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# Neighborhood-level factors affecting seat belt use

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ABSTRACT

Despite the well-known safety benefits of seat belt use, some vehicle occupants still do not use them. This is a challenge in Tennessee, which has a lower seat belt use rate compared to the United States national average. Roadside observations and interviews are the two main sources for estimating seat belt use rate and have several limitations (e.g., small sample size, social desirability bias). To address these limitations, we attributed seat belt use of individuals who were involved in traffic crashes ($N$ = 542,776) to their corresponding home-addresses. Home-addresses were retrieved from police crash reports and were geocoded, and assigned to their corresponding census tract revealing added information about the spatial distribution of seat belt use and socioeconomics of the areas surrounding the crash victim's home. The average seat belt use rate in the metropolitan area was 88% and for the non-metropolitan area was 87%. A Tobit model was used to evaluate the relationship between the seat belt use rate for both drivers and passengers over 16 years old, with neighborhood sociodemographic variables. Population, age cohorts, race, household vehicles' ownership, household size, and education were among the predictors of the seat belt use rate. Results of this analysis could be used in safety campaign design to reach specific geographic areas and groups with a lower seat belt use rate.

## 1. Introduction

Approximately 1,000 individuals die on Tennessee's roads every year and most of them are vehicle occupants. One known solution that reduces the fatality rate of the vehicles' occupant is a proper use of a seat belt. Several studies have reported the merits of wearing a seat belt in reducing crash fatalities and injury rates. Appropriate use of seat belts increases the chance of vehicle occupants surviving potential fatal crash by 44%–73% depending on seating position and the type of vehicles involved in a traffic crash (Blincoe et al., 2015).

There are mandatory seat belt laws in the United States and its territories (except New Hampshire). In 34 States, the District of Columbia, and Puerto Rico seat belt laws are primary, which enable law enforcement officers to stop vehicles and write citations when they observe a seat belt non-use (IIHS, 2018). In 15 states the laws specified secondary enforcement, meaning that law enforcement officers are permitted to issue a seat belt citation only after they stop a vehicle for another primary violation. Notably, only 28 states and two territories enforce rear seat belt use (NHTSA, 2017b). In Tennessee, seat belt use is a primary law, and it is mandatory for all the vehicles occupants to be restrained by a seat belt (i.e., secured shoulder and lap belts) when riding in the front seat of a vehicle. Licensed passengers 16 years old or older are responsible for their own conduct. Nevertheless, a ten-year trend of traffic crashes shows that 30% of Tennessean who died in traffic crashes failed to wear their seat belt properly at the time of the crash, this rate was 54% and 70% for incapacitating injuries and non-incapacitating injuries, respectively (TITAN, 2017).

Based on NHTSA roadside observations, front row passengers in Tennessee had an 88.9% seat belt use rate in 2016, which was 1.2% lower than the National average (NHTSA, 2017a). In 2017, roadside observations of 27,000 vehicles' occupants at 190 sites in Tennessee revealed that, on average, 88.5% in Tennessee used their seat belt (CTR, 2018), which was still lower than the national average. Females seat belt use rate was 93.8%, and males had an 85.0% seat belt use rate. Furthermore, freeways showed the highest usage rate (91.2%) of all roadway types, while those observed on local roadways had the lowest usage rate (86.1%) (THSO, 2016; CTR, 2018). In addition, another phone interview in Tennessee in 2017 reported that 90% of respondents always wore their seat belt, and females had higher seat belt use rate than males (Hezaveh et al., 2019).

Seat belt non-use could be attributed to human factors such as forgetfulness, laziness, perceived low risk of injury, and discomfort (Begg and Langley, 2001); attitudes, beliefs, and intentions (Fhaner and Hane, 1975; Jonah and Dawson, 1982; Chliaoutakis et al., 2000; Şimşekoğlu and Lajunen, 2008); habits (Knapper et al., 1976; Chliaoutakis et al., 2000; Calisir and Lehto, 2002); and lack of

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enforcement (Jonah et al., 1982; Farmer and Williams, 2005). Each of these behaviors could be targeted by proper countermeasures through education and enforcement.

Sociodemographic of those who wear their seat belt less frequently is also helpful for identifying and reaching the groups with higher risk. Generally, males have lower seat belt use rate compared to females (Preusser et al., 1991; Reinfurt et al., 1997; Nelson et al., 1998; Calisir and Lehto, 2002; Wells et al., 2002; Glassbrenner et al., 2004; Gkritza and Mannering, 2008; Pickrell and Ye, 2009). This is also true for younger drivers compared to the older adults (Reinfurt et al., 1997; Calisir and Lehto, 2002; Glassbrenner et al., 2004). Individuals with higher education and/or income tend to have higher seat belt use rate (Preusser et al., 1991; Reinfurt et al., 1997; Wells et al., 2002; Houston and Richardson, 2005). Studies in the United States have also shown that African-Americans are less likely to use a seat belt than Whites or Hispanics (Vivoda et al., 2004; Gkritza and Mannering, 2008; Pickrell and Ye, 2009). Several studies have reported that occupants of pickup trucks have the lowest seat belt use rate compared to occupants of other vehicle types (e.g., (Boyle and Vanderwolf, 2004; Glassbrenner and Ye, 2007; Gkritza and Mannering, 2008)).

Nearly all of the studies that investigated seat belt use relied on the direct roadside observation or responses to self-reported surveys. Although these methods are easy to conduct and can provide information at a relatively low cost, they have their limitations that may negatively affect the outcomes of a study. For instance, one issue that could negatively affect results of self-reported questionnaires is social desirability bias (Lajunen and Summala, 2003; Nordfjærn et al., 2015; Hezaveh et al., 2018a, 2018b). Social desirability bias refers to the tendency of respondents to provide socially desirable answers rather than choosing an answer that reflects their state of mind (Grimm, 2010). Social desirability may bias the respondents' answers with regard to questions related to traffic violations (Lajunen et al., 1997).

Considering the roadside observations, the amount of data that researcher records are very limited, mainly due to the short amount of the time that the observers have to record the data and conspicuity challenges. In roadside observations, usually observed data elements are limited to the vehicle type, number of front row occupants, gender, age group, and roadside site characteristics (CTR, 2018). Also, the number of observations sites are usually a small sample of the transportation network, and they usually take place within daylight or in the nighttime in the areas with sufficient lighting to observe inside of vehicles.

Police crash reports are the main source for evaluating road safety especially for analyzing crash severity and frequency. However, using police crash reports for studying seat belt use has its own limitations. The main limitation is the possible incorrect assignment of seat belt use or crash severity to individuals by a responding officer (Cherry et al., 2017). For example, some vehicle occupants who survived a crash may falsely claim that they used a seat belt at the time of the crash in order to avoid a traffic ticket (Cummings, 2002). Nevertheless, several studies of police reports show that reported seat belt use is consistent with roadside observations (Li et al., 1999) and National Accident Sampling System Crashworthiness Data System (CDS) (Schiff and Cummings, 2004). Using police crash reports have several advantages compared to roadside observations and self-reported studies. First, it provides a nearly comprehensive dataset of all serious crashes with an objective observer of many reported variables. Second, it covers a vast geographic area with hundreds of thousands of observations.

While the literature on road safety delivers seat belt use rate at coarse geographical level (e.g., county, state, country), it does not provide information about seat belt use rate at fine geographical level such as neighborhood level (e.g., census tract or traffic analysis zone). Knowing about the neighborhood seat belt use rate and seat belt non-use hotspots would benefit safety practitioners by focusing resources on areas where their residents have lower seat belt use rate. This is one of the main challenges in designing an effective and geographically targeted safety campaign. To date, most safety campaigns provide blanket coverage of regions with lower seat belt use rate, rather than precise and targeted messaging. Targeted education could be more cost effective at increasing the overall seat belt use rate.

This study aims to propose a new method to measure seat belt use rate at the neighborhood level and evaluate the relationship between seat belt use rate and socio-demographic variables based on the home-address of the individual (i.e., home-based approach) who were involved in traffic crashes at the zonal level. Although some studies used police crash reports to evaluate seat belt effectiveness and seat belt use rate, to the best of our knowledge no studies have used this dataset for investigating the relationship between sociodemographic data elements and seat belt use rate based on home-address of individuals involved in traffic crashes (i.e., drivers, passengers). Using the home-address of the individuals in a large database of the traffic crashes enables researchers to identify the geographic and surrounding socioeconomic factors that affect seat belt use and neighborhoods where their residents have lower seat belt use rate. Additionally, we compare the seat belt use rate extracted from police crash reports with other sources of the seat belt use rate in Tennessee. Our findings are not only limited to the front row occupants but include all the vehicle occupants in different times of the day, context, weather, light conditions, and road types.

In the next section, we discuss the proposed database, the geocoding process, and the analytical methods. The rest of the paper presents the results and discusses the findings of this study.

## 2. Methodology

### 2.1. Database

The data in this study were provided by Tennessee Integrated Traffic Analysis Network (TITAN), a portal provided by Tennessee Highway Patrol (THP) as a repository for traffic crash and surveillance reports completed by Tennessee law enforcement agencies. The traffic crash records from January 1, 2016, through December 31, 2016, were retrieved from TITAN. Each crash record includes information about road user type (e.g., pedestrian), geographic coordinates of the crashes, addresses of the individuals who were involved in a traffic crash, and other variables related to the crash (MMUCC, 2012). The Police crash reports database contained 246,777 crashes and information about 580,767 individuals who were involved in traffic crashes in 2016. Data included different road users' classifications; namely driver, motorcyclist, passenger, pedestrian, bicyclist, and other road user types. In order to analyze seat belt use rate, we only considered vehicle occupants. The database included information on 577,131 vehicle occupants (i.e., driver or passenger); 73% of the occupants of the vehicle were drivers, and the rest were passengers.

### 2.2. Geocoding process

Bing API was used in this study for geocoding the residential address of the individuals. Only those addresses with an accuracy level of premise (e.g., property name, building name), address level accuracy, or intersection level accuracy were used for analysis. A sample of addresses was verified by manual inspection. After geocoding the home-addresses, we were able to retrieve home-addresses' coordinates of 542,776 individuals (94% success rate), which met address quality filter criterion. Among geocoded addresses, 62,741 individuals lived out of state. After controlling for age, vehicles' occupants sixteen years old and older were selected for the analysis. Census data from US survey in 2010 were also used for obtaining sociodemographic data elements. Table 1 provides a summary of the sample characteristics of the variables considered as input for model estimation for Tennessee.

### 2.3. Tobit model

In order to model seat belt use rate, first, there is a need to select a

**Table 1**
Sample statistic for the state of Tennessee at the census tract.

| Variable | Mean | Std. Deviation. | [95% Conf. Interval] | |
|---|---|---|---|---|
| Total Population | 1530.02 | 788.68 | 1,505.98 | 1,554.06 |
| Age Cohort Proportion | | | | |
| < 16 years Old | 0.23 | 0.08 | 0.22 | 0.23 |
| 16-42 Years Old | 0.32 | 0.11 | 0.32 | 0.33 |
| 43-59 Years Old | 0.25 | 0.08 | 0.24 | 0.25 |
| 60 Years Old And More | 0.20 | 0.10 | 0.20 | 0.20 |
| Age Median | 38.96 | 8.63 | 38.75 | 39.27 |
| Race Proportion | | | | |
| Race White | 0.77 | 0.30 | 0.76 | 0.78 |
| Race Black | 0.18 | 0.28 | 0.18 | 0.19 |
| Race Indian | 0.00 | 0.01 | 0.00 | 0.00 |
| Race Asian | 0.01 | 0.03 | 0.01 | 0.01 |
| Race Hawaiian | 0.00 | 0.01 | 0.00 | 0.00 |
| Means Of Transportation To Work Proportion | | | | |
| Personal Vehicle | 0.92 | 0.11 | 0.92 | 0.93 |
| Carpool | 0.10 | 0.08 | 0.10 | 0.11 |
| Bus | 0.01 | 0.04 | 0.01 | 0.01 |
| Motorcycle | 0.00 | 0.01 | 0.00 | 0.00 |
| Bicycle | 0.00 | 0.01 | 0.00 | 0.00 |
| Walk | 0.02 | 0.05 | 0.01 | 0.02 |
| Other Means | 0.01 | 0.03 | 24.96 | 25.36 |
| Children (%) | 0.20 | 0.08 | 0.19 | 0.20 |
| Household Size | 2.72 | 5.30 | 2.57 | 2.89 |
| Education Degree Proportion | | | | |
| Number Of Educated Over 25 Years | 1021.62 | 514.10 | 1,005.96 | 1,037.29 |
| Education Degree Proportion | | | | |
| High School And Lower | 0.52 | 0.20 | 0.51 | 0.53 |
| Some College Degree | 0.20 | 0.08 | 0.20 | 0.21 |
| Bachelor's Degree | 0.20 | 0.12 | 0.19 | 0.20 |
| Other Degrees | 0.08 | 0.08 | 0.07 | 0.08 |
| Median Household Income ($1000) | 45.9 | 25.1 | 45.2 | 46.7 |
| Occupied Household Proportion | 0.87 | 0.13 | 0.87 | 0.88 |
| Vacant Household Proportion | 0.12 | 0.10 | 0.12 | 0.12 |
| Household Vehicles' Ownership Proportion | | | | |
| No-Vehicle | 0.07 | 0.09 | 0.07 | 0.07 |
| One Or Two Vehicles | 0.70 | 0.13 | 0.33 | 0.33 |
| Three Or More Vehicles | 0.22 | 0.13 | 0.22 | 0.23 |

Data Source: US Census.

suitable model specification. Since the value of seat belt use rate for each zonal level is limited between 0 and 1, it is appropriate to use a regression model with a censored dependent variable. Considering the nature of seat belt use rate at zonal level, we can conclude the dependent variable is left-censored at 0 and right censored at 1. To address censoring in the dependent variables, Tobin (1958) proposed the Tobit model or censored regression model. This model was used by several researchers to model crash rate in various types of road sections (e.g., Anastasopoulos et al., 2008, 2012; Zeng et al., 2017).

In the Tobit model, the regression is obtained by making the mean in the preceding correspond to a classical regression model. The general form of the model is usually given in terms of index function as follows:

$$y_i^* = x_i^{'}\beta + \varepsilon_{i,}$$

Where $y_i^*$ defined as:

$$y_i^* = \begin{cases} y_i & if \quad a < y_i < b \\ a & if \quad y_i \le a \\ b & if \quad y_i \ge b \end{cases}$$

$\varepsilon_i$ assumes that the error term is normally distributed with mean 0 and variance equals to $\sigma^2$. In this study, the seat belt use rate is the dependent variables, and $\beta$ is the coefficient corresponding to each independent variable presented in Table 1. The dependent variable is a proportion confined between 0 and 1. In addition to the estimated coefficients, we also measured the elasticities of each coefficient for measuring the sensitivity of the dependent variables to a change in the independent variable. For more information regarding elasticity estimation, please see Stata (2015).

### 2.4. Variable selection

A combination of intuition and stepwise regression modeling was used to select the best subset of the predictors with an exclusion criterion of p-values greater than 0.20. Moreover, Variance Inflation Factors (VIF) was used to control for the multicollinearity in each step. Curious readers could refer to O'brien (2007) for more details about the VIF.

### 2.5. Model performance

Veall and Zimmermann (1996) concluded that Maddala pseudo-r-squared is a valid measurement for evaluating the goodness of fit of censored regression. The general form of Maddala pseudo-r-squared displayed below (Maddala, 1986):

$$R^2 = 1 - \left[e^{LL_{Null} - LL_{Full}}\right]^{2/N}$$

where, $LL_{Null}$ and $LL_{Full}$ are log likelihoods of the null and full model respectively, and $N$ is the number of observations. The likelihood function of the Tobit model is:

$$L = \prod_0 \left[1 - \Phi\left(\frac{\beta X}{\sigma}\right)\right] \prod_1 \sigma^{-1}\phi[(Y_i - \frac{\beta X}{\sigma})]$$

where, $\Phi$ is the standard normal distribution function, and $\phi$ is the standard normal density function (Anastasopoulos et al., 2008).

We also used the Akaike Information Criterion (AIC) as a measure of the relative goodness of fit for identification of the models with a better fit in the sample. AIC is a function of the number of parameters in the model (k) and log-likelihood of the model specification ($ln(L)$); $AIC = 2k - 2ln(L)$. As a rule of thumb, a three-point change in an AIC value indicates a significant improvement in the goodness of fit (Bozdogan, 1987).

**Table 2**
Age and Gender distribution of the vehicles' occupants over 16 years old.

| Seat Belt Status | Female | | | Male | | | Total* | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Obs | Mean | SD | Obs | Mean | SD | Obs |
| No seat belt | 38.70 | 17.22 | 25285 | 38.76 | 16.97 | 32178 | 38.76 | 17.09 | 57708 |
| Wear Seat belt | 39.24 | 17.74 | 205296 | 39.52 | 17.54 | 220700 | 39.39 | 17.64 | 425999 |
| Total | 39.18 | 17.69 | 230581 | 39.42 | 17.47 | 252878 | 39.31 | 17.58 | 483707 |

* Including the unknown observations; Source: Authors' analysis from TITAN data.

**Table 3**
Seat belt use rate (number of observations) among vehicles' occupants over 16 years old regarding seat position.
Source: Authors' analysis from TITAN data.

| Row | Left | Middle | Right | Other/Unknown |
|---|---|---|---|---|
| Front | 0.88 (395,641) | 0.55 (912) | 0.89 (66,464) | 0.2 (55) |
| Second | 0.84 (6647) | 0.65 (1101) | 0.85 (8913) | 0.38 (216) |
| Third | 0.74 (424) | 0.67 (143) | 0.71 (438) | 0.12 (54) |
| Fourth | 0.45 (127) | 0 (33) | 0.50 (166) | 0.04 (128) |
| Other Seats | | | | 0.40 (2203) |

## 3. Results

### 3.1. Seat belt use rate

Table 2 presents the average age and gender distribution of the vehicle occupants considering their seat belt use based on the police crash reports. The average age of the males' occupants (16 years old and older) was 39.4 ($SD$ = 17.5) and for females was 39.2 ($SD$ = 17.7). In addition, the average age of those who wore a seat belt properly (i.e., lap and shoulder) was 39.4 ($SD$ = 17.6), and those who did not wear a seat belt was 38.8 ($SD$ = 17.1). In general, the average age of those who wore a seat belt was higher than who did not ($t$ = 8.278, $p$ = 0.000). Moreover, females (89.1%) had a higher seat belt use rate in comparison to males (87.2%) ($t$ = 23.889, $p$ = 0.000). Table 3 also presents the seat belt distributions of the occupants over 16 years old. The highest seat belt use rate was for the front passenger (90.0%) followed by the driver (88.4%). The seat belt use rate dropped as passengers seating position row number increased (Table 3).

Table 4 shows the seat belt use rate under different circumstances. Considering the weather condition, occupants seat belt use rate was higher during the harsh weather, and at its lowest rate during clear weather. Regarding daylight, occupants wore seat belts at higher rate during daylight and less during the night. Seat belt use rate at night were lower when there was no lighting on the road. Regarding the road classification, Interstate and US highways had higher seat belt rate than other route types. In addition, the seat belt use rate was lowest on frontage and urban roads.

**Table 4**
Seat belt use rate regarding weather, lighting, and route signage.
Source: Authors' analysis from TITAN data

| Variable | Mean | SD | Number of observation |
|---|---|---|---|
| Weather | | | |
| Clear | 0.868 | 0.338 | 395975 |
| Cloudy | 0.889 | 0.314 | 58743 |
| Fog | 0.868 | 0.339 | 1377 |
| Smog/Smoke | 0.934 | 0.249 | 196 |
| Rain | 0.884 | 0.321 | 54611 |
| Sleet/Hail | 0.895 | 0.307 | 1181 |
| Snow | 0.909 | 0.287 | 4749 |
| Blowing Snow | 0.912 | 0.284 | 272 |
| Severe Cross-Winds | 0.902 | 0.297 | 123 |
| Blowing Sand/Soil/Dirt | 0.922 | 0.269 | 51 |
| Other | 0.883 | 0.321 | 342 |
| Unknown | 0.025 | 0.157 | 24318 |
| Lighting | Mean | SD | Count2 |
| Daylight | 0.879 | 0.326 | 389436 |
| Dark-Not Lighted | 0.843 | 0.364 | 39391 |
| Dark-Lighted | 0.860 | 0.347 | 69524 |
| Dark-Unknown Lighting | 0.787 | 0.409 | 1499 |
| Dawn | 0.875 | 0.330 | 6821 |
| Dusk | 0.864 | 0.343 | 10632 |
| Other | 0.865 | 0.342 | 429 |
| Unknown | 0.033 | 0.106 | 25044 |
| Route Signage | Mean | SD | Count2 |
| Interstate | 0.885 | 0.319 | 45397 |
| US Route | 0.871 | 0.335 | 43581 |
| State Route | 0.868 | 0.338 | 68086 |
| County Route | 0.823 | 0.382 | 36707 |
| Municipal Route | 0.850 | 0.357 | 138721 |
| Frontage Road | 0.826 | 0.379 | 317 |
| Other | 0.789 | 0.408 | 14054 |
| Unknown | 0.796 | 0.402 | 195913 |

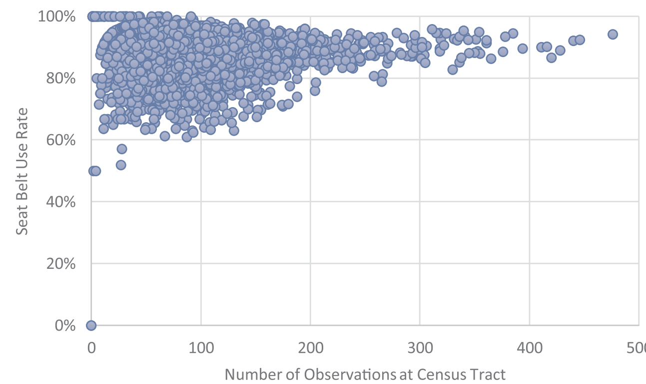


**Fig. 1.** Number of observations and corresponding seat belt use rate at the census tract level for drivers.

### 3.2. Seat belt use rate distribution

After assigning respondents home-address to their corresponding census tract, we learned that Tennessee residents had a higher compliance rate (88.2%) than those with out-of-state addresses (86.9%) ($t$ = 8.615, $p$ < 0.001). Using crash data, 480,035 (7.2% of state population) individual addresses in Tennessee were assigned to their corresponding census tracts. The average seat belt use rate at census tracts for the driver's seat was 0.88 ($SD$ = 0.06) and for the passengers' seat was 0.86 ($SD$ = 0.12); the correlation between driver's seat and passengers' seat was 0.32 ($p$ < 0.001), which indicated a weak positive linear relationship. Fig. 1 and Fig. 2 present number of observations and seat belt use rate for driver and passengers over 16 years old at the zonal level. Each point represents a seat belt use rate in a census tract (number of seat belted drivers or passengers divided by total number of participants in a crash), and the number of observations reflects the total number of observations in each census tract. In cases of driver crashes, the range of rates spans 60–100% for tracts with reasonably large crash counts (Fig. 1). For passenger seat belt use rate, there are fewer observations in the dataset, and more observations below 60% seat belt use rate (Fig. 2).

Figs. 3 and 4 present average seat belt use rate for the drivers and vehicle passengers at zonal levels in Tennessee; the red color in the figures indicates census tracts with low seat belt use rate and the green color indicates a high seat belt use rate. The white color also represents the state average. Visual Comparison of Figs. 3 and 4 indicate the

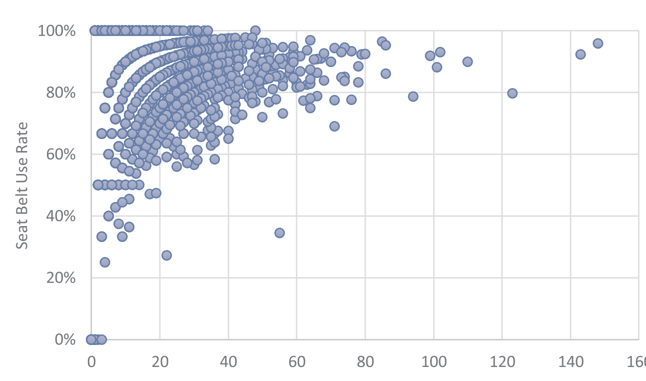


**Fig. 2.** Number of observations and corresponding seat belt use rate at census tract level for passengers (over 16).

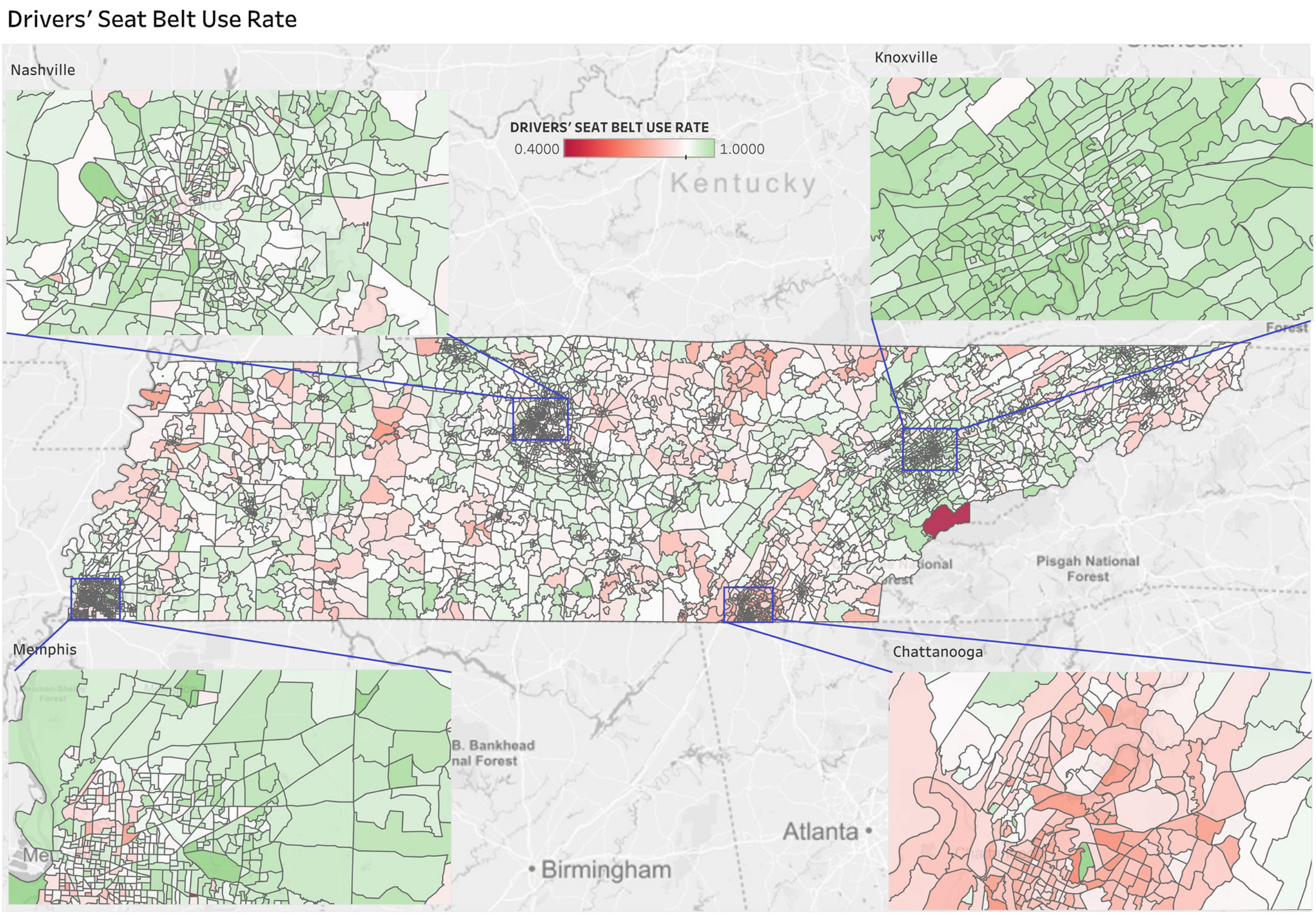


**Fig. 3.** Drivers' seat belt use rate distribution in Tennessee.

passengers' seat belt use rate has more variation in Tennessee compared to driver seat belt use rate.

Table 5 presents the average seat belt use rate in metropolitan areas. The average seat belt use rate for vehicle occupants in the metropolitan area was 88% ($SD$ = 0.06), which is slightly higher than the non-metropolitan area (87%; $SD$ = 0.06). Moreover, comparing the six metropolitan areas in Tennessee indicates that the driver's seat belt use rate is the highest among residents of Knoxville, followed by Jackson and Tri-cities. This trend also holds for the passenger's seat belt use rate. Chattanooga metropolitan area also has the lowest seat belt use rate for both passenger and driver seat. In addition, Chattanooga is the only metropolitan that passenger seat belt use rate is higher than the driver seat belt use rate.

### 3.3. Tobit model estimates

Table 6 presents the estimated saturated Tobit model based on the variables in Table 1. After performing stepwise regression and controlling for multicollinearity, insignificant variables were excluded from analysis. Table 7 presents the estimated coefficients for predicting driver seat belt use rate (DSBUR) and passengers seat belt use rate (PSBUR) at the census tract level, and their corresponding elasticity values. The chi-square results for all models indicate that both models are significantly different from the null model (DSBUR: $\chi^2$ = 328; PSBUR: $\chi^2$ = 233). The variables that are presented in Table 7 have a significant correlation with both dependent variables. The mean VIF value for DSBUR model and PSBUR are respectively 1.31 (max = 1.59) and 1.34 (max = 1.71).

Findings of estimated models in Table 7 indicate that population size, the percentage of the white race and child percentage at zonal level have a positive association with seat belt use rate in both models. In the DSBUR model, elasticity values indicate that 1% increase in population, child percentage, and portion of white race increase average seat belt use rate by 1.0%, 0.5%, and 0.3%, respectively; the corresponding elasticity values for the PSBUR model are higher, 0.8%, 3.7%, and 1.9%, respectively.

Vehicle ownership variables also have a significant association with seat belt use rate; however, the sign of the coefficients are dissimilar in both models. In the DSBUR model, the proportion of household with vehicle (i.e., 0–2) has a negative association with seat belt use rate. The elasticity values for the proportion of households with one or two vehicles (-2%) is greater than the proportion of households with no-vehicles (-0.6%). In the PSBUR model, the proportion of households with one or two vehicles has a positive correlation with passenger seat belt use, whereas the proportion of households with no-vehicles has a negative association with passenger seat belt use. The elasticity values for the proportion of families with one or two vehicles is 3%, and the corresponding value for households with no-vehicle is -0.3%.

Education-related variable signs are dissimilar in DSBUR model. Percentage of individuals with a college degree has a negative association with drivers' seat belt use rate. On the other hand, the percentage of bachelor degree has a positive association with seat belt use rate in both models. Elasticity values indicate one percent increase in the proportion of the population with bachelor's degree increases seat belt use rate by 0.4% and 1.3%, respectively, for DSBUR and PSBUR models.

The metropolitan indicator variable in both models has a positive association with seat belt use rate, which indicates that seat belt use in the metropolitan area is higher than non-metropolitan area. The magnitude and elasticity value of the metropolitan coefficient in the DSBUR model is greater than PSBUR model. Alternatively, the population

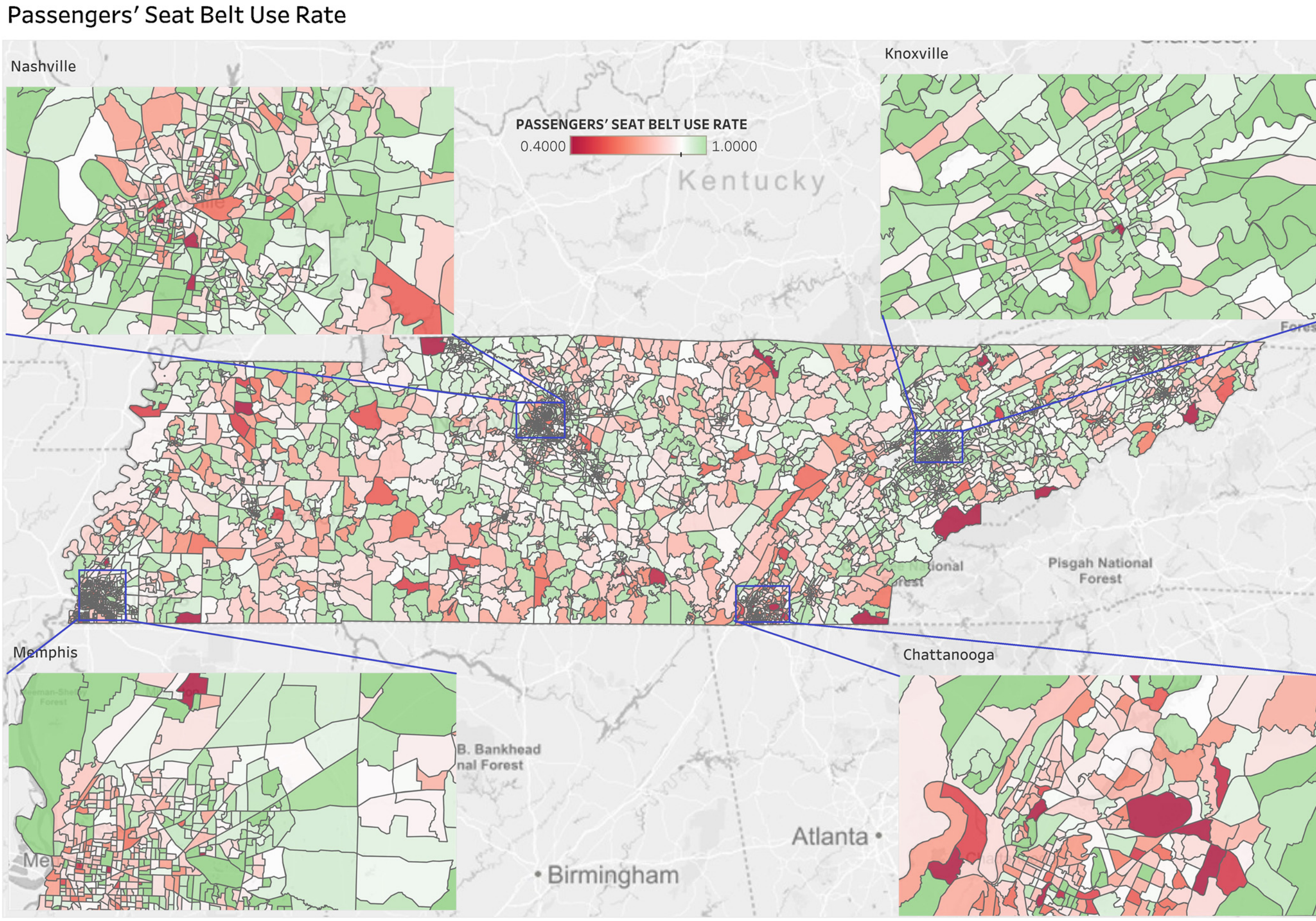


**Fig. 4.** Passengers' seat belt use rate (over 16) distribution in Tennessee.

**Table 5**
Mean and Standard Deviation of The Seat Belt Use Rate in Metropolitan Areas. Source: Authors analysis of TITAN data.

| Metropolitan Area | Driver | | Passenger | | Overall | |
|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD |
| Knoxville | 0.92 | 0.04 | 0.90 | 0.10 | 0.91 | 0.04 |
| Nashville | 0.89 | 0.05 | 0.87 | 0.11 | 0.88 | 0.05 |
| Jackson | 0.90 | 0.04 | 0.87 | 0.11 | 0.90 | 0.04 |
| Tri-cities | 0.89 | 0.05 | 0.88 | 0.13 | 0.89 | 0.05 |
| Chattanooga | 0.77 | 0.07 | 0.81 | 0.14 | 0.77 | 0.06 |
| Memphis | 0.87 | 0.06 | 0.83 | 0.12 | 0.86 | 0.06 |
| Non-metropolitan area | 0.87 | 0.06 | 0.86 | 0.12 | 0.87 | 0.06 |
| Grand Total | 0.88 | 0.06 | 0.86 | 0.12 | 0.87 | 0.06 |

density variable has a negative correlation with PSBUR variable; the elasticity values indicate that one percent change in population density results in 1.1% reduction in seat belt use rate in the PSBUR model. Household size also has a significant negative association with passenger seat belt use; the elasticity value for this variable is -0.4%.

## 4. Discussion

Analysis of seat belt use rate for vehicles' occupants over 16 years old indicates that seat belt use rate for drivers and the front passenger in 2016 was approximately 88.2%, which is close to 88.9% observed in roadside observations in Tennessee (THSO, 2016; CTR, 2018). Comparison of the driver and front row passenger seat belt use rate indicates that front row passenger had higher compliance rate, which is also in line with the roadside observation in Tennessee (THSO, 2016; CTR, 2018). Generally, the seat belt use rate of passengers (including back row) was lower than the driver, which is influenced by substantially lower seat belt use rate of the passengers in back rows. This lower seat belt use rate for passengers in back rows could be attributed to the current seat belt law in Tennessee, which only covers front row passengers (IIHS, 2018).

In line with previous studies (Wells et al., 2002; Gkritza and Mannering, 2008; Ojo, 2018), police crash reports analysis indicates that males and younger individuals are more prone to seat belt non-use. Findings also indicate that seat belt use rate are higher in daylight and harsh weather, which is consistent with roadside observations (NHTSA, 2016). Additionally, seat belt use on interstates is higher than other classes of roads. Variation in seat belt use rate in different circumstances could be attributed to the perception of safety. For instance, those who drive in harsh weather (e.g., rainy or high-speed routes like interstates) may perceive more hazard, and as a result, have a higher seat belt use rate. These abovementioned findings yield the conclusion that police crash reports of seat belt use are broadly in agreement with roadside observations in Tennessee (CTR, 2018) and road safety literature (Gkritza and Mannering, 2008; Pickrell and Ye, 2009; Ogunleye-Adetona et al., 2018; Ojo, 2018).

Comparison of the driver and passenger seat belt use rate in different metropolitan areas indicates that driver's seat belt use was higher than other passengers, except for Chattanooga metropolitan area. Overall, the Chattanooga region has the lowest seat belt use rate among both metropolitan and non-metropolitan areas. The spatial variation in seat belt use in metropolitan areas reflects different traffic cultures and social and psychological factors within Tennessee. Identifying social and psychological factors (e.g., attitudes, beliefs, and intentions) that affect seat belt use and using them for educational purposes in safety

**Table 6**
Estimated saturated Tobit model for prediction of the seat belt use rate for drivers.
Source: Authors' analysis of TITAN data and the US Census.

| Variable | DSBUR | | PSBUR | |
|---|---|---|---|---|
| | Coef. | Standard Error | Coef. | Standard Error |
| Population (1000) | 0.006*** | 0.001 | 0.005* | 0.003 |
| Age Cohorts | | | | |
| Population 16-42 | 0.001 | 0.015 | −0.059* | 0.030 |
| Population 43-59 | −0.019 | 0.027 | −0.024 | 0.053 |
| Population over 60 | −0.037 | 0.029 | 0.021 | 0.056 |
| Age Median | 2.93E-04 | 3.41E-04 | −8.42E-04 | 6.71E-04 |
| Race (%) | | | | |
| Race White | 0.012 | 0.017 | 0.042 | 0.035 |
| Race Black | −0.025 | 0.017 | 0.007 | 0.035 |
| Race Indian | −0.031 | 0.093 | 0.115 | 0.182 |
| Race Asian | −0.043 | 0.037 | 0.040 | 0.074 |
| Race Hawaiian | 0.004 | 0.148 | 0.181 | 0.291 |
| Travel Mode to Work | | | | |
| Morning Share Car | −0.029* | 0.015 | 0.031 | 0.031 |
| Morning Share Carpool | −0.010 | 0.012 | −0.026 | 0.024 |
| Morning Share Bus | −0.028 | 0.032 | 0.007 | 0.063 |
| Morning Share Motor | −0.060 | 0.132 | 0.201 | 0.259 |
| Morning Share Bicycle | −0.196* | 0.103 | 0.056 | 0.202 |
| Morning Share Walk | −0.101*** | 0.027 | −0.023 | 0.057 |
| Education Degree | | | | |
| % High school degree | −0.057*** | 0.015 | 0.027 | 0.031 |
| % College degree | −0.068*** | 0.018 | 0.039 | 0.036 |
| % Bachelor Degree | −0.036*** | 0.020 | 0.105** | 0.042 |
| Median Household Income | −1.13E-07 | 6.39E-07 | 1.61E-07 | 1.29E-07 |
| Vehicle Ownership (%) | | | | |
| Household with no Vehicle | −0.051*** | 0.015 | −0.017 | 0.029 |
| Household with One or Two Vehicles | −0.014* | 0.009 | 0.041** | 0.018 |
| Density (1000 population per square km) | −1.13E-07 | 1.18E-07 | −1.28E-06*** | 2.34E-07 |
| Constant | 0.970*** | 0.018 | 0.776*** | 0.044 |
| Scale Parameter | 0.004*** | 0.000 | 0.014*** | 0.000 |
| $\chi^2$ | 373.78 | | 217.54 | |
| $LL_0$ | 5,563.87 | | 2,841.95 | |
| $LL_M$ | 5,750.76 | | 2,950.72 | |
| Maddala Pseudo-$R^2$ | 0.09 | | 0.09 | |
| N | 4,114 | | 4,103 | |
| AIC | −11,453.53 | | −5,853.44 | |

*p < .10; **p < .05; ***p < .01.

campaigns could increase seat belt use. Moreover, seat belt use rate distribution maps in Tennessee indicate that passenger seat belt use rate has more spatial variation than driver seat belt use. Spatial variation in seat belt use could be attributed to both traffic laws in Tennessee and cultural differences, which should be investigated in the future studies.

A Tobit model was used to investigate the association between seat belt use for the drivers and passengers 16 years or older who were involved in traffic crashes and sociodemographic variables of the occupant's home location, at the aggregate level. This is the first time, to the authors' knowledge, that this type of analysis has been conducted. Results indicate that the percentage of the white race in the neighborhood had a positive impact on seat belt use rate for both models; this finding parallels previous research (e.g., Gkritza and Mannering, 2008; Pickrell and Ye, 2009; Bhat et al., 2015). Using a safety campaign in neighborhoods with a high percentage of non-white populations could be used as an effective method for improving seat belt compliance rate. Consistent with other road safety literature, sociodemographic variables have a significant impact on seat belt use rate (Preusser et al., 1991; Reinfurt et al., 1997; Wells et al., 2002; Houston and Richardson, 2005). Different neighborhood education levels also have a different effect on seat belt use rate for both models. Percentage of bachelor's degree have a positive impact on the seat belt use rate for both DSBUR and PSBUR models. On the other hand, in the drivers' model, the percentage of a college degree has a negative association with the driver's seat belt use rate. The motive for not wearing a seat belt for lower education driver could be different; perhaps lower seat belt use of drivers with lower-education could be attributed to their subjective norm and attitude toward wearing a seat belt. On the other hand, for higher education and higher income portion of society lower seat belt use rate could be attributed to perceived behavioral control or overconfidence. This may also explain the negative sign of average neighborhood vehicle ownership for the driver seat belt use. Using social psychological tools to investigate how attitudes, beliefs, and values influence seat belt use for different road users would be beneficial for designing a better safety campaign and targeting human factors that predict seat belt use.

Quite the opposite, passengers' with higher education and higher vehicle ownership have higher seat belt use rate. This behavior may be attributed to the fact that passengers (particularly front row passengers) have little or no control over the driver's behavior (i.e., perceived behavioral control), and as a result, passengers tend to wear their seat belt more frequently when they are not in the driving position. Psychological factor that affects lower seat belt use rates of the back rows passengers needs to be investigated in the future studies. The home-address environment also has a significant effect on seat belt use rate in both models. Results indicate metropolitan indicator has a positive impact on seat belt use rate for both models. Metropolitan indicator could be used as a surrogate for urban areas, which traditionally have a higher seat belt use rate (NHTSA, 2017a).

## 5. Conclusion and future implications

In sum, results of analysis point out that police crash reports have the potential to be used as a source to examine seat belt use at the neighborhood level. Using the home-address of the individuals extracted from police crash report could be used to identify areas with lower seat belt use rate, which could be useful in the design of safety campaigns in programs such as "Click-It or Ticket" to efficiently reach individuals that are more prone to lower seat belt use. This method could be more effective than blanket campaigns that tend to show small population-level effects. There is also a need for developing a methodology that enables researchers and safety practitioners to identify seat belt non-use hotspots.

Increase in the enforcement mainly by covering passengers in back rows under the primary seat belt use law in Tennessee could be a practical solution for increasing seat belt use rate of passengers. Besides, findings indicate that there are differences between drivers and passengers in terms of factors correlating with their seat belt use at the zonal level. As a result, the seating position needs to be considered in the design of a road safety campaign.

It is also worth mentioning that there are difficulties in accessing crash data with identifiers and it is not possible to obtain this data in some cases. One possible direction for future researchers could be to develop a methodology to identify seat belt hotspots based on the conventional sources of data (i.e., temporal and spatial transformation of the models). The sample in this study represents an individual who had reported a traffic crash in Tennessee in 2016 and careful consideration needed in order to apply the findings to all residents of the state.

**Table 7**
Estimated Tobit model for prediction of the seat belt use rate for drivers.
Source: Authors' analysis of TITAN data and the US Census

| Variable | DSBUR | | | PSBUR | | |
|---|---|---|---|---|---|---|
| | Coef. | Standard Error | Elasticity | Coef. | Standard Error | Elasticity |
| Population (1000) | 0.006*** | 0.001 | 0.010 | 0.005* | 0.003 | 0.008 |
| % Children | 0.023* | 0.012 | 0.005 | 0.085*** | 0.024 | 0.037 |
| % Race White | 0.036*** | 0.004 | 0.031 | 0.042*** | 0.008 | 0.019 |
| *Vehicle Ownership* | | | | | | |
| % Household with no Vehicle | −0.078*** | 0.013 | −0.006 | −0.041* | 0.025 | −0.003 |
| % Household with One or Two Vehicles | −0.025*** | 0.008 | −0.020 | 0.036** | 0.016 | 0.029 |
| *Education* | | | | | | |
| % College degree | −0.032** | 0.013 | −0.007 | | | |
| % Bachelor Degree | 0.016* | 0.009 | 0.004 | 0.058*** | 0.018 | 0.013 |
| Metropolitan Indicator | 0.007*** | 0.002 | 0.005 | 0.015*** | 0.005 | 0.012 |
| Household Size | | | | −0.001*** | 0.000 | −0.004 |
| Density (1000 population per square km) | | | | −1.46E-06*** | 2.24E-07 | −0.011 |
| Constant | 0.863*** | 0.008 | | 0.773*** | 0.016 | |
| Scale parameter | 0.004*** | 7.97E-05 | | 0.014*** | 3.03E-04 | |
| $\chi^2$ | 328.37 | | | 233.50 | | |
| $LL_0$ | 5,563.87 | | | 2,841.95 | | |
| $LL_M$ | 5,728.06 | | | 2,958.70 | | |
| Maddala Pseudo-$R^2$ | 0.077 | | | 0.056 | | |
| N | 4,114 | | | 4,103 | | |
| AIC | −11,436.12 | | | −5,897.41 | | |

*p < .10; **p < .05; ***p < .01.

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## References

Anastasopoulos, P.C., Shankar, V.N., Haddock, J.E., Mannering, F.L., 2012. A multivariate tobit analysis of highway accident-injury-severity rates. Accid. Anal. Prev. 45, 110–119.
Anastasopoulos, P.C., Tarko, A.P., Mannering, F.L., 2008. Tobit analysis of vehicle accident rates on interstate highways. Accid. Anal. Prev. 40 (2), 768–775.
Begg, D.J., Langley, J.D., 2001. Seat-belt use and related behaviors among young adults. J. Saf. Res. 31 (4), 211–220.
Bhat, G., Beck, L., Bergen, G., Kresnow, M.-j., 2015. Predictors of rear seat belt use among us adults, 2012. J. Saf. Res. 53, 103–106.
Blincoe, L., Miller, T.R., Zaloshnja, E., Lawrence, B.A., 2015. The economic and societal impact of motor vehicle crashes, 2010. (revised) (report no. Dot hs 812 013). Washington, dc: National highway traffic safety administration.
Boyle, J., Vanderwolf, P., 2004. 2003 Motor Vehicle Occupant Safety Survey, Volume 2: Safety Belt Report.
Bozdogan, H., 1987. Model selection and akaike's information criterion (aic): the general theory and its analytical extensions. Psychometrika 52 (3), 345–370.
Calisir, F., Lehto, M.R., 2002. Young drivers' decision making and safety belt use. Accid. Anal. Prev. 34 (6), 793–805.
Cherry, C.R., Mohamadi Hezaveh, A., Grembek, O., Sandt, L., Merlin, L., 2017. Better data integration to create a complete picture for cycling safety. Year. In: Proceedings of the 2017 International Cycling Safety Conference Held in Davis.
Chliaoutakis, J.E., Gnardellis, C., Drakou, I., Darviri, C., Sboukis, V., 2000. Modelling the factors related to the seatbelt use by the young drivers of athens. Accid. Anal. Prev. 32 (6), 815–825.
CTR, 2018. 2017 survey of safety belt usage in tennessee final report. In: Research, T.U.O. T.C.F.T. ed.
Cummings, P., 2002. Association of seat belt use with death: a comparison of estimates based on data from police and estimates based on data from trained crash investigators. Inj. Prev. 8 (4), 338–341.
Farmer, C.M., Williams, A.F., 2005. Effect on fatality risk of changing from secondary to primary seat belt enforcement. J. Saf. Res. 36 (2), 189–194.
Fhaner, G., Hane, M., 1975. Seat belts: changing usage by changing beliefs. J. Appl. Psychol. 60 (5), 589.
Gkritza, K., Mannering, F.L., 2008. Mixed logit analysis of safety-belt use in single-and multi-occupant vehicles. Accid. Anal. Prev. 40 (2), 443–451.
Glassbrenner, D., Carra, J.S., Nichols, J., 2004. Recent estimates of safety belt use. J. Saf. Res. 35 (2), 237–244.
Glassbrenner, D., Ye, J., 2007. Seat belt use in 2006—overall results. In: National Highway Traffic Safety Administration, U.S.D.O.T. ed., Washington, DC.
Grimm, P., 2010. Social Desirability Bias. Wiley international encyclopedia of marketing.
Hezaveh, A.M., Zavareh, M.F., Cherry, C.R., Nordfjærn, T., 2018a. Errors and violations in relation to bicyclists' crash risks: development of the Bicycle Rider Behavior Questionnaire (BRBQ). J. Transp. Health 8, 289–298.
Hezaveh, A.M., Nordfjærn, T., Mamdoohi, A.R., Şimşekoğlu, Ö., 2018b. Predictors of self-reported crashes among iranian drivers: exploratory analysis of an extended driver behavior questionnaire. PROMET-Traffic Transp. 30 (1), 35–43.
Hezaveh, Amin Mohamadi, Nordfjærn, Trond, Everett, Jerry, Cherry, Christopher R., 2019. Considering Spatial Heterogeneity and Time of Day in Self-Reported Seat Belt Use. No. 19-02918.
Houston, D.J., Richardson, L.E., 2005. Getting americans to buckle up: the efficacy of state seat belt laws. Accid. Anal. Prev. 37 (6), 1114–1120.
IIHS, 2018. Safety Belts. Insurance Institute for Highway Safety.
Jonah, B.A., Dawson, N.E., 1982. Predicting reported seat belt use from attitudinal and normative factors. Accid. Anal. Prev. 14 (4), 305–310.
Jonah, B.A., Dawson, N.E., Smith, G.A., 1982. Effects of a selective traffic enforcement program on seat belt usage. J. Appl. Psychol. 67 (1), 89.
Knapper, C., Cropley, A., Moore, R., 1976. Attitudinal factors in the non-use of seat belts. Accid. Anal. Prev. 8 (4), 241–246.
Lajunen, T., Corry, A., Summala, H., Hartley, L., 1997. Impression management and self-deception in traffic behaviour inventories. Personal. Individ. Diff. 22 (3), 341–353.
Lajunen, T., Summala, H., 2003. Can we trust self-reports of driving? Effects of impression management on driver behaviour questionnaire responses. Transp. Res. F: Traff. Psychol. Behav. 6 (2), 97–107.
Li, L., Kim, K., Nitz, L., 1999. Predictors of safety belt use among crash-involved drivers and front seat passengers: adjusting for over-reporting. Accid. Anal. Prev. 31 (6), 631–638.
Maddala, G.S., 1986. Limited-Dependent and Qualitative Variables in Econometrics. Cambridge university press.
MMUCC, 2012. Model minimum uniform crash criteria. DOT HS 811, 631.
Nelson, D.E., Bolen, J., Kresnow, M.-j., 1998. Trends in safety belt use by demographics and by type of state safety belt law, 1987 through 1993. Am. J. Public Health 88 (2), 245–249.
NHTSA, 2016. Traffic safety facts research noteseat belt use in 2015—overall results. In: Analysis, N.S.N.C.F.S.A. (Ed.), NHTSA'S National Center for Statistics and Analysis. 1200 New Jersey Avenue SE, Washington, DC 20590.
NHTSA, 2017a. In: Analysis, N.S.N.C.F.S.A. (Ed.), Seat Belt Use in 2017—Use Rates in the States and Territories.
NHTSA, 2017b. Traffic Safety Facts 2016 State Traffic Data. Department of Transportation, National Highway Traffic Safety Administration. DOT-HS-812-581, Washington, DC: US. .
Nordfjærn, T., Hezaveh, A.M., Mamdoohi, A.R., 2015. An analysis of reported driver behaviour in samples of domestic and expatriate iranians. J. Risk Res. 18 (5), 566–580.
O'brien, R.M., 2007. A caution regarding rules of thumb for variance inflation factors. Quality Quantity 41 (5), 673–690.
Ogunleye-Adetona, C., Ojo, T., Afukaar, F., 2018. Assessment of seat belt use in university of cape coast campus, Ghana. Urban Plann. Transp. Res. 6 (1), 22–34.
Ojo, T.K., 2018. Seat belt and child restraint use in a developing country metropolitan

city. Accid. Anal. Prev. 113, 325–329.
Pickrell, T., Ye, T., 2009. Traffic Safety Facts (Research Note): Seat Belt Use in 2008–demographic Results. National Highway Traffic Safety Administration/ Department of Transportation, Washington DC.
Preusser, D.F., Williams, A.F., Lund, A.K., 1991. Characteristics of belted and unbelted drivers. Accid. Anal. Prev. 23 (6), 475–482.
Reinfurt, D., Williams, A., Wells, J., Rodgman, E., 1997. Characteristics of drivers not using seat belts in a high belt use state. J. Saf. Res. 27 (4), 209–215.
Schiff, M.A., Cummings, P., 2004. Comparison of reporting of seat belt use by police and crash investigators: variation in agreement by injury severity. Accid. Anal. Prev. 36 (6), 961–965.
Şimşekoğlu, Ö., Lajunen, T., 2008. Social psychology of seat belt use: a comparison of theory of planned behavior and health belief model. Transp. Res. F: Traff. Psychol. Behav. 11 (3), 181–191.
Stata, A., 2015. Stata Base Reference Manual Release 14.
THSO, 2016. In: Office, T.H.S. (Ed.), Tennessee'S Average Seat Belt Usage Rate Soars to 88.95% in 2016. Tennessee Highway Safety Office.
TITAN, 2017. Tennessee Integrated Traffic Analysis Network. Tennessee Highway Patrol.
Tobin, J., 1958. Estimation of relationships for limited dependent variables. Econometrica 24–36.
Veall, M.R., Zimmermann, K.F., 1996. Pseudo-r2 measures for some common limited dependent variable models. J. Econ. Surv. 10 (3), 241–259.
Vivoda, J.M., Eby, D.W., Kostyniuk, L.P., 2004. Differences in safety belt use by race. Accid. Anal. Prev. 36 (6), 1105–1109.
Wells, J.K., Williams, A.F., Farmer, C.M., 2002. Seat belt use among african americans, hispanics, and whites. Accid. Anal. Prev. 34 (4), 523–529.
Zeng, Q., Wen, H., Huang, H., Pei, X., Wong, S., 2017. A multivariate random-parameters tobit model for analyzing highway crash rates by injury severity. Accid. Anal. Prev. 99, 184–191.