervals, if not continuously. The location of each vehicle is projected in a vector map. Travel times can be calculated by using data such vehicle's mean velocity and variance, in real-time mode (Perkinson, 1994). AVL system has become common on freight ffeets, as well as in emergency and rescue vehicles. There are several different technologies (ground based and satellite) that can be categorized as AVL. Global positioning system (GPS) is the most common satellite technology utilizing orbiting satellites for continuous location determination.

Loop detectors

Inductive loop detectors (ILD) consist of one or more loops of wire embedded in the pavement and connected to a control box, excited by a signal ranging from lOKHz to 200KHz (Raj and Rathi, 1994). When a vehicle passes over or rests on the loop, the inductance of the loop is reduced showing the presence of a vehicle. The data supplied by inductive loop detectors are vehicle passage, presence, and occupancy. Although loops cannot directly measure speed, the latter can be estimated by using a two-loop trap {dual-loop detector) or a single-loop detector and an algorithm whose inputs are effective loop length, average vehicle length, time over the detector, and the number of vehicles counted (Klein, 2001) For incident detection, loop data is usually relayed to a centralized transportation management centre for analysis with a computer based incident detection algorithm.

In this brief survey, six distinct surveillance technologies have been identified. The amount of attention given to the research field of traffic surveillance and travel-time estimation clearly suggests that a surveillance system that can provide reliable and accurate travel time data would have great potential. The following section presents a comparison of the aforementioned surveillance devices so as to identify the most suitable for real-time travel information and incident detection.

Comparison of surveillance devices

The previous section described a series of devices for travel time collection. Tables 2.3 and 2.4 proved provide a comparison of the travel time collection devices with regard to accuracy, costs, and potential applications based on the findings of Turner (1996) and Ford (1998).

Electronic DMIs are low in cost but are limited to congestion monitoring applications. License Plate Matching is more expensive, and would be most applicable for congestion measurement and monitoring. However both of them cannot provide realtime travel information or incident detection. On the other hand, cellular phone tracking, AVI, AVL and loop detectors provide real-time information and incident detection. However, cellular phone tracking provides moderate accuracy of travel times and a large investment for creating a control centre for tacking phone calls is needed. In addition, cellular phones must be in use to track, thereby limiting sample sizes and coverage (Turner, 1996). AVI technology has a high initial equipment cost and the motorists must acquire and display the tag. In addition, travel time estimation is limited to fixed route and checkpoints (i.e. in points where a roadside reading unit is available). As far as loop detectors is concerned, Berka and Lall (1998) claim that loop detection reliability is low and that maintenance and repair of such a pavement-based system creates safety risks for repair crews. They also argue that loop detector systems may suffer from poor reliability, primarily from improper connections made in the pull boxes. In addition sources of loop malfunction such as stuck sensors can produce erroneous data and may lead to inaccurate detection. Ford (1998) notes that inaccurate results can be generated by loops because they do not easily identify congestion that occurs between loop stations. Finally, AVL systems although they have moderate capital and operating costs they can give excellent accuracy of travel time by providing real-time information and incident detections. This is due to the ability of AVL systems to continuously monitor the progress of vehicles, giving in that way more accurate estimations.

Thus, it can be concluded that AVL (i.e. on board telematic equipment) is the most suitable surveillance device (i.e. data collection device) for real-time travel information and incident detection. However apart from the surveillance device, travel time prediction is also based on the prediction technique that is being used.

Travel time prediction & traffic forecasting methods

One of the major issues in travel time and traffic forecasting is the selection of the appropriate methodological approach. Current practice involves two separate modelling approaches: parametric and non-parametric techniques {Vlahogianni et al., 2004). In the vast category of statistical parametric techniques, several forms of algorithms have been applied with greater weight to historical average algorithms (Smith and Demetsky, 1996) and smoothing techniques {Smith and Demetsky, 1997; Williams et al,, 1998). In the early 1990s, autoregressive linear processes, such as the auto-regressive integrated moving average (ARIMA) family of models, which were first introduced in traffic forecasting by Ahmed and Cook (1979) and Levin and Tsao (1980), provided an alternative approach based on the stochastic nature of traffic. Davis et al. (1991) applied a single auto-regressive integrated moving average (ARIMA) model to forecast the bottleneck formulation in a freeway. Later, Hamed et al. (1995) applied an ARIMA model to forecast urban traffic volume.

Research has also used state-space models that belong to the multivariate family of time series models. The main reason is that they provide a good basis for modelling transportation data, due both to their multivariate nature and also to their ability of modelling simpler univariate time series. Generally, the term 'state-space' refers to the model and the term 'Kalman filter' refers to the estimation of the state. The advantage of the Kalman filter algorithm is that it allows the selected state variable to be updated continuously. The potential of this was first demonstrated by Okutani and Stephanedes (1984) who used Kalman filtering in urban traffic volume prediction and then developed an extended Kalman filter to predict traffic diversion in freeway entrance ramp areas. Whittaker et al. (1997) demonstrated the potential of this method in a multivariate setting. Both Chen and Chien (2001) and Chien and Kuchipudi (2002) then used Kalman filtering for travel time prediction. Stathopoulos and Kariaftis (2003) demonstrated its superiority over a simple ARIMA formulation when modelling traffic data from different periods of the day.

CONCLUSION

Recent advances in object-oriented programming, as well as, in real-time collecting, storing and managing large databases from several points of an extended transportation network, have given the opportunity to explore the robustness of non-parametric techniques in traffic and travel time forecasting. Non-parametric techniques do not assume any specific functional form for the dependent and independent variables. Frequently, these models are data driven, implying that their successful implementation is strongly related to the quality of the available data. The general idea behind these techniques is that they analyse the characteristic of interest of, say, a time series by allowing it to have a general form which is gradually approximated with a certain precision using a growing data set. Two distinct forms of non-parametric techniques, namely non-parametric regression and neural networks, have gained a great portion of short-term traffic forecasting research interest over the last decade.