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Editorial

Analytical methods for quantifying driver behavior in a dilemma zone prologue

1. Introduction

The design and safe operation of transportation systems that are used by all road users require an understanding of driver behavior. Driving simulators are an attractive option for researchers to examine driver behavior in a controlled, repeatable environment. Often, data collected using this tool is specific to a research question and institution. At the 93rd Annual Meeting of the Transportation Research Board (TRB), a data contest was held with submissions from six different countries. The data contest showcased different ways that the same dataset from one driving simulator study can be analyzed to examine differences in driver behavior in a dilemma zone while distracted. The findings from this dataset are presented along with other studies that examined a dilemma zone using other data collection tools.

The yellow light dilemma zone is a situation where the clearance intervals at an intersection are not properly timed, and drivers are forced to either stop abruptly or run a red light. This transportation problem has been examined for many decades (see Gazis et al., 1960; Crawford, 1962; May, 1968, for some early work). Studying the dilemma zone in a controlled environment, such as a driving simulator, provides the capability to manipulate the signal timing for different driving situations in a repeatable manner, and to examine the impact of potential safety measures. Many of these driving simulator studies are typically conducted within one research setting and comparisons among many analytical methods are not often performed. This special issue provides a unique opportunity to compare several analytical methods using the same dataset. The papers submitted as part of the data contest were reviewed and rated by a panel of experts in traffic engineering, driving simulation, and statistical methods. Dr. Matthew Karlaftis was chair of the TRB Committee on Artificial Intelligence and Advanced Computing Applications (ABJ70) at the time. He passed away shortly after the contest and we dedicate this special edition to him and the leadership he showed in encouraging new approaches to data analysis.

2. Data from TRB data contest

The dataset used in the first five papers of this special issue came from a study previously conducted at the University of Iowa, National Advanced Driving Simulator (NADS). The details of the study are provided in Ranney et al. (2005) and a brief summary is provided in this prologue. Each of the five articles in this special issue also includes a detailed description of the study as it pertains to their research objectives, the events that were examined, and the analytical tools used. The initial NADS study was designed to examine the effects of wireless telephone use on driving performance across three age groups: young drivers (aged 18–25 years), middle (aged 30–45 years) and older (aged 50–60 years). Participants were asked to drive through a signalized intersection while engaged in one of three secondary tasks. The traffic signal would transition from green to yellow to red to green again. The three secondary task conditions included a baseline condition (no phone call), outcoming call, and incoming call. Each drive consisted of three equivalent segments that exposed the participant to the three cell phone interfaces. For each visit, the participant experienced a different order of segments/interfaces. The incoming and outgoing calls were started prior to the arrival at each segment. The dataset and data dictionary are available at: http://depts.washington.edu/hfsm/upload.php.

3. Analysis of University of Iowa NADS data

The findings from the first five papers demonstrated that traditional prediction models as well as classification tools are useful in examining driver behavior at a dilemma zone. In the first paper of this special issue, Xiong et al. (2016) used a general linear mixed models (GLMM) with a binomial distribution and logit link to predict the likelihood that a driver will continue through a yellow signal. They went one step further to also examine the likelihood of continuing through when the traveling speed was 20 mph or less. They showed that the speed approaching the stop sign was bimodal and that these two groups needed to be segmented. Eluru and Yasmin (2016) used a generalized extreme value framework to understand the impact of cell phone use on the driver's decision to stop or cross at an intersection and the eventual success of executing the maneuver. The dataset provided did not include information on whether the driver successfully crossed the intersection; they therefore, inferred success as those vehicles that successfully entered the intersection prior to the end of the red at a velocity of at least 15th percentile. Haque et al. (2016) used a combination of traditional statistical inferences and data mining techniques to identify the a priori relationships among the main effects, nonlinearities, and interaction effects. In this way, the researchers were

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able to exploit the best qualities of both modeling techniques to assess the appropriateness of the higher order interactions and to develop theoretically defensible model specifications. Savolainen (2016) compared two modeling techniques (random parameters and latent class logit models) that are useful for dealing with unobserved heterogeneity across drivers. Even though a latent class model does not make any assumptions about the underlying heterogeneity, both were shown to perform better than the traditional logistic regression. The fifth paper in this first section, by Ghanipoor Machiani and Abbas (2016a) used data from the NADS study and another driving simulator study (DriveSafety simulator), also designed to examine driver behavior in a dilemma zone. Given the multitude of driving simulators available to researchers, this paper demonstrates the value of using datasets across different platforms. Discriminant analyses were used to identify the appropriate time period and data type for a driver decision prediction model.

4. Examining the dilemma zone

In the second section of this special issue, we invited authors to consider other data sources and collection methods to demonstrate ways that researchers can examine driver behavior in dilemma zones. These next six papers showcase ways to investigate driver behavior in the dilemma zone using both real world and simulated data. For example, Jahangiri, Rakha, and Dingus (2016) used data from both observational and simulator data to examine red-light running. They used a common set of factors from both datasets (e.g., time-to-intersection (TTI), distance to intersection (DTI), and velocity at the onset of the yellow indication next) and conducted random forest (RF) machine-learning to develop red light running violation prediction models.

Kim et al. (2016) used two different tools to examine drivers' decisions in a dilemma zone. They began with data collected from a driving simulator study conducted at the U.S. Department of Transportation, Federal Highway Adminstration. The data from this controlled environment was then used to generate an agent-based simulation model to capture driver's decisions in a dilemma zone with more varied road environments. Gates and Noyce (2016) used video recordings from five intersections to examined red-light running. Their dataset included over 1900 vehicles, which were classified into a conceptual zonal scheme to assess whether an approaching vehicle required addition time to safely clear. This novel approach can be used for real-time operations, and could also provide insights for systems that connect vehicles to the infrastructure. This is a timely consideration with the increasing levels of automation being considered in vehicles. Savolainen, Sharma, and Gates (2016) used data from 87 intersections in five US regions. The authors looked at the effectiveness of enforcement cameras and advanced warning systems using a panel data random parameters probit model. Ghanipoor Machiani and Abbas (2016b) used real-time radar field data to capture vehicle trajectories and time-to-collision before, during, and after the change intervals at signalized intersections. Using field data, they developed a safety surrogate histogram to capture the degree and frequency of dilemma zone related conflicts. Their outcomes provide insights for the design of future crash avoidance systems. The last paper in this special issue is by Bar-Gera et al. (2016). They used data from loop detectors and digital enforcement cameras at non-urban signalized intersections in a multi-analysis approach. Their approach is interesting as they began by checking the frequency stability of crossing at all intersections and then conducted subsequent analysis on only those intersections that demonstrated stability. This multi-stage analyses approach helps minimize the impact of heterogeneity, and to more precisely quantify driver behavior following the onset of the yellow traffic signal phase.

5. Conclusions

These papers demonstrate that safety in the dilemma zone is still a concern but there are many approaches to examine this issue. The studies in this special issue show the value of using data from controlled driving simulator environments as well as from observational data collected at intersections. The collection of papers also showcase a wide range of analytical techniques that include linear mixed models, random forest trees, latent class variables, and structural equations models. Agent-based simulation was also used to examine the impact of various roadway environments on red light violations at an intersection.

The initial review of these papers suggest that some of the outcomes may be quite different, but all authors noted the importance of examining traveling speed and distance to stop line, and the driver's decision to stop or cross. Many authors extended the analysis to account for other driver (age, gender, expectancy) and vehicle characteristics. The best data collection tool and analytical method is highly dependent on the research question. As these set of studies show, the development of a safety solution requires knowledge of the drivers' capabilities and limitations, their understanding of the situation, and the context and road environment that may foster a higher likelihood of an incorrect decision. Driving simulators are useful for examining driver's performance for a specific road environment while video recordings at intersections may be better in capturing changes in vehicle behavior over extended periods of time. The data from these controlled and observational studies on driver behavior can then provide further insights for the design of dilemma zone warning systems. These same data collection tools and analysis methods can then be used to examine the effectiveness of such warning system in the car, on the roadway, or some combination of both.

There are still many research topics to examine as crashes continue to occur in the dilemma zone. The collection of papers in this special issue provides comparative methods, tools, and factors that we hope are useful for researchers, engineers, and designers as we move forward in the future design of roadways.

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Linda Ng Boyle *
Industrial & Systems Engineering, Civil & Environmental Engineering, University of Washington, Seattle, WA, USA

Susan Chrysler
Texas A&M Transportation Institute, College Station, TX, USA

Matthew Karlaftis
National Technical Universities in Athens, Athens, Greece

* Corresponding author.
E-mail address: linda@u.washington.edu (L.N. Boyle)

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