Accident Analysis and Prevention 51 (2013) 56–67

Contents lists available at SciVerse ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

Modeling school bus seat belt usage: Nested and mixed logit approaches

Gaurav Mehta, Yingyan Lou*

Civil, Construction, and Environmental Engineering, 260 H.M. Comer Hall, Box 870205, The University of Alabama, Tuscaloosa, AL 35487-0205, United States

ARTICLE INFO

Article history:
Received 7 January 2012
Received in revised form 5 June 2012
Accepted 19 October 2012

Keywords:
School bus safety
Seat belt usage rate
Discrete choice analysis
Nested logit model
Mixed logit model

ABSTRACT

School bus seat belt usage has been of great interest to the school transportation community. Understanding factors that influence students' decisions about wearing seat belts or not is important in determining the most cost-effective ways to improve belt usage rate, and thus the seat belt safety benefits. This paper presents a rigorous empirical analysis on data from Alabama School Bus Pilot Project using discrete choice modeling framework. In order to collect relevant information on individual student-trips, a new data collection protocol is adopted. Three choice alternatives are considered in the study: wearing, not wearing, and improperly wearing seat belts. A student's choice probabilities of these alternatives are modeled as functions of the student's characteristics and trip attributes. The coefficients of the variables in the functions are estimated first using standard multinomial logit model. Moreover, to account for potential correlations among the three choice alternatives and individual-level preference and response heterogeneity among users, nested and mixed logit models are employed in the investigation. Eight significant influence factors are identified by the final models. Their relative impacts are also quantified. The factors include age, gender and the home county of a student, a student's trip length, time of day, seat location, presence and active involvement of bus aide, and two levels of bus driver involvement. The impact of the seat location on students' seat belt usage is revealed for the first time by this study. Both hypotheses that some of the choice alternatives are correlated and that individual-level heterogeneity exists are tested statistically significant. In view of this, the nested and the mixed logit model are recommended over the standard multinomial logit model to describe and predict students' seat belt usage behaviors. The final nested logit model uncovers a correlation between improper wearing and not wearing, indicating there are some unknown or unobserved contributing factors that are common to these two choices. In the final random-parameter mixed logit model, individual preference heterogeneity is captured by random coefficients of county variables. Individual response heterogeneity is reflected in the random effect of a driver's remarks on students' seat belt usage. Both recommended models are helpful in predicting seat belt usage rate quantitatively for given circumstances, and will provide valuable insights in practice of school transportation management.

© 2012 Elsevier Ltd. All rights reserved.

1. Introduction

The American School Bus Council estimates that approximately 475,000 school buses operate each day, carrying 25 million students—more than half of school-aged children in the United States (American School Bus Council, 2011). School buses have been a relatively safe mode of school transportation. From 1990 to 2000, there have been 26,000 crashes involving school buses in the U.S., resulting in less than 1000 incapacitating and slightly more than 7000 non-incapacitating passenger injuries. During the same time period, on average, ten people died every year as school bus occupants. 75% of these fatalities involved passengers, while 25% of the time it was the driver (Hinch et al., 2002). Passenger fatalities and injuries related to school buses only account for 2% and 4% of the total numbers occurred during normal school travel hours (Transportation Research Board, 2002). However, several recent tragic school bus crashes (Dornin, 2006; Berning and Yablonski, 2010; Associated Press, 2010) have raised attention and new interests in school bus safety issues.

Compartmentalization is the prevalent safety feature mandated by federal laws on school buses to provide passenger protection in crashes. Compartmentalization is a passive restraint system consisting of tightly spaced and energy-absorbing padded high-back seats (Committee on Injury, Violence, and Poison Prevention and Council on School Health, American Association of Pediatrics, 2007). While compartmentalization is effective in frontal crashes (National Transportation Safety Board (NTSB), 1999; National Highway Transit Safety Administration (NHTSA), 2002), its effectiveness during lateral impacts is considered insufficient (NTSB, 1999). On the other hand, lab tests indicate that lap/shoulder belts

* Corresponding author. Tel.: +1 205 348 5859; fax: +1 205 348 0783.
E-mail address: ylou@eng.ua.edu (Y. Lou).

0001-4575/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.aap.2012.10.008

(also called 3-point belts) are more effective in frontal crashes than compartmentalization only (NHTSA, 2002), although its effectiveness during side impacts remains unknown (NTSB, 1999). These studies lead to a federal regulation update in 2008 that requires lap/shoulder belts on new school buses less than 10,000 pounds (NHTSA, 2008). In addition, laws that require seat belts on large school buses have also been enacted in six states, including California, Florida, New Jersey, New York, Louisiana, and Texas (Frisman, 2010). More recently, Connecticut has created a program to fund lap/shoulder seat belts on school buses (State of Connecticut Executive Chambers, 2010). Some other countries have also started the move toward mandated school seat belts, such as UK and China (BBC News, 2008; China Daily, 2010).

However, the use of seat belts on large school buses has long been a controversy. With the introduction of lap/shoulder belts to replace lap-only belts, early debates (e.g., Wineland, 1986) on whether seat belts will do more harm than good in bus crashes seems to be resolved by the findings from lab tests that lap/shoulder belts outperform compartmentalization in frontal crashes (NHTSA, 2002). But the controversy remains regarding the significance of potential safety improvement and the requirement of universal installation. Low benefit–cost ratio due to the low bus crash rate is one of the major concerns; others include the potential reduction of bus capacity and the impeded emergency egress (NHTSA, 2008; Hall, 1996; Lapner et al., 2003; Gurupackiam et al., 2011). Moreover, it is believed by some that drivers will suffer from increased distractions caused by the duty of monitoring belt usage (Hall, 1996).

Yet another critical point that has been somewhat overlooked in the long-standing debate is students' seat belt usage rate. Universal installation of seat belts does not guarantee students will wear them, and the benefits of installing school bus seat belts will not be fully utilized with a low usage rate. Very limited studies have been conducted to address this issue. The earliest documented study is a pilot study conducted in Australia from 2002 to 2003 with an advanced automatic monitoring system (Coutts et al., 2003; Griffiths et al., 2005). Note that the system is for seat belt usage rate only, and does not monitor relevant student and trip characteristics. Aggregated usage rates were estimated to vary from 14% to 89% with an average of 45%. A general negative correlation was observed between the aggregated bus belt usage rate and the students' age group. The study also concluded that encouragement from teachers and parents had little effect on increasing students' seat belt usage rate. A similar trial was carried out in North Carolina during 2003–2005 with eleven buses equipped with lap/shoulder belts (Graham and Tsai, 2006; Pupil Transportation Group, North Carolina State University, 2007). Although the estimates of seat belt usage rates given in this study were limited (for elementary routes only) and very rough, it was observed during site visits that there was an overall reduction in bus discipline problems. It was also observed that belt misuse was a nontrivial issue. Drivers reported difficulty in enforcing belt usage alone during morning routes. Both the Australia and the North Carolina studies suggested the need of some sort of regulations but did not specify any. In 2007, the Alabama State Department of Education and the Governor's Study Group on School Bus Seat Belts authorized and funded a research project to investigate the effects of lap/shoulder seat belts on Alabama school buses. Twelve pilot buses from ten counties were equipped with seat belts and ceiling mounted cameras to participate in the study. A preliminary analysis by Tedla et al. (2009) reports an average usage rate of 65.9% with an additional 9.3% of improper use (see Sections 2 and 3 for definition and more discussion). Belt usage trends similar to those indicated in the Australia and the North Carolina studies were observed. In addition, the study found that day of week had some impact, but the presence of bus aide had no effect.

These previous studies focused mainly on aggregated usage rates with limited empirical analysis on potential impact factors. While these studies provided valuable insights, their general observations were obtained through simple cross tabulation and may not be statistically significant without controlling other variables as can be achieved in regression analysis.

More recently, Lou et al. (2011) conducted a rigorous quantitative analysis using Alabama Pilot Project videos based on the framework of discrete choice modeling. Discrete choice analysis focuses on individual-level behavior modeling and is able to predict aggregate measurements accordingly. This modeling technique requires detailed information at disaggregate level, such as a student's age group, gender, trip length, and encouragements or regulations received from bus aides and/or drivers. In order to collect such information, a new data collection protocol focusing on individual students was developed. A binary logit choice model involving two choice alternatives (wearing and not wearing seat belts) was estimated in order to quantify relative influences of a range of factors on students' belt usage. Lou et al. (2011) identified several impact factors that appear to have been overlooked or underestimated in the literature, including gender and the home county of a student, trip length, time of day, and active involvement of bus drivers. It confirms the positive influence of bus aides, and reveals that different age groups responded differently to bus aides.

While Lou et al. (2011) is the first to quantify relative impacts of different factors using rigorous econometric modeling techniques, it ignored observations of improper wearing (or misuse) of seat belts, which are not uncommon (Tedla et al., 2009). In addition, it did not consider possible correlations among unknown or unobserved factors that may contribute to students' seat belt usage choices. Moreover, model parameters were treated as constants, meaning individual-level preference and response heterogeneity among students was not considered. To improve the prediction accuracy of school bus seat belt usage and to enhance model flexibility, this study employs more advanced discrete choice modeling techniques to account for the additional choice alternative of improperly wearing seat belts, as well as potential correlations among the choice alternatives and individual-level heterogeneity among students. A variety of models are extensively tested in this study, including multinomial, nested, and mixed logit models. Two particular model specifications, one as a nested logit and the other as a random-parameter mixed logit model, are found competitive to best describe students' seat belt usage. Overall, both of the improved models are expected to provide more accurate estimations of relative impacts from various factors, and lead to better predictions of seat belt usage rate. The quantitative results will be valuable in cost-benefit analysis of school bus seat belts, and in helping to determine the most cost-effective measures to increase school bus belt usage rate and thus the overall school bus safety.

2. Methods

2.1. Overview of discrete choice modeling techniques

As a widely used econometric modeling approach, discrete choice analysis attempts to quantify empirically the impacts of individual characteristics and alternative attributes on an individual's choice. Random utility function is the fundamental concept in discrete choice modeling. An individual is assumed to choose the alternative with the highest utility value, where the utilities are functions of the individual's characteristics and attributes of available alternatives. Since human decision process is very complex, an outside modeler is not able to accurately pinpoint or measure the factors that may affect the utilities values. For example,

Download English Version:

https://daneshyari.com/en/article/6966561

Download Persian Version:

https://daneshyari.com/article/6966561

Daneshyari.com