THE ROLE OF INSTRUMENTED VEHICLE DATA IN TRANSPORTATION DECISION MAKING

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ABSTRACT

During 2002, more than 1600 Atlanta vehicles are being equipped with onboard computer systems designed to monitor second-by-second travel activity and deployed in representative households. Approximately 1100 vehicles are participating in a two-year NHTSA safety study, which includes collection of high-resolution speed, acceleration, origin, destination, and route choice data (via GPS). The NHTSA equipment also performs crash detection and evaluation for these vehicles. Another 500 vehicles are participating in a three-year FHWA value pricing insurance study. All of these vehicles will report second-by-second vehicle activity data, including speed, acceleration, and position data. Approximately 400 of the instrumented vehicles will also provide second-by-second data from engine computers, capturing such operating parameters as engine speed, manifold pressure, throttle position, etc.

The goals of each of study are briefly overviewed and details provided on the collected data streams. The detailed uses of the various data streams in transportation model development and calibration, transportation control measure evaluation, congestion studies, and vehicle emissions modeling are outlined. The paper focuses on potential model improvements for improved long-term decision making as well as the use of real-time data in short-term decision making.

Keywords: Instrumented vehicle data, Transportation modeling, Vehicle emissions modeling, Advanced transportation management systems.

INTRODUCTION

This paper discusses the role that instrumented vehicle data can play in transportation decision making. The context for this discussion is the vehicle instrumentation currently underway in Atlanta under the aegis of companion projects principally sponsored by the National Highway Traffic Safety Administration (NHTSA) and Federal Highway Administration (FHWA). The goals of these two projects are outlined and details provided on the collected data streams. The detailed uses of the various data streams in transportation model development and calibration, transportation control measure evaluation, congestion studies, and vehicle emissions modeling are outlined. The paper focuses on potential model improvements for improved long-term decision making as well as the use of real-time data in short-term decision making.

ATLANTA’S INSTRUMENTED VEHICLE STUDIES

Researchers at the Georgia Institute of Technology have recently undertaken two federal research projects that include the instrumentation of 1600 vehicles from 875 households in the Atlanta metropolitan area. The households are representative of the Atlanta region, based upon a random stratified sample that accounts for household size, income, and net residential density. The studies are designed to monitoring the details of every trip made by these vehicles for the next three years. Data from the studies will be analyzed to: 1) identify factors affecting crash risk, and 2) understand the price elasticity of trip making behavior. The vehicles are equipped with electronic “black box” systems capable of tracking actual onroad vehicle activity, reporting speed, acceleration, and position...
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DMinUCE London 2002  

information on a second-by-second basis. The event data recorders, developed through a Georgia Tech public-private partnership, are approximately 8.5” x 10” x 2” (21.6 cm x 25.4 cm x 5.1 cm), installing readily under the front seat of passenger vehicles (See Figure 1).

Figure 1. Black Box Equipment Components and Installation

NHTSA Safety Study
Approximately 1100 of the 1600 Atlanta vehicles are being deployed in a NHTSA sponsored study. The equipment in this study includes a crash detection system that records crash forces and automatically notifies the emergency services operator in the event of a crash. These units have been tested in NHTSA’s Ohio Laboratory and found to accurately report crash forces at 300 Hz. The vehicles monitored in Atlanta will provide data for crash reconstruction analysis that will allow researchers to compare calculated crash forces (based upon skid marks, vehicle deformation, and other observations from crash reconstruction) with monitored vehicle speeds at the time of the crash. However, the main benefit of the study will be the opportunity to link actual driver behavior, as revealed through two years of monitored onroad operating data, to crash risk. The study will specifically examine the relationships between aggressive driver behavior and crash risk and severity through the analysis of more than 100 crash events.

FHWA Value Pricing Insurance Study
Approximately 500 of the 1600 vehicles are equipped with a slim version of the NHTSA system that records vehicle activity data, but does not record crash forces. The reduction in equipment cost made it possible to deploy instrumented vehicles in a value pricing project sponsored by the FHWA. The three-year value pricing program examines consumer response to a simulation of insurance premium payments on a cent-per-mile basis. During the first year of the study, baseline household travel behavior and commute patterns are monitored. In the second year of the study, a household cent-per-mile insurance premium rate is established, based upon the annual premium payment and baseline miles traveled. Households that reduce miles traveled in the second year, by carpooling, taking alternative transit modes, or foregoing trips will receive a quarterly insurance premium rebate based upon the reduction in miles traveled and their cent-per-mile rate. The research team will monitor the changes in driving patterns of the participants and a control group to determine whether the participants modified their behavior as a function of the pricing incentives. In the third year of the study, a risk-based program will account for where, when, and how the vehicles are operated. Cent-per-mile rates will be adjusted upward for operating conditions that are generally believed to be accompanied by higher risks (e.g., operating the vehicle after 11:00 PM, when crash probability is higher, or operating the vehicle at high rates of speed, where potential crash damage is higher). Again, households that change their travel and/or driver behavior will be eligible to receive quarterly insurance premium rebate checks. Statistical analyses and choice modeling using the vehicle activity, household demographic, and relevant employer survey data will be used to examine the relationships between the incentives offered and the travel behavior changes.

DATA STREAMS
Once installed, the black box monitoring devices record high-resolution data for each trip. The onboard units include a global positioning system to accurately record when, where, and how Atlanta drivers choose to operate their vehicles. The instruments provide detailed trip data (start, end, distance, and duration), route choice, and
second-by-second speed and acceleration. A cellular communications platform allows all of the data to be transmitted weekly to a central data warehouse during off-peak hours. The system was developed as an end-to-end system solution for securely transmitting, storing, managing, and reporting vehicular data. These two studies will collect data for approximately 10 million trips (roughly 1 terabyte of data) with 95% of the positioning information accurate to 5 meters. The high degree of spatial accuracy makes the data stream extremely useful in the development and calibration of travel demand models (Figure 2). In addition to basic trip generation data, the systems can provide valuable input to mode choice and route choice modeling efforts when supplemented with household and employer surveys.

Household interviews are combined with two-day travel diaries to collect information on home and work locations, commute routes, and to identify routine trips to daycare, shopping, etc. The comprehensive data allow the researchers to examine vehicle trip information across numerous household demographic variables.

Of the 1600 vehicles in these studies, approximately 400 are equipped with onboard diagnostic (OBD) monitoring systems capable of simultaneously reporting as many as 10 engine and vehicle operating parameters, such as: engine speed, manifold pressure, throttle position, coolant temperature, oxygen sensor, engine misfire, fuel injection, evaporative purge, exhaust gas re-circulation, air injection, etc.

USES IN DECISION MAKING

Instrumented vehicles can provide a wealth of planning data which can be used by multiple agencies for a wide variety of purposes, both short and long term. Research efforts are now being implemented in safety and value pricing in the Atlanta region. However, some of the most valuable uses for instrumented vehicle data are in the planning and environmental field (even though instrumented vehicle research funding has not been specifically provided for these purposes). Instrumented vehicle studies are also currently planned for Boston and Milwaukee.

Instrumented vehicle data play a significant role in advanced traffic management systems by enabling a more complete picture of the overall system state in support of tactical traffic operations and control decisions. The types of decisions that will be strengthened by instrumented vehicle data include message selection for changeable message signs, routing and dispatching of incident response assets, and the design and implementation of dynamic vehicle routing strategies. This section briefly outlines these and other tactical decisions that will be supported by instrumented vehicle data.

Transportation Model Development, Validation and Calibration

Although traditional static travel behavior surveys have served as the principal data source throughout the brief history of urban and interurban travel demand modeling, the difficulty and expense of conducting these surveys has dictated that they be conducted infrequently. The modeling paradigm that has emerged involves calibrating to essentially a single sample of travel data for the modeled network and then using this “calibrated” model until the next major travel survey effort. This scarcity of trip-based data has rendered it practically impossible for travel demand modelers to rigorously validate their models.
Instrumented vehicle data holds the promise for providing ongoing travel pattern data that will enable legitimate model validation. The data streams can also empower continuous model tuning, thereby allowing network travel demand models to track with evolving travel patterns and travel behavior. Open research questions in this area include how the relative percentage of instrumented vehicles in the travel stream impacts model reliability.

Transportation Control Measure Evaluation

Traffic control measures to improve traffic flow, such as ramp metering and variable speed limits on freeways and signal coordination on surface street networks and arterials, have traditionally been developed on limited sample data on the before conditions and evaluated on often more limited data on the after conditions. Instrumented vehicle data will provide ongoing information on which to evaluate the efficacy and the need for modification and fine tuning of these transportation control measures. As data integration and control algorithms improve, instrumented vehicle data will ultimately play a role in “real-time” adaptive control measures.

Congestion Studies

A university linkage with Atlanta’s regional advanced traffic management system will enable researchers to use the instrumented vehicle data to better understand the relationships between driving patterns and congestion levels (Figure 3). Researchers can examine route choice as a function of network system speeds and the potential influence of other conditions of the operating environment on vehicle operations. The bottom line is that these vehicles serve as traffic probes within the network, providing data on system performance in the locations where these vehicles are operating.

As discussed in the next section, current urban traffic condition detection systems provide snapshots of traffic flow characteristics at fixed locations in the freeway network. Fixed point freeway surveillance does not provide information on how congestion effects route choice nor on the interplay between surface streets and the controlled access facilities.

Incident Detection, Queue Detection, and Recurrent Congestion Prediction

Instrumentation in urban surface transportation networks has been largely limited to the major freeways and motorways and has been founded on arrays of fixed detection stations with a nominal spacing on the order of ½ kilometer (or 1/3 mile). Various detection technologies have been employed with in-pavement inductive loop detection being the predominant legacy technology and with the use of video and radar-based technologies increasing. These systems typically provide vehicle counts, average speeds and average vehicle stream concentration (most often measured as lane occupancy) on a lane-by-lane basis. Although this fixed location detection paradigm has provided useful decision support in urban transportation management systems, it provides no method for tracking individual vehicle trajectories or directly measuring vehicle travel times.

Automatic incident detection algorithms have been a software system feature beginning with the earliest advanced freeway management system deployments. However, in practice these algorithms, built on fixed point surveillance...
data, have been unable to deliver timely detection without suffering from unacceptably high false alarm rates. Therefore, alarms triggered by these automatic algorithms have been largely ignored if not disabled. The negative impact of these failed automatic detection systems has been mitigated by the increasing prevalence of private wireless phone users willing and able to call in incident reports. Incidents can also be detected by operator visual detection on closed circuit television images. However, there is a growing consensus that the need for reliable and accurate automatic incident detection algorithms will become increasingly keen as the scope of the transportation networks under the purview of urban freeway management systems continues to grow at a faster rate than does management center staff and facilities. In the future, data from instrumented vehicles will be fused with fixed point surveillance data to enable automatic incident detection with the necessary time critical accuracy. Instrumented vehicle data will also extend automatic incident detection capabilities to the surface street network.

The aggregate travel delay resulting from incidents and recurrent congestion is largely determined by the formation, growth and dissipation of traffic queues. Fixed point surveillance data by its nature of averaging fixed point data over time does not provide accurate information on the presence, location and propagation speed of the upstream end of traffic queues. However, the trajectory information from instrumented vehicles will provide a significantly more detailed picture of the location and dynamic characteristics of the queue margins. This information may be sufficient to allow predictions of queue growth and dissipation thereby greatly improving overall delay and travel time estimates. Vehicle trajectory data from within queues will also provide increased understanding of the stop-start wave phenomenon.

In addition to random capacity-reducing incidents, urban freeway and surface street networks suffer from recurrent congestion at system bottlenecks. By its freedom from time average smoothing of dynamic traffic conditions, instrumented vehicle data also holds the promise of enabling more rapid detection and prediction of near capacity conditions at known bottlenecks. This improved information will in turn support improved traveler information and traffic control decisions.

**Vehicle Emissions Modeling**

Many of the monitored OBD parameters are critical in emissions formation and can be used in development of advanced emissions models if real-time emissions measurements are collected in parallel. The current vehicle instrumentation package provides four on/off inputs as well as a full serial port for integration of data from outside sensors. Hence, real-time vehicle emissions measurements can be collected in parallel with second-by-second vehicle and engine operating parameters, with combined data streams transmitted via cellular connection to a centralized data warehouse. Simultaneous monitoring of vehicle activity, the engine on-board diagnostic (OBD) system, and direct emissions measurement will provide data streams necessary for modal emission rate modeling and for confirmation that the technology can be used in EPA’s development of the MOVES emission rate model (deigned to replace the current MOBILE6 model). The robust datasets of such a large-scale effort facilitate the development of more accurate regional and microscale emissions modeling capabilities to satisfy long-term conformity reviews and short-term project evaluation.

In June, the research team will deploy a SEMTECH-G analyzer to collect accurate high-resolution emissions measurements in parallel with engine and vehicle activity (Figure 4). The SEMTECH-G has been used by automobile manufacturers to aid in the development of engine subsystems and, more recently, by the EPA used data for model development purposes. The system monitors CO, CO\textsubscript{2} concentrations (up to 0.001% and 0.01%, respectively) and THC and NO concentrations (up 1 ppm). All measurements are within a 3% tolerance, except for THC, which the monitoring equipment can measure within 1% of the actual value. High-resolution emissions data supplemented by the available data from the instrumented vehicle monitoring equipment creates a highly powerful dataset for the development and verification of modal emission rate models.
CONCLUSIONS

The vehicle instrumentation for the Atlanta NHTSA and FHWA studies will provide an unprecedented vehicle trajectory and travel behavior data set. The detailed travel and vehicle performance data can be viewed as a prototype for permanent instrumented vehicles data systems. The data will serve as the basis for the development and evaluation of various concepts involving the use of instrumented vehicle data in strategic and tactical transportation decision making.

REFERENCES