Transactions on the Built Environment vol 30, © 1997 WIT Press, www.witpress.com, ISSN 1743-3509

# Forecasting travel times based on actuated and historic data

Danko A. Roozemond
*Delft University of Technology, Department of Civil Engineering, P.O. box 5048, Delft, The Nethelands*
*E-mail: d.roozemond@ct.tudelft.nl*

## Abstract

In this research a model of forecasting the travel times of links will be addressed. Forecasting is one of the main topics of an integrated traffic management system and a necessity of dynamic route planning systems. To be able to forecast properly we use both historic data and current data from monitoring devices as input for our dynamic model. Thus, combining the best of both worlds, we are able to forecast travel times in the near future based largely on current data as well as travel times for some time ahead based on current and historic data. Accuracy and variability of data are important as they are the key element if these models will be incorporated in route guidance and traffic management schemes.

## 1 Introduction

Current estimates are that 65 percent of peak-hour travel on highways and urban roads and some ten percent of all daily urban travel is conducted under congested conditions [1]. In recent decades traffic problems have become both a social and economical embarrassment: congestion, deteriorating road safety, regression of mobility and environmental effects of traffic are widely considered important issues. The inability of the existing road network to cope with increased demand has been identified as one of the pressing infrastructure issues of this decade. Past custom to counter increased congestion with more, safer and wider roads, is currently giving way to more complex management and control systems and road pricing policies. Traffic management professionals and policy makers now turn to traffic management systems. The goals of traffic management systems are, among others: maximise safety and transport productivity; minimise congestion and damage through incidents; distribute information on traffic-conditions, road-conditions, weather, etc. A traffic management system should invoke appropriate intervening action when undesirable situations arise.

As transportation is widely accepted as a crucial economic factor, a system of

Transactions on the Built Environment vol 30, © 1997 WIT Press, www.witpress.com, ISSN 1743-3509


social and economic dependencies on transportation in the world. A more efficient use of existing infrastructure may gain time in which to develop alternate modes of transport and/or infrastructure. As with all demand-supply problems, solutions made through traffic management can be viewed as either increasing capacity to meet demand or modifying demand to levels deliverable under certain conditions. Both views rely as much on the actual transport conditions as on the perception of those conditions by the road user. A definite advantage can be gained by making the right kind of information available to the right kind of users. This requires the exchange of information between road system managers and the public.

To handle the information requirements for route-guidance, traffic management and intelligent traffic control, one needs systems that accurately handle the behaviour of large complex road systems, while maintaining high levels of usability. To handle these information requirements one needs systems that accurately predict the, in essence unpredictable, behaviour of traffic participants. To be able to forecast we use both historic data and current data from monitoring devices as input for our dynamic model. Accuracy and variability of data are important as they are the key element if these models will be incorporated in traffic management schemes.

## 2 Integrated Dynamic Traffic Management System

To put IDTMS in perspective, integration of dynamic traffic management systems is no cure for all traffic problems, although it may streamline and reduce the traffic load and give better information and advise. Whatever the improvements, more direct routes available or more up-to-the-minute information, there would be a traffic problem, or new ones would arise.

Benefits are not always easy to quantify as they are related to aspects like environment, information and finance and are difficult to quantify for groups or the whole system. The IDTMS is more than a mere management system, although operational benefits rely heavily on the forecasting properties of the system and the ability to act and adapt dynamically.

### 2.1 Decision making in an IDTMS

Traffic management can be divided into three different levels of decision making each with its own data demands [2]:

- short term traffic control decisions; traffic management with a time-frame of a few minutes, implemented in traffic control systems; in most cases no human action is required.
- medium term traffic management; based on a few hours time-frame, implemented in traffic management systems.
- long term planning; based on a large (days to years) time scale, also called traffic planning systems used in a highly interactive environment as a tool to human design and planning efforts.

The different levels of decision making have consequences for the required data. Long term planning can be done with aggregated, semi-dynamic data and

Transactions on the Built Environment vol 30, © 1997 WIT Press, www.witpress.com, ISSN 1743-3509



term planning. Highly accurate, up-to-date data is necessary for short term decisions in traffic control. To get the required data, on-line monitoring of traffic conditions is crucial for traffic control, but also very valuable for traffic management applications and profitable for planning purposes.

## 2.2 Architecture of an IDTMS

One of the main overall objectives of this project is to develop a framework integrating traffic and infrastructure planning, traffic management, traffic control, information and simulation systems into one multi-user, multi-discipline Integrated Dynamic Traffic Management System (IDTMS). To satisfy that objective, a dynamic traffic management system should be based on modular and distributed components that can operate within an open, evolutionary, distributed and scalable architectural framework serving the needs of several management layers [3, 4]. Standardisation is a requirement for components within the system to facilitate access to and manipulation of the information and models present in the system. Sub-systems are designed to perform as autonomously as possible, co-ordinating their own actions, interacting with other sub-systems trough standardised interfaces when necessary. This increases overall robustness of the system and creates an appropriate environment for information and traffic management systems that can address several goals and even can handle different and opposite goals. Forecasting is one of the main topics of an IDTMS and a necessity of dynamic route planning systems.

When focusing on integrated network control, forecasting, incident detection and re-routing systems, there is a need for systems that accurately handle the large quantities of data and dependable data collection. In order to be effective, such systems need to collect and maintain data locally for immediate use, and on request aggregate data before it is presented to other components via a data handling system. For data handling, databases based on a GIS are proposed as one of the possible solutions. The GIS will perform the function of underlying database (storage, handling, etc.) and query language. Uniform standards should apply to any particular service in the overall system. What we need is a scalable system for shared use of distributed data that will search for the data, after merging available data from different sources, generate (un)available values or transpose the data and present it. The R&D efforts on distributed computing can be exemplified by a number of projects. The Andrew File System (AFS) is an ongoing project on distributed file systems, creating a virtual single file system with potential to provide terra-bytes of data on-line [5]. Project Athena recently ended in a campus wide distributed computing environment supplying services from and across networked resources by virtualising the classical link between node and user [6]. The wide spread of data across different organisations and installations within organisations creates a very practical problem for users and developers of modelling software for data intensive engineering applications. The obvious advantages of shared use of data are dwarfed by the problems generated when restricted use, data integrity, access security and cross accounting has to be considered. Not only do these pose a problem in general, but especially when large volumes of data have to be gathered in order to satisfy a single request, the system overhead to handle all details can easily explode.

Transactions on the Built Environment vol 30, © 1997 WIT Press, www.witpress.com, ISSN 1743-3509


The data handling system should be able to deal with the large volumes of distributed data generated and consumed by modelling, simulation and DSS applications common to integrated traffic management systems. These problems will have to be addressed in a single comprehensive system, making use of existing distributed sources of scientific data sets [7]. Specific problems dealt with are the following:

- access to and storage of time series data and spatial grid data independent of storage format and storage location;
- storage and context mapping of data generated, making it available for later retrieval using the same system;
- extending and transforming data to specified interval or grid, delivery of data in a format suitable for the requesting application.

## 3 Dynamics in traffic systems

As we all know: traffic is not fully predictable. Given all the initial facts, it is not always certain that accurate predictions can be made about the future; not everything is fully deterministic and non linearity is intrinsic to the system. This raises the question of how to avoid getting into an uncontrollable chaotic situation, which is not that functional for traffic control and traffic management systems; or when found in the middle of it, how get out of this situation with as many positive side-effects possible. Concerning traffic management and control we are in need of a theory that can cope with this uncertainty and complexity. From a mathematical point of view the stability and behaviour of participants in transportation systems are essential parts of the system. Traffic management and information provision for minimising congestion is made difficult not only by the magnitude of the problem but by the diversity of the interacting "intelligent agents" whether persons, (automated) control objects, etc. An intelligent transportation system must not only handle real-time needs; it must also be a system that adapt to changing system parameters and structures, continually improving its ability to act as well as react.

Traffic management and traffic control in cities is the most problematic and complicated the whole transportation system as well as the most challenging and least researched. In urban areas the complexity exceeds that of the highway conditions due to the variety in means of transport, the difference in the speed of the participant and the greater probability of unanticipated events. Influences on the instability in highway conditions are for example geometry of the road, types of vehicles, motive for the trip, weather conditions and light conditions. Furthermore the driver itself is a great source of instabilities.

As traffic management systems must react to the different states of traffic flow in the network the management system is the actor controlling and reacting to dynamic actions in the system. To be able to do so, a fully pro-active dynamic control mechanism should be an integral part of the IDTMS. For a more elaborate overview of adaptive traffic management we recommend Cuena et al [8]. To satisfy the information requirements for route guidance, traffic management and intelligent traffic control, one needs systems that cope with and predict the dynamic behaviour of large complex road systems. And, as the aim is to predict and prevent unwanted situations in the transport system there is an obvious need for traffic forecasting models on all time scales and the most

Transactions on the Built Environment vol 30, © 1997 WIT Press, www.witpress.com, ISSN 1743-3509



# 4 Forecasting dynamic transport systems

As the reasons for forecasting may be obvious, the real advantages are viable when there are applications become available that do something with these models. We can see this happen in the next decade as more and more in-car equipment becomes available and humans are getting used to. As congestion levels grow and opposition to new roads grow also, the temporarily solution is to get more people over the same road. When people (traffic managers and the road users) get the forecasting information they are, given the information content is useful, using that information. Dynamic route guidance systems, with integrated forecasting properties, could provide significant benefits to both individual drivers as well as the overall transportation system. The effectiveness of systems that provide traffic information and their potential for reducing congestion, depends heavily on drivers' reaction to additional information. Drivers would avoid traffic congestion and incidents, and (theoretically, at least) arrive at their destination as fast as possible. Utilisation of the roadway system would improve, because many drivers could (theoretically, again) avoid already congested thoroughfares and lessen the severity of existing congestion. Usually traffic participants can choose between the different modes of transport. Given enough information the preferred mode of transport may change.

## 4.1 Travel time forecasting

Given a road map, the possible roads can be represented by several sections, each with their own characteristics. Every section has an entrance and an exit gate; the traversing time can be calculated with historic data. Every road sub-system has the underlying smaller-road-set that will only be used for transport inside the section and adjoining sections. Several specified road segments can be combined to a traversing link, thus creating a higher level for non local traffic. Example: Travelling from origin to a destination in an other city; the system start using the most detailed network with all routes bottom-up wards, until you are on a tertiary road-network; from there you are directed to travel further upwards until you use the main road-net (highways). Coming close to the destination the system uses the road-networks from the high level down.

The basis for travel time forecasting is not that difficult: if a person can address the travel times on all possible routes and links, one can calculate the overall travel time of a proposed journey. As mentioned earlier this is only true for predictable situations and in most cases this isn't the case in traffic forecasting nowadays. The kind of calculus used is effectively a state prediction model: predicting the states on time $t_j$. Every road segment has its travel time prediction, based on historic data, at a certain time or time span.

For the several possible routes from origin to destination the chosen objective (time) should be calculated by formula's like [3]:

$$\text{total travel time} = \sum_{\text{All links}} \Delta t_{j,k} \cdot \zeta_{j,k} \quad \text{, where}$$

$j$ = Start Node of link $j,k$
$k$ = End Node of link $j,k$

(1)

DOCKET ALARM

# Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

## Real-Time Litigation Alerts

Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

## Advanced Docket Research

With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

## Analytics At Your Fingertips

Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

## API

Docket Alarm offers a powerful API (application programming inter-face) to developers that want to integrate case filings into their apps.

**LAW FIRMS**

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

**FINANCIAL INSTITUTIONS**

Litigation and bankruptcy checks for companies and debtors.

**E-DISCOVERY AND LEGAL VENDORS**

Sync your system to PACER to automate legal marketing.