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Integrity of estimates of the two-fluid model and gender impacts

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ABSTRACT

This paper summarizes a research study to develop a methodology for utilizing naturalistic Global Positioning System (GPS) driving data for two-fluid model estimation. The two-fluid vehicular traffic flow model describes traffic flow on a street network as a mix of stopped and running vehicles. The parameters of the model essentially represent 'free flow' travel time and the level of interaction among vehicles. These parameters have traditionally been used to evaluate roadway networks and corridors with partially limited access. However, the two-fluid model has been found to be a direct result of driver behavior, and can also be used to represent behavioral aspects of driver populations, e.g., aggressiveness, passiveness, etc. Through these behavioral aspects they can also be related to safety on roadways. Due to which the two-fluid model can be considered to be a safety *footprint* for a particular road or individual driver. Due to which it is critical to understand factors that influence the two-fluid model. In this study, two-fluid models were estimated using naturalistic driving data collected with GPS data loggers in San Luis Obispo (SLO), California. Linear referencing in ArcMap was used to link the GPS data with roadway characteristic data for each element of the roadway network. The linear referencing methodology is the key to relate the GPS driving data with the elements of roadway network. This study explores two fundamental questions: (1) how sensitive are the estimates of the two fluid parameters to various samples? This question is fundamentally important to help define the integrity of the two-fluid model for planning and operational purposes. To this end we use a random sampling approach to address this question. (2) Are there behavioral differences across gender? This provides important behavioral insights on driving behavior across gender. Significant differences were observed between male and female drivers, with female drivers being more aggressive.

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1. Introduction

In addition to the assessment of operational conditions, the analysis of traffic flow can be used to assess a variety of conditions associated with traffic processes, including roadway safety and travel time. Although there are a variety of techniques for quantitatively evaluating such parameters, many are hampered by significant limitations due to difficulties and complexities in data collection and processing. Recently, however, emerging technologies such as geographic information systems (GIS) and GPS have made it possible to collect, process, and graphically illustrate traffic flow data at levels of detail and accuracy not possible only a decade ago.

This paper describes a methodology that can be used for the assessment of driving behavior and flow parameters for a range of operational and safety assessments. Specifically, the research focused on the collection and utilization of driving data collected through GPS data loggers to estimate two-fluid model parameters. The two-fluid model developed by Prigogine and Herman (1971) has traditionally been used to characterize quality of traffic flow on a street network, which essentially models the relationship between the stop-time and travel-time per unit distance. However, motivated by the findings of Herman et al. (1988), that driver behavior significantly influences the two-fluid model, Dixit (2013) showed that the two-fluid model is a direct consequence of drivers' utility maximization behavior and essentially can be used as a *footprint* for drivers' aggressiveness and crash likelihood. This was verified by an earlier study by Dixit et al. (2011) that showed that the parameters of the two-fluid model for arterial corridors (which *do not* include uninterrupted flow facilities such as interstates, expressways and freeways) are significantly correlated with crash rates. Hence, they can be used to characterize safety. In this study the researchers have estimated the parameters of the two-fluid model from naturalistic driving data collected through the GPS data loggers. This methodology developed here can potentially open a novel way for researchers around the world to examine naturalistic driving data being collected through SHRP2 (Strategic Highway Research Program Phase 2 of the Federal Highway Administration in the USA) (Hallmark et al., 2013).

This study explores two fundamental questions: (1) how sensitive are the estimates of the two fluid parameters to various samples? This question is fundamentally important to help define the integrity of the two-fluid model for planning and operational purposes. To this end we use a random sampling approach to address this question. (2) Are there important behavioral differences across gender? Significant differences were observed among male and female drivers, with female drivers apparently being more aggressive. Note that we try to avoid the confounding effect of age by only selecting drivers who were between 25 and 55 years old.

2. Data collection

In this research effort, data was collected from 16 participants in San Luis Obispo, CA. Participants in the study were selected using a screening questionnaire which solicited both personal and driving information. Using the information provided on the questionnaires, participants were segregated based on specific age groups, typical route selections, and driving frequency. Participants were assigned a random identification number that correlated to the GPS data collection unit to maintain driver confidentiality. Drivers ranged in age from 25 to 55 years old (hence excluding very young and old drivers) and included 11 female drivers and 5 male drivers. Data collection was undertaken during the period from July 2012 to January 2013.

2.1. GPS device information

The SD GPS Data Loggers V3.15 (loggers) used to collect data for this project were manufactured by OHARARP, LLC and were designed for ease of implementation, user friendly interface, sufficient battery life, and an organized output system. GPS loggers were programmed to record in comma-separated value (CSV) file type from parsed sentences that followed National Marine Electronics Association (NMEA) standards. A memory card was used to store the collected data while LED lights indicated proper functionality of the logger and recognition of the memory card. The information recorded included the following: latitude; longitude; altitude; heading; speed; number of satellites used; position dilution of precision (PDOP); horizontal dilution of precision (HDOP); vertical dilution of precision (VDOP); fix; universal time code (UTC); year; month; and day. All data were recorded at an average of 3 Hz based on GPS performance capabilities. A vibration mode of 300 s was implemented to pause recording when the vehicle was idle in an effort to preserve battery life for the one week data collection period for each individual drivers. The loggers also had the ability to receive a signal during all weather conditions and under all day and night driving periods.

During the period of the experiment, the loggers were strategically placed in the vehicles of the subjects to prevent them from sliding and collecting erroneous data. Typically, the GPS loggers were placed in vehicle center consoles or glove boxes. It was determined by the researchers that placing the logger in either locations did not affect the GPS communication. Participants were asked to refrain from allowing other relatives or friends to drive their vehicle while the logger was collecting data. A sample output data trip on the San Luis Obispo County GIS base map is provided in Fig. 1.

3. Two-fluid model

Prigogine and Herman (1971) developed the two-fluid model after years of observing vehicular traffic on multi-lane roadway facilities. Their model was a macroscopic flow model that viewed traffic flow in a network as a collection of stopped and