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16. Abstract
The National Highway Traffic Safety Administration estimates that despite the recent trend towards higher national seat belt use rates, 10% of drivers still only use seat belts occasionally. The current study examined occasional seat belt use among participants in the Strategic Highway Research Program 2 (SHRP2) Naturalistic Driving Study. The study was exploratory research with the specific objectives of: (1) identifying individual factors that differentiate seat belt user groups, and (2) identifying the impact of *situational* factors in seat belt use patterns of occasional seat belt users. Seat belt use data were available for 895 SHRP2 participants, and researchers examined belt use within and across each driver's trips. Approximately 10% of study participants were clearly occasional seat belt users. The data provided evidence for two types of occasional seat belt users: those who made a pre-trip decision to buckle or remain unbuckled for the entire trip, and those who made a within-trip decision to buckle or unbuckle for part of the trip. Occasional seat belt users were more likely to be older and male, in addition to differing across several other demographic and psychological variables. Situational factors, such as trip distance, average speed, and start-time also predicted occasional seat belt use.

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Table of Contents

Table of Figures

Table of Tables

Executive Summary

Seat belts are the most effective injury prevention tool available in motor vehicles. Estimates show that proper seat belt use reduces the risk of death by 45% for passenger car and 60% for light-truck front seat occupants in motor vehicle crashes (Kahane, 2015). The National Highway Traffic Safety Administration estimates that, during the day, 88.5% of drivers and right-front passengers used seat belts in 2015 (Pickrell & Li, 2016).

Despite the increases in belt use, some occupants only use seat belts occasionally. In the 2007 Motor Vehicle Occupant Safety Survey (MVOSS) conducted by NHTSA, 88% of drivers reported always wearing seat belts (Boyle & Lampkin, 2008). Only 2% of drivers reported "never" or "rarely" using seat belts, while the remaining 10% reported using seat belts "some" or "most" of the time. Thus, one way to increase overall seat belt use rates is to focus countermeasures on these occasional seat belt users. Since it is impossible to predict when a crash will occur, convincing occasional seat belt users to become consistent seat belt users could save many lives (Yates et al., 2011). Understanding the factors that contribute to inconsistent, improper, and infrequent seat belt use is essential to developing programs aimed at promoting increased seat belt use among occasional users (Bradbard et al., 1998; Hedlund, Preusser, & Shultz, 2004).

While researchers have a limited understanding of the factors underlying occasional seat belt use, previous research has shown some consistent patterns. Specifically, occasional seat belt users:

- Report that they are rarely mindful of risk and safety while driving, especially when traveling familiar roads (Bradbard et al., 1998; Bradbard, Panlener, & Lisboa-Farrow, 1996);
- Are less likely to buckle on short trips or when they drive without passengers (Bradbard et al., 1998; Boyle & Lampkin, 2008; Yates et al., 2011);
- Are less likely to buckle if the trip involves frequent stops, low-speed driving, or good weather (Bradbard et al., 1998), or if they are in a rush (Boyle & Lampkin, 2008); and
- Are less likely to buckle if there are distractions that prevent belts from being worn, if they are wearing nice clothing, or if the belt is uncomfortable (Bradbard et al., 1998, Boyle and Vanderwolf, 2004; Boyle & Lampkin, 2008).

Naturalistic studies of driving behavior provide researchers ways to develop detailed understanding of occasional belt use behavior and the associated driver, vehicle, and situational factors. One such study is the Strategic Highway Research Program 2 (SHRP2) Naturalistic Driving Study (NDS), which was a comprehensive naturalistic study that collected driving data in six regional sites across the United States. SHRP2 collected data from 3,600 passenger vehicle drivers over 12 to 24 months. The SHRP2 data provide detailed information about driver seat belt use from the continuous observation that can be used to determine whether drivers were buckled or unbuckled for the entire trips and whether drivers made mid-trip decisions to change their status. Moreover, the driver assessment data provide a way to identify driver-specific and situational factors associated with occasional seat belt use.

Objectives

This study was an exploratory investigation of seat belt use in the SHRP2 NDS dataset focused on occasional seat belt users. The specific objectives were to:

1. Identify individual differences that differentiate seat belt user groups; and
2. Identify the impact of *situational* factors in seat belt use patterns of occasional seat belt users.

General Approach

The research team conducted a series of analyses using the SHRP2 seat belt data. The team first operationalized seat belt use on a trip and categorized all trips based on the percentage of recorded seat belt use. Researchers then aggregated these trip types within drivers to classify participants into seat belt user types based on the relative proportion of trip types. Statisticians then conducted analyses to identify driver-specific and trip-specific predictors of seat belt user types.

Operationalizing Belt Use

Three types of trips were most relevant for examining occasional seat belt use:

- Full-trip buckled,
- Part-trip unbuckled (participants buckle or unbuckle partway through the trips), and
- Full-trip unbuckled.

The primary challenge in defining the boundaries for the trip types was that fully buckled trips did not always appear as 100% seat belt use because of sensor fluctuations, or behaviors such as participants not buckling until they entered roadways. Belt use within trips had a bi-modal distribution with separate peaks at less than 5% and greater than 95%. These two boundaries became the thresholds for defining trips as fully unbuckled (<5%) and full buckled (>95%). The remaining trips that fell between these boundaries were defined as part-trip unbuckled trips.

Seat Belt User Types

Over 70% of the participants were fully buckled on at least 95% of their trips; 9% never drove unbuckled. Researchers used a combination of heuristic analysis and cluster analysis to divide participants into seat belt user groups based on their use patterns.

Table 1 shows the number of drivers in each group, and organizes the groups based on the frequency of unbuckled trips and seat belt use type.

Table 1. Number of participants in each type of seat belt use group.

		Seat Belt Use Type	
	Frequency of Unbuckled Trips	*Mostly Part-Trip Unbucklers (N, %)*	*Mostly Full-Trip Unbucklers (N, %)*
Consistent Seat Belt Users	*Never*	A (82, 9.3%)	
	Almost Never	B (274, 31.2%)	
Occasional Seat Belt Users	*Rarely*	C1 (288, 32,8%)	D1 (99, 11.3%)
	Occasionally	C2 (80, 9.1%)	D2 (43, 4.9%)
	Frequently	---	D3 (13, 1.5%)

Most participants used seat belts for the entirety of most, if not all, of their trips. This certainly holds for Groups A and B, but even the participants in groups C1 and D1 had were fully belted on more than 90% of their trips. Groups C2 and D2/D3 provide the clearest examples of occasional belt users.

Characteristics of Seat Belt User Types

Researchers examined driver characteristics associated with the different seat belt user groups. The predictors in the analyses included responses to driver assessment questions and questionnaires that participants completed during the enrollment process.

The key trends across the demographic variables included:

- *Sex*: Females were more likely to be consistent users than males.
- *Age Group*: Belt use became less consistent as age increased.

To understand the factors related to different seat belt user types, statisticians analyzed the association between driver-level measurements and seat belt user types. Statisticians built statistical and machine-learning models to make two key comparisons:

1. Between consistent seat belt users (groups A and B) and occasional seat belt users (groups C2 and D2/D3), and
2. Among the occasional seat belt users; between typically part-trip unbuckled participants (cluster C) and typically full-trip unbuckled participants (cluster D).

Table 2 below summarizes the key significant variables that differentiated consistent seat belt users (groups A and B) from those that represented the most frequent occasional seat belt users (C2 and D2/D3).

Table 2. Factors that predicted occasional (groups C2/D2/D3) versus consistent seat belt users (groups A/B)

Predictor	Occasional seat belt users:
AgeGroup	Were more likely to be 40 or older
Sex	Were more likely to be male
BMI	Were more likely to be overweight
MaritalStatus	Were more likely to be single
NumViolations	Had more traffic violations
NoBelt_is_Risky	Were less likely to perceive no seat belt as unsafe
RiskTakingScore	Were more likely to report engaging in risky driving behaviors
DrivingKnowledge	Had lower scores on a basic driving knowledge test
ClockDrawing	Had worse clock-drawing scores
ADHD_Confidence	Had higher ADHD confidence score

Table 3 below summarizes the key significant variables that differentiated the two types of occasional seat belt users. To increase the statistical power, the statisticians ran the models with all group C participants combined (part-trip unbuckled) and all group D participants (full trip unbuckled) combined.

Table 3. Factors that predicted type of occasional seat belt user: part-trip unbuckling (cluster C) versus full-trip unbuckling (cluster D).

Predictor	Among occasional seat belt users, participants who typically were full-trip unbuckled:
AgeGroup	Had a greater proportion of age 16 to 24 and smaller proportion of age 40 to 64
MaritalStatus	Were more likely to be single
NumViolations	Had more traffic violations
RiskTakingScore	Had higher risk-taking scores
ClockDrawing	Had worse clock-drawing scores
Sensation Seeking	Had higher sensation seeking scores
SS_Disinhibition	Had higher disinhibition scores
SS_ThrillSeeking	Had higher thrill-seeking scores
Left_Hand_Strength	Had lower left-hand strength
ShiftWork	Were more likely to work evening or night shifts

The analyses of driver-specific predictors confirmed many of the patterns that researchers have found in other seat belt use studies. Regarding the research objective of identifying driver-specific predictors of occasional seat belt use, the statistical modeling indicated that multiple factors differentiated participants who were either mostly part-trip or mostly full-trip unbucklers.

Situational Factors Associated with Occasional Seat Belt Use

Thirty percent of participants in this study were neither consistent seat belt users or non-users. These participants seemed to decide to buckle or unbuckle at the trip outset or partway through the trip. This suggests that situational factors influenced these driver decisions. The second research objective examined whether situational aspects of trips, either before or during, influenced belt-use decisions.

The research team used three approaches to investigate this question. First, they examined the trip summary data to identify trip-wide difference between the three types of seat belt use trips (fully buckled, partially unbuckled, fully unbuckled). Second, they focused on situational factors within trips. They divided partially buckled trips into buckled and unbuckled driving epochs, and compared the two types of epochs to identify factors associated with buckled or unbuckled driving. Third, they examined immediate driving conditions that occurred during the 30 seconds before and 30 seconds after a buckling/unbuckling event. These three approaches examined situational factors across a range of levels, and covered both pre-trip belt use decisions, and factors that may have influenced mid-trip decisions. The key findings from each of these analyses are described below.

Trip-Wide Predictors of Seat Belt Use: Logistic regression analyses indicated that the trip types (fully buckled, partially unbuckled, and fully unbuckled) differed significantly in terms of trip distance, average speed, and start-time. Partially unbuckled and fully unbuckled trips were shorter and had lower average speeds than fully buckled trips, with fully unbuckled being the shortest and slowest overall. Although significant, differences in start hour did not follow an interpretable pattern.

Situational Factors Associated With Partial Seat Belt Use Trips: Partial use trips were divided into separate buckled and unbuckled parts of a trip (referred to as epochs). Participants were more likely to be belted during epochs in which they drove at higher speeds, for longer duration, in higher density traffic, and on higher-capacity roads as compared to unbuckled epochs. A trip in which the driver unbuckled during the trip tended to be at higher speed, for a shorter duration, in higher density traffic, and on a higher-capacity road than a trip in which the driver started unbuckled and buckled mid-trip.

Influence of Immediate Driving Conditions on Driver Buckling and Unbuckling: There were clear differences in the immediate driving conditions associated with buckling and unbuckling transitions. The finding that most buckling events occurred at speed and in traffic was somewhat unexpected since reaching for and latching the buckle is easier and safer to accomplish while stopped. It is possible that buckling was motivated by events prompting an immediate response, such as participants seeing a police vehicle. The driving conditions during seat belt transitions on unbuckling trips were qualitatively different. A large proportion of these occurred while the vehicle was momentarily stopped but not parked. It is possible that some participants may have stopped to do something that required unbuckling, and that they did not buckle up again once they continued with their trips.

Analysis of Seat Belt Use

To obtain further insight regarding factors influencing these behaviors, researchers analyzed SHRP2 video data to identify other factors that influenced seat belt use that were not apparent in previous analysis. These could include in-vehicle factors such as the presence of passengers and the physical state of the driver, external factors such as traffic, weather, presence of law enforcement, and/or involvement in crash/near-crash events. Video coding confirmed several known patterns related to driver buckling/unbuckling behaviors, including:

- Participants buckled late or did not buckle until they reached a road with traffic;
- The presence of passengers led to more buckling;
- Some younger participants did not buckle when peers were in the car but they did buckle when alone;
- Participants frequently unbuckled when distracted by cell phones that were in pockets, while reaching for objects, or doing other distracting tasks like changing clothes while driving; and
- The perception of nearby law enforcement led part-time belt users to react in a startled manner and quickly buckle.

Another common finding was that many people either unbuckled mid-trip, or never buckled at all, on “low demand/risk” trips or portions of trips. A number of participants repeatedly unbuckled when exiting high-speed, limited-access roads while others never buckled at all when the trips were on local or neighborhood roads. These behaviors imply some participants assessed risk and made conscious decisions to either buckle or unbuckle based on the perceived risk on a given trip or segment of a trip.

Part-time belt users also frequently buckled while approaching intersections or lines of traffic at intersections. In most cases, there was no other apparent reason for buckling at these times other than the approach and stop at the intersections. Most of the time the buckling behavior was very casual, as if the driver had simply forgotten to buckle and the intersection cued the buckling behavior.

The video coding analysis also examined how an unbuckled participant behaved after experiencing a crash or near-crash event. Only about a fifth of the unbelted participants who experienced events put on the seat belts for the remainder of the trips after the events. Event severity did not appear to be a major factor as participants involved in some of the most severe events did not buckle after experiencing what should have been frightening incidents. Other participants experienced much less severe events but responded by immediately buckling. Those participants who did buckle after their events, however, tended to have higher belt use rates (either partial belt use or full belt use) both before and after the events than those who did not buckle. This suggests the events served as reminders to wear seat belts for these people who already tended to wear seat belts more often.

Overall, the SHRP2 dataset proved to be a useful source of information about occasional seat belt use. Although there are limitations regarding the availability of continuous seat belt status information across the full sample, the data examined in the current study were sufficient to support a wide range of analyses. These analyses confirmed expected trends among key predictor variables and situational factors, and they broadened our understanding of how individual and situational factors influence occasional seat belt use.

Background and Objectives

Seat belt restraints are the most effective injury prevention tool available in motor vehicles. Estimates show that proper seat belt use reduces the risk of death by 45% for front seat occupants in motor vehicle crashes (Kahane, 2015). NHTSA estimates that during the day 88.5% of drivers and front-right passengers used seat belts in 2015 (Pickrell & Li, 2016).

Despite the increases in belt use, some occupants only use seat belts occasionally. In the 2007 Motor Vehicle Occupant Safety Survey (MVOSS) conducted by NHTSA, 88% of drivers reported always wearing seat belts (Boyle & Lampkin, 2008). Only 2% of drivers reported "never" or "rarely" using seat belts. The remaining 10% of drivers reported using seat belts "some" or "most" of the time. Thus, one way to increase overall seat belt use rates is to focus countermeasures on occasional seat belt users. Since it is impossible to predict when a crash will occur, convincing these occasional seat belt users to become consistent seat belt users could save many lives (Yates et al., 2011). Understanding the factors that contribute to inconsistent, improper, and infrequent seat belt use is essential to the development of programs aimed at promoting an increased level of seat belt use among occasional users (NHTSA, 1998; Hedlund et al., 2004).

Previous research has identified a variety of demographic, individual, and personality factors associated with driving unbelted (see Table 4). A literature review conducted by Jans et al., (2015) provides a comprehensive review of factors associated with observed and self-reported seat belt use. These included:

- Demographic characteristics (age, sex, race, socio-economic status, marital status),
- Environmental aspects (roadway types, vehicle types, passengers),
- Personality factors (personality constructs, sensation seeking, locus of control, self-efficacy),
- Decision factors (risk perception, decision modes, assumptions),
- Emotional characteristics (affect, fatalism), and
- Behavioral characteristics (plans/intention, health behavior).

This type of driver-specific information is important for developing effective safety messages and targeting those messages towards the relevant driver populations.

Table 4. Driver-specific factors that are associated with not wearing seat belts all of the time.

Drivers who do not regularly wear seat belts…	**Research Source**
Are more likely to be older	Boyle & Lampkin, 2008 Shinar, Schechtman, & Compton, 2001 Strine et al., 2010 Boyd, Kresnow, & Dellinger, 2008
Are more likely to have lower educational achievement	Shinar, 1993 Shinar, Schechtman, & Compton, 2001 Kweon & Kockelman, 2006 Strine et al., 2010 Boyd, Kresnow, & Dellinger, 2008 Demirer, Durat, & Hasimoglu, 2012
Are more likely to have lower incomes	Boyle & Lampkin, 2008 Shinar, 1993 Kweon & Kockelman, 2006 Colgan et al., 2004
Are more likely to be African American	Pickrell, Choi, & KC 2016 Strine et al., 2010 Price, Dake, Balls-Berry, & Wielinski 2010 Boyd, Kresnow, & Dellinger, 2008 Glassbrenner, 2004 Vivoda et al. 2004
Are more likely to be male	Price, Dake, Balls-Berry, & Wielinski 2010 Pickrell, Choi, & KC 2016 Boyle & Lampkin, 2008 Shinar, Schechtman, & Compton, 2001 Boyd, Kresnow, & Dellinger, 2008
Are more likely to have a higher BMI	Strine et al., 2010 Price, Dake, Balls-Berry, & Wielinski 2010
Are more likely to find seat belts uncomfortable	Boyle & Vanderwolf, 2004
Are more likely to be single	Kweon & Kockelman, 2006 Strine et al., 2010 Boyd, Kresnow, & Dellinger, 2008
Are less likely to perceive no seat belt as unsafe	Boyle & Lampkin, 2008
Are more likely to have a ticket in past year	Kweon & Kockelman, 2006 Schneider et al., 2017
Have higher risk-taking scores	Boyle & Lampkin, 2008 Iverson, 2004
Pickup truck drivers	Boyle & Lampkin, 2008 Kweon & Kockelman, 2006
Are more likely to have fatalistic beliefs	Boyle & Lampkin, 2008 Boyle & Vanderwolf, 2004
Are likely to drink more	Boyle & Lampkin, 2008 Kweon & Kockelman, 2006
Are more likely to drink and drive	Boyd, Kresnow, & Dellinger, 2008

Despite the wealth of knowledge about the factors that influence seat belt use in general, researchers have a narrower understanding of the factors underlying occasional seat belt use. Previous research examining these factors is limited; however, consistent patterns do emerge.

Occasional seat belt users:

1. Report that they are rarely mindful of risk and safety while driving, especially when traveling familiar roads (Bradbard et al., 1998);
2. Are less likely to buckle on short trips or when they drive without passengers (Bradbard et al., 1998; Boyle & Lampkin, 2008; Yates et al., 2011);
3. Are less likely to buckle if the trip involves frequent stops, low-speed driving, or good weather (Bradbard et al.,1998) or if they are in a rush (Boyle & Lampkin, 2008);
4. Are less likely to buckle if there are distractions that prevent belts from being worn, if they are wearing nice clothing, or if the belts are uncomfortable (Bradbard et al., 1998; Boyle & Vanderwolf, 2004; Boyle & Lampkin, 2008).

One limitation of previous seat belt research is that it has relied heavily on observational (e.g., National Occupant Protection Use Survey) and self-report techniques (e.g., MVOSS). Observational techniques are designed to provide snapshots at points in time, so they miss instances in which drivers buckle or unbuckle during trips. In addition, observational studies provide limited information about drivers, typically only characteristics that can be reliably recorded from outside the vehicles. Self-reported techniques can obtain more detailed information about individual factors as well as driver attitudes and beliefs. However, self-reported measures are subject to inaccurate recall (Richard et al., 2015) and socially desirable response biases (Paulhus & Vazire, 2007).

The recent emergence of naturalistic studies of driving behavior provides a way to overcome limitations of observational and self-report data collection techniques. This type of study involves continuously collecting driving behavior data from the same people over time. Once participants enroll in this type of study, they drive as they normally would for extended periods, which yields a rich and comprehensive dataset of driving behaviors, including objectively recorded seat belt use for each trip. These data can be combined with driver-specific demographic, health, and behavioral information collected during participant enrollment.

In 2003 and 2004 NHTSA sponsored a naturalistic driving study (the “100-car” study) that collected video and driving metrics for each trip taken by over 100 drivers in a 12-month period (Dingus et al., 2006). Analysis of these data showed that likelihood of seat belt use by occasional users (defined as those who wore belts 40 to 85% of the recorded trips) on a given trip increased with the average speed during a trip and, to a lesser degree, distance traveled (Reagan, McClafferty, Berlin, & Hankey, 2013). However, due to the small sample size (n = 28 occasional users) and geographic location of the study (Northern Virginia and Washington, DC), interpretation and generalization of these findings are limited.

Another limitation of the seat belt analysis from the 100-car study was that it coded belt use based on a single, mid-trip observation. While this approach works if drivers remain buckled or unbuckled throughout all trips, it does not provide any information about drivers who decide to buckle or unbuckle during trips. Identifying and understanding factors that prompt a driver to change buckle status mid-trip provides insight about what motivates this behavior. Understanding such motivations may be useful in developing countermeasures.

In a different naturalistic driving study, researchers recorded 12 days of driving in an instrumented vehicle from 24 young males who were self-reported "part-time" seat belt users (Yates et al., 2011). For the purpose of the analyses, researchers combined trips in which each driver was buckled for a full trip with those in which each driver was only buckled for part of the trip. This approach precluded examining mid-trip, situational factors that influenced drivers' decisions to buckle or unbuckle, but it provided high-level information about the types of trips in which participants drove fully unbuckled. The analyses indicated that seat belt use was higher for daytime trips, long trips, and trips that included passengers (Yates et al., 2011).

The previous analyses of naturalistic driving data suggest that this approach is effective for gaining insight into the factors associated with occasional seat belt use; however, the data ultimately yield limited information about these factors. The SHRP2 Naturalistic Driving Study (NDS) provides an opportunity to examine occasional seat belt use more fully. This was a comprehensive naturalistic study that collected driving data in six regional sites across the United States. SHRP2 collected data from 3,600 passenger vehicle drivers over 12 to 24 months and generated four types of data files:

1. Naturalistic Trip or NDS Data – NDS data includes vehicle records, such as GPS, speed, driver seat belt status, acceleration, braking, steering, and forward radar, as well as multiple video views of the driving environment and inside the vehicles.
2. Driver Assessment Data - This includes data on each driver's vision, visual-cognitive, cognitive, and physical status collected at the beginning of the driver's participation.
3. Roadway Inventory Data - Detailed roadway data, including lane and road width, road geometry, posted speed limit, and intersection data.
4. Driving Event Data – Detailed descriptions of over 4,000 safety-related driving events including crashes.

The SHRP2 data provide information about driver seat belt use that can be used to determine whether drivers were buckled or unbuckled for the entire trip and whether drivers made a mid-trip decision to change their status. The driver assessment data provides a way to identify driver-specific factors associated with the type of seat belt use. Additionally, the detailed trip data provide a way to identify situational factors associated with seat belt use.

This study was an exploratory investigation of seat belt use in the SHRP2 NDS dataset with a focus on occasional seat belt users. Specific objectives were to (1) identify individual differences that differentiate user groups and (2) identify the impact of *situational* factors in seat belt use patterns of occasional seat belt users.

General Approach

This section provides an overview of the SHRP2 data used in this study. It also describes how the team operationalized seat belt use on a trip and how they divided drivers into different types of seat belt users.

The research team conducted a series of analyses using the SHRP2 seat belt data (see Figure 1). The first step was to categorize all trips based on the percentage of seat belt use recorded on the trip. Researchers aggregated these trip types by driver to classify drivers into seat belt user types based on their proportion of trip types. Statisticians conducted analyses to identify driver-specific and trip-specific predictors of seat belt user types.

Statisticians conducted the remaining analyses using the subset of trips in which drivers buckled or unbuckled partway through the trip (partially unbuckled trips). Analyses of time-series data identified situational predictors of buckled and unbuckled parts of a trip. To obtain more detailed information about situational factors, researchers plotted parts of these trips on street maps and examined vehicle speeds and locations (i.e., at an intersection, on roadway, etc.) where drivers buckled or unbuckled. Finally, research staff examined video recordings of the driver and exterior vehicle views to document additional factors that may have influenced driver decisions to buckle or unbuckle (e.g., passing a police vehicle or picking up a passenger).

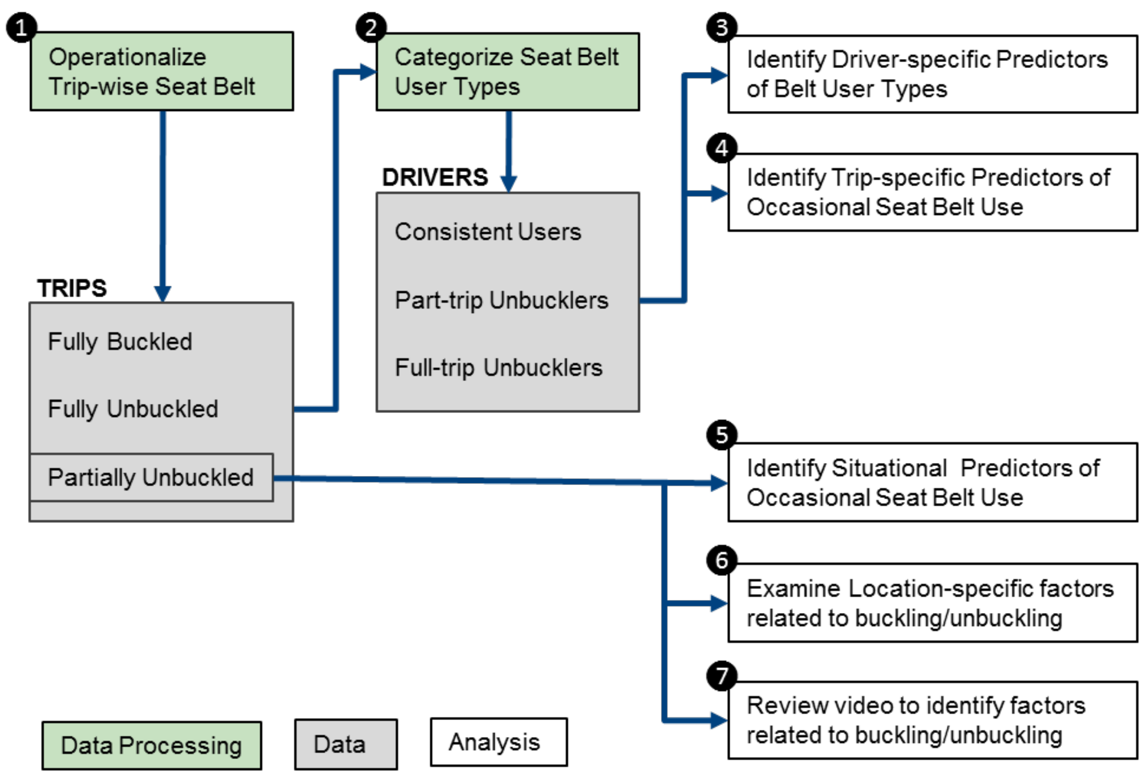

Figure 1. Overview of belt use data and corresponding analyses.

Description of the Data

SHRP2 includes multiple datasets that provide information about drivers and trips. The research team conducted different analyses on the datasets to obtain multiple perspectives on driver seat belt use behavior. Table 5 describes how the research team used the key SHRP2 data sets.

Table 5. Descriptions of the SHRP2 data types used in the various analyses.

Data Type	Description	Role in Analyses
Trip Summary Data	Summary characteristics of individual trips, including percentage of seat belt use calculated for each trip	- Identifying trips with seat belt use - Measuring seat belt use within a trip - Analysis of general situational factors
Driver Assessment Data	Participant answers to a battery of cognitive, health, and behavioral questionnaires from drivers who were primary participants[1]	- Analysis of driver-specific factors associated with seat belt use type
Trip Time-Series Data	1-Hz time-series records of vehicle variables, including vehicle speed and seat belt status	- Identifying situational factors that affect buckling decision within trips
Video Data	Video recordings of the driver and exterior-facing view from trips in which drivers buckled or unbuckled partway through a trip	- Coding additional factors that affect buckling decision within trips

The "Percent Seat Belt Use" variable from the Trip Summary dataset provided the percentage of the trip in which the data collection equipment recorded that the seat belts were buckled. Coders defined a trip as beginning when the vehicle began moving; time spent with the ignition on before the vehicle moved (e.g., idling) was not included in the calculation.

The complete SHRP2 dataset contains 5.4 million trips collected from 3,492 participants. However, due to equipment-vehicle compatibility issues, seat belt data recorded continuously by sensors were only available for a subset of participant vehicles in which the data-collection equipment could properly decode seat belt status from the vehicle's computer network. This subset of "network vehicle" data included 1,252,304 trips from 879 drivers. The analyses in this study only include data collected from participants who drove these network vehicles. Within this subset of trip data, the average percentage of seat belt use across trips was 95%, and the average trip distance was 7.4 miles.

Comparisons indicated significant differences between network-vehicle participants and the rest of the SHRP2 driver sample that limit the generalizability of the findings. (Appendix A provides further details about this analysis.) However, given the exploratory nature of this research, the findings still provide useful insight regarding factors that affect seat belt use behavior.

Data limitations

Data quality is a key limitation in this analysis. The primary belt-use measure is aggregated sensor data that has not been independently validated within the SHRP2 study sample. In particular, seat belt sensor malfunctions can produce records that indicate less than full time use

[1] Data were also collected from consenting secondary participants who were typically family members or others who regularly drove the primary participant's vehicle. Driver assessment data was unavailable for most secondary drivers.

even if the driver is buckled the entire trip. In addition, driver efforts to circumvent in-vehicle seat belt alarms would also yield inaccurate data since trips where driver were unbelted or improperly belted would be falsely recorded as being belted the entire time. Under these conditions, the amount of partial or non-use of seat belts would be overestimated for certain drivers.

Belt Use

A unique aspect of the SHRP2 seat belt data is that belt use was continuously recorded throughout each trip. In contrast, previous studies have gauged seat belt use based on a single observation taken at one point during a trip (Reagan et al., 2013). Therefore, a key advantage of the SHRP2 data is the ability to identify trips in which drivers were buckled for only part of a trip. The three types of trips based on belt use were:

- Full-trip buckled,
- Part-trip unbuckled (drivers buckle or unbuckle partway through the trip), and
- Full-trip unbuckled.

The primary challenge in defining the boundaries for the trip types is that fully buckled trips might not always appear as 100% seat belt use because of sensor fluctuations or behavioral aspects such as drivers not buckling until they enter the roadway. Likewise, fully unbuckled trips may not show up as 0% buckled for similar reasons. To identify reasonable boundaries between the three trip categories, researchers used multiple approaches to examine the distribution of the Percent Seat Belt Use measure across all trips.

Figure 2 below shows the distribution of percentage belt use across all trips. The distribution is bi-modal with separate peaks at less than 5% and greater than 95%. These two boundaries became the thresholds for defining trips as fully unbuckled (<5%) and full buckled (>95%). The remaining trips that fell in between these boundaries were defined as part-trip unbuckled. Table 6 below shows the frequency of the three trip types aggregated across all drivers.

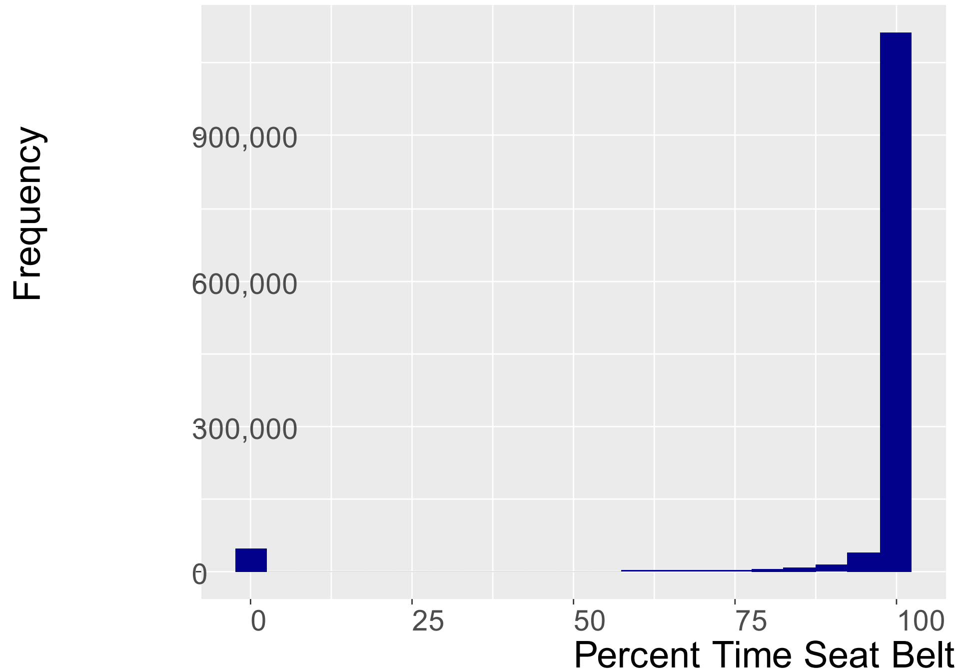

Figure 2. Frequency of percentage of a trip that the seat belt was recorded as engaged.

Table 6. Frequency and percentage of fully buckled, partially buckled, and fully unbuckled trips.

	Fully Buckled	**Partially Buckled**	**Fully Unbuckled**
N	1,140,793	62,537	48,974
%	91%	5%	4%

Seat Belt User Types

This section describes analyses that parsed drivers based on seat belt use.

In a previous investigation of occasional seat belt use, Reagan et al. (2012) used a blocking approach to divide drivers into groups based on their average seat belt use rates across trips. As noted above, they sorted drivers by percentage of trips in which drivers were belted during a single observation. The authors selected boundaries between driver types that maximized within-group homogeneity and minimized between-group heterogeneity. Figure 3 illustrates this approach using the SHRP2 data. The dashed lines indicate the category breakpoints selected by Reagan's group.

Over 70% of drivers were fully buckled on at least 95% of their trips, and 9% of all drivers never drove unbuckled. The 70% number is notably lower than the 88.5% estimates that come from national estimates of seat belt use (Pickrell & Li, 2016). One explanation for this difference could be that the observational studies may under-sample the types of trips that occasional belt users typically drove unbuckled (e.g., shorter local trips). Analyses in later chapters examine the importance of situational factors in occasional seat belt use. All but a few people used a seat belt at least some of the time; even the least compliant drivers were motivated to wear seat belts on some trips.

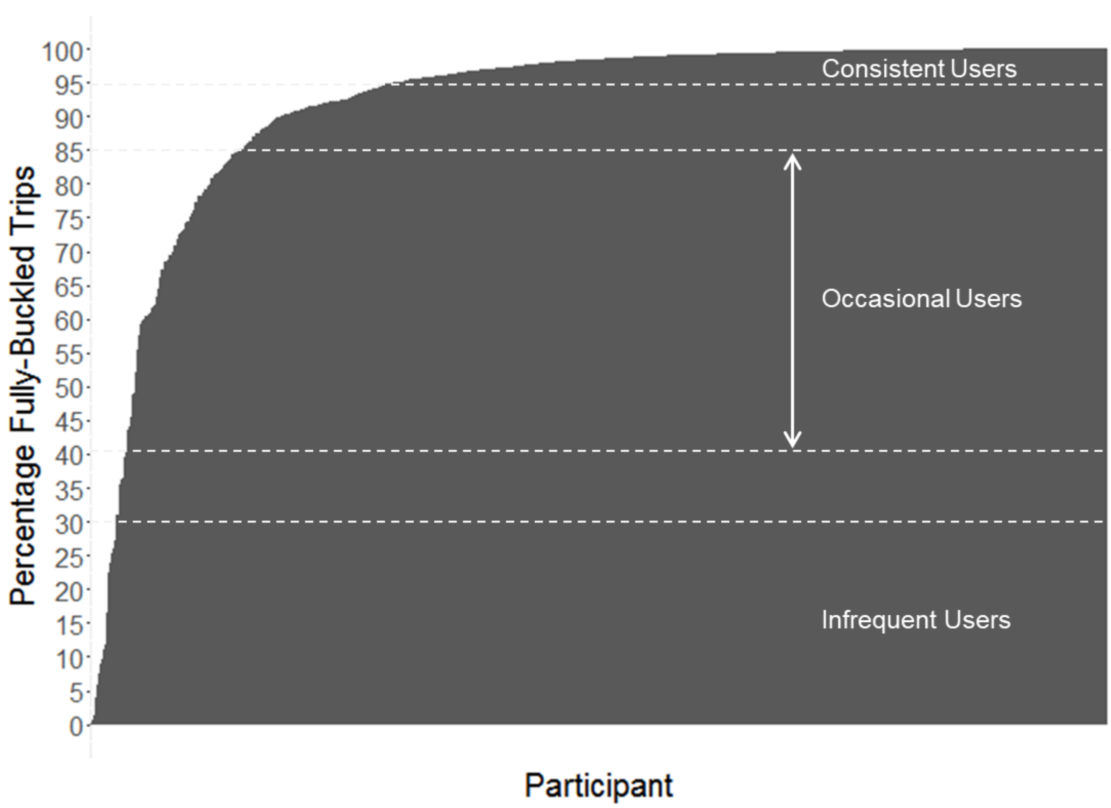

Figure 3. Seat belt use rates across all participants in the sample ordered by percentage of fully buckled trips. Belt user labels are from Reagan et al., 2012.

A limitation of the approach shown in Figure 3 as applied to the SHRP2 data is that the distribution is relatively continuous and lacks obvious "steps" or break-points to clearly demark belt user types. Moreover, the SHRP2 data set provided a richer set of variables, including records of continuous seat belt use, which permitted the research team to consider additional factors in developing the seat belt user typology. Thus, researchers used a different approach to group SHRP2 drivers into seat belt user types.

Defining the Seat Belt User Typology

Researchers developed an initial set of categories by visually inspecting the proportion of fully buckled, part-trip unbuckled, and unbuckled trips across drivers. For the subset of drivers who were unbuckled for parts of a trip, researchers created growth curves to examine trip-level seat belt use within the various categories as a function of time. From both approaches, researchers found four recurring patterns:

A. Drivers who were fully buckled on all their trips

B. Drivers who were fully buckled on almost all their trips

C. Occasional users whose unbelted trips generally fell in the middle belt use categories, suggesting buckling/unbuckling mid-trip

D. Occasional users for whom fully unbuckled trips were more common than part-trip unbuckled trips, suggesting a pre-trip decision on belt use

Groups A and B represent essentially the same type driver in terms of overall behaviors and high belt use overall. Researchers combined these two groups into a singular "consistent belt user" group for most of the analyses in the current study. However, they retained the distinction between groups A and B to explore whether any systematic factors prompted some consistent belt users to drive unbelted in certain situations. Since the group B drivers were already willing seat belt users, focused safety messages could convert these drivers to consistent users.

The research team used the 25th percentile value as the threshold to define the boundary between consistent seat belt users (A and B) and occasional seat belt users (C and D). Seat belt use rates were smoothly distributed across this level and there were no logical break points based on the data alone. The 25th percentile value, in which a driver was fully buckled on 99.1% of their trips, generally coincided with the minimal practical number of non-fully buckled trips that could be included in analyses (median = 35 trips/year). Consequently, drivers in the upper end of the C and D ranges likely shared many characteristics in common with consistent belt users.

Although they represented different behaviors, the seat belt use patterns among drivers in groups C and D lacked clear demarcations, so the statisticians used a cluster analysis to parse the C and D drivers into groups. Specifically, statisticians used Ward's hierarchical clustering technique method to group drivers based on the following variables:

- Percentage of trips in which the driver was buckled part, but not all, of the time (% part-trip unbuckled)
- Percentage of fully buckled trips (% trips buckled)

- Percentage of fully unbuckled trips (% trips unbuckled)
- Average seat belt use time across all trips for each driver (mean belt time)
- Standard deviation of trip seat belt use time (standard belt time)

Statisticians chose five C and D clusters by process of elimination. Using only four clusters resulted in an inhomogeneous cluster in which some drivers always buckled and some did not, while using six clusters resulted in groups with very small sample sizes.

Key variables for the clustering were % Trips Buckled and % Part-Trip Unbuckled. The latter measure differentiated drivers based on whether they tended to make a pre-trip decision about belt use (thus having a smaller relative proportion of part-time unbuckled trips) or to decide partway through the trip (thus having a larger relative portion of part-time unbuckled trips). Typically, part-trip unbuckled drivers are in cluster C, and typically full-trip unbuckled drivers are in cluster D. That is, group D drivers usually remained either fully buckled or unbuckled for the entire trip but had a smaller portion of fully buckled trips than groups A and B. The clustering algorithm further broke down C into two clusters (C1 and C2) and D into three clusters (D1, D2, and D3) based on the percentage of fully buckled trips. Most drivers in Groups C and D drove fully buckled at on at least 90% of their trips. Groups C2, D2, and D3 had the lowest percentages of fully buckled trips.

Table 7 shows the number of drivers in each group and organizes the groups based on the frequency of unbuckled trips and seat belt use type. Part-trip unbucklers (group C) were substantially more common than full-trip unbucklers (group D).

Table 7. Number of drivers in each type of seat belt use group.

		Seat Belt Use Type	
	Frequency of Unbuckled Trips	*Mostly Part-Trip Unbucklers (N, %)*	*Mostly Full-Trip Unbucklers (N, %)*
Consistent Seat Belt Users	*Never*	A (82, 9.3%)	
	Almost Never	B (274, 31.2%)	
Occasional Seat Belt Users	*Rarely*	C1 (288, 32,8%)	D1 (99, 11.3%)
	Occasionally	C2 (80, 9.1%)	D2 (43, 4.9%)
	Frequently	---	D3 (13, 1.5%)

Figure 4 shows the percentage of partially buckled trips by the percentage of fully unbuckled trips for all drivers. The colors of the points denote seat belt user type. The points in the graph are concentrated near the origin, which indicates that most drivers used seat belts for the entirety of most, if not all, of their trips. This certainly holds for Groups A and B, but even the drivers in groups C1 and D1 are concentrated in the region representing greater than 90% seat belt use.

Groups C2 and D2/D3 provide the clearest examples of occasional belt users. There are several notable patterns across these groups.

- Most drivers in groups C2 and D2/D3 engaged in both part-trip unbuckled and fully unbuckled types of non-seat belt use.

- Four drivers in group D3 almost never wore seat belts.
- A moderate proportion of drivers in Group C2 only engaged in part-trip unbuckling and did not take any full-trip unbuckled trips (points located along the y-axis). A few drivers in Group D2 show the reverse pattern (no part-trip unbuckling), but they encompass a relatively smaller proportion of the D2 drivers.

The distribution of data points from groups C and D indicates that occasional seat belt users comprised different seat belt user types. The data also confirm that drivers regularly made different types of seat belt wearing decisions (i.e., pre-trip and mid-trip). Occasional seat belt users also differed widely in terms of the frequency with which they drove unbelted.

The research team used the categories described in Table 7 for the remaining analyses although some categories were combined for specific analyses. The definition of consistent and occasional seat belt users in the current study differs from the Reagan et al., (2012) study. The research team for the current study did not exclude more frequent occasional seat belt users (C1 and D1) even though these two groups have been considered consistent users in most analyses. Another difference is that the current study retained some of the drivers at the low-use end of the occasional use range. The few complete non-users were excluded, but the remainder were retained because they used seat belts at least some of the time, and understanding the factors that caused these infrequent users to buckle up may provide insight about factors that may change their behavior.

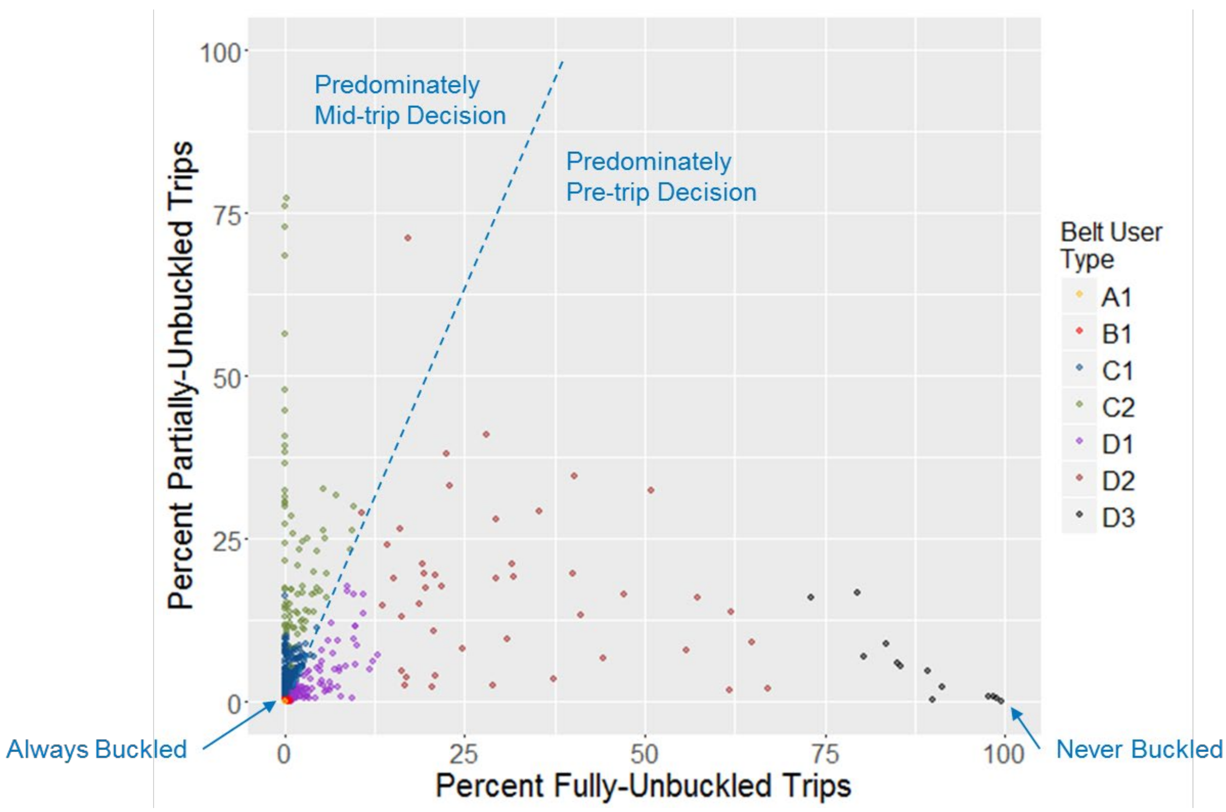

Figure 4. Scatterplot showing distribution of individual drivers in each seat belt use group based on percentage of partially unbuckled trips and percentage of full-unbuckled trips.

Figure 5 below shows the same ordinal ranking of drivers by percentage of fully buckled trips as in Figure 3. The difference is that participants are color-coded by seat belt user type.

Drivers from groups A and B who were always or almost ways buckled form solid blocks of drivers at the high end of the percentage of fully buckled trips. The group with the next highest percentage of belt use is C1; however, these drivers are interspersed with drivers from the D1 group. Most of these drivers were fully buckled on at least 90% of their trips. Below this level, the percentage of fully buckled trips varies greatly. Drivers in the C2 group comprise the group next highest level of belt use, while drivers in groups D2 and D3 cluster at the bottom end of this scale, ranging from below 10% to 35% of trips fully buckled.

A clearly discernable pattern is the interspersing of drivers from different groups within most of the C and D range. This suggests that the multidimensional approach for grouping drivers in the cluster analysis picks up differences across groups that are lost with a simpler unidimensional ranking of drivers based on observed belt use across trips. Figure 5 also shows that Group C2 corresponds most closely to the occasional belt user group in Reagan et al., (2012), which ranges from 30 to 80% observed seat belt use. This range also includes drivers from groups D2 and D3 at the lower end.

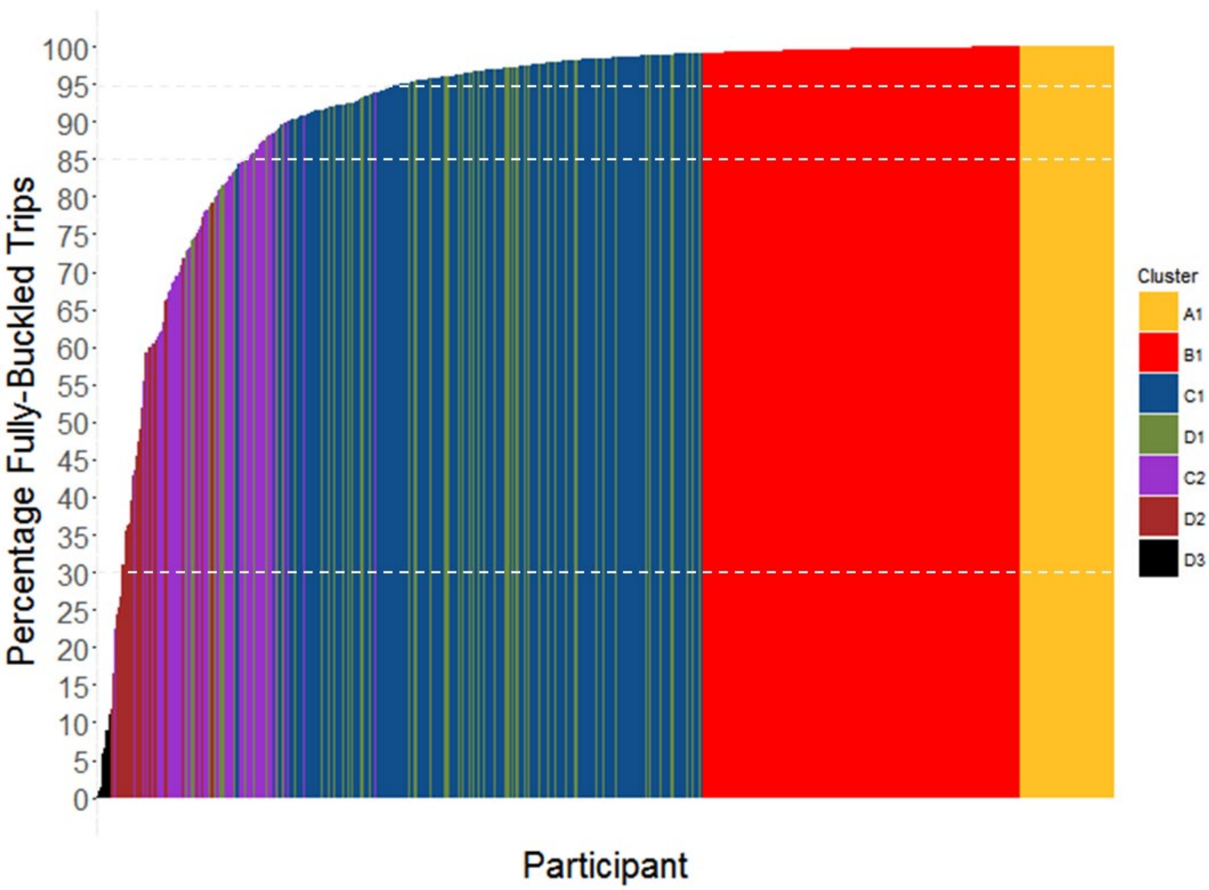

Figure 5. Seat belt use rates across all participants in the sample ordered by percentage of fully buckled trips and color coded by seat belt user type.

Characteristics of Seat Belt User Types

This section describes driver characteristics associated with the different seat belt user groups. The predictors in the analyses included responses to driver assessment questions and instruments that participants completed during the enrollment process. Since there are over 1,000 driver assessment measures available, the research team focused on summary measures that represented groups of questions (e.g., overall scale scores). A complete list of assessment variables is available on the SHRP2 data portal (www.insight.shrp2nds.us).

Demographic Factors

Table 8 below shows the distribution (counts and percentages) of driver characteristics across the primary seat belt user types. The consistent seat belt users represented by groups A and B were combined. In addition, since there were so few drivers in group D3, this group was combined with group D2, whose drivers were the most similar. Chi-square tests of independence identified variables that showed significant differences across seat belt user type. The research team used an alpha level of 0.05 for all statistical tests. The next chapter describes analyses using a larger set of variables.

Table 8. Distribution of demographic characteristics across seat belt user types.

		Seat Belt User Type					
Factor		*AB*	*C1*	*D1*	*C2*	*D2/3*	Total
Sex	*Female*	215 (44.8%)	141 (29.4%)	60 (12.5%)	38 (7.9%)	26 (5.4%)	480 (100%)
p < 0.01	*Male*	141 (35.4%)	146 (36.7%)	39 (9.8%)	42 (10.6%)	30 (7.5%)	398 (100%)
Age Group	*16-24*	75 (52.4%)	32 (22.4%)	21 (14.7%)	4 (2.8%)	11 (7.7%)	143 (100%)
p < 0.001	*25-39*	94 (45.6%)	63 (30.6%)	25 (12.1%)	13 (6.3%)	11 (5.3%)	206 (100%)
	40-64	107 (38.8%)	103 (37.3%)	20 (7.2%)	33 (12.0%)	13 (4.7%)	276 (100%)
	65+	80 (31.5%)	90 (35.4%)	33 (13.0%)	30 (11.8%)	21 (8.3%)	254 (100%)
Marital Status	*Married*	188 (36.9%)	197 (38.7%)	52 (10.2%)	45 (8.8%)	27 (5.3%)	509 (100%)
p < 0.01	*Other*	55 (40.1%)	42 (30.7%)	17 (12.4%)	14 (10.2%)	9 (6.6%)	137 (100%)
	Single	111 (48.9%)	49 (21.6%)	30 (13.2%)	18 (7.9%)	19 (8.4%)	227 (100%)
Education	*Less than Coll.*	109 (37.5%)	99 (34.0%)	35 (12.0%)	28 (9.6%)	20 (6.9%)	291 (100%)
p > 0.05 (NS)	*Graduate/Adv.*	132 (42.7%)	102 (33.0%)	30 (9.7%)	26 (8.4%)	19 (6.1%)	309 (100%)
	College	114 (41.5%)	86 (31.3%)	33 (12.0%)	26 (9.5%)	16 (5.8%)	275 (100%)
Income	Under $50K	98 (38.7%)	75 (29.6%)	32 (12.6%)	30 (11.9%)	18 (7.1%)	253 (100%)
p > 0.05 (NS)	$50K to $100K	122 (37.2%)	114 (34.8%)	40 (12.2%)	29 (8.8%)	23 (7.0%)	328 (100%)
	Over $100K	110 (44.7%)	87 (35.4%)	20 (8.1%)	17 (6.9%)	12 (4.9%)	246 (100%)
BMI	*Normal & Under*	131 (48.9%)	79 (29.5%)	24 (9.0%)	21 (7.8%)	13 (4.9%)	268 (100%)
p > 0.05 (NS)	*Overweight*	102 (36.4%)	98 (35.0%)	34 (12.1%)	30 (10.7%)	16 (5.7%)	280 (100%)
	Obese	86 (36.3%)	76 (32.1%)	32 (13.5%)	24 (10.1%)	19 (8.0%)	237 (100%)

Notes: The results for Chi-square tests of independence are shown below each variable name.

The key trends across the demographic variables included:

- *Sex*: Females were more likely than males to be consistent belt users (A and B), and the lowest belt user groups included a higher proportion of males (C2 and D2/3).
- *Age*: Belt use became less consistent as age increased.
- *Marital Status*: Single drivers were most likely to be consistent seat belt users (AB), followed by drivers with “Other” status, which included those divorced and widowed. Married drivers had the lowest proportion of consistent seat belt users.
- *Education*: Belt use type did not differ significantly across education levels.
- *Income*: Belt use type did not differ significantly across income levels.
- *BMI*: Belt use type did not differ significantly across levels of the drivers’ body mass indices.

At a high level, the trends regarding the demographic variables are consistent with those from previous studies and listed in Table 4. The one major exception was marital status. Previous reported being single as associated with lower levels of seat belt use; however, the opposite appeared in the current study. One factor that likely contributes to this pattern is the higher rate of seat belt use among younger study participants, who were also likely to be single. Other departures from previous research include the absence of major seat belt use differences across education and income. This could result from the subset of SHRP2 drivers that had continuous seat belt data (i.e., network vehicles analyzed in this study) generally having higher income and education levels than the rest of the SHRP2 driver sample.

Analysis of Driver-Specific Factors

To understand the factors related to different seat belt user types, statisticians analyzed the association between driver-level measurements and the cluster assignments. Statisticians built statistical and machine learning models to make two key binary comparisons:

1. Consistent seat belt users (A and B) versus occasional seat belt users (C2 and D2/3), and
2. Among the occasional seat belt users; typically, part-trip unbuckled drivers (cluster C) versus typically full-trip unbuckled drivers (cluster D).

In the first analyses, statisticians excluded drivers from groups C1 and D1 because most drivers in these groups used seat belts on over 90% of their trips. Thus, excluding these two groups provides a starker contrast between consistent seat belt users and those who more frequently drive unbelted. However, in the second comparison, groups C1 and D1 were included because of the small sample sizes of just the C2 and D2/3 groups.

Four statistical and machine learning methods assessed the relationship of driver-specific factors on seat belt use (see Table 9). Each model has strengths and weaknesses, and therefore they provide a more complete and reliable picture when considered together. Statisticians ran appropriate tests of statistical significance at the 0.05 level for contingency tables and logistic regressions to determine which factors were significant on their own. Researchers also ran Least Absolute Shrinkage and Selection Operator (LASSO) and Random Forests machine learning models. The LASSO method helped determine the variables for a logistic regression model. The algorithm selects the variables that are the strongest predictors to help reduce over-fitting the model. Random Forests can create complex models of the response variable, including automatically finding non-linearities and interactions. The algorithm also determines the most important variables by adding additional randomness to the variables in the model and observing which perturbations cause the predictions to degrade the most. Statisticians analyzed results from six methods to find common trends.

Table 9. Characteristics of analytical techniques to examine driver-specific predictors of seat belt use

	Contingency Tables	**Logistic Regression**	**LASSO**	**Random Forest**
Categorical Variables	x	x	x	x
Continuous Variables		x	x	x
Easily Interpretable Coefficients		x	x	
Non-linear Relationships and Interactions				x

Comparison of Consistent and Occasional Seat Belt User Types

Statisticians conducted the first analysis of driver characteristics by comparing consistent seat belt users (groups A and B) to those that represented the most frequent occasional seat belt users (C2 and D2/D3). Table 10 below shows the results from the modeling analyses. The covariates that have an asterisk, plus sign, or negative sign were significant or important in the given model. Plus (+) and minus (-) signs indicate positive and negative relationships, respectively. An asterisk (*) indicates that the variable was statistically significant at the 0.05 level but that there is no interpretable direction in the categorical variable or there was a non-linear fit.

The final column of the tables includes an interpretation of the relationship for covariates that show a strong relationship with buckling behavior. Note that the research team used descriptive statistics to interpret predictors that could not be interpreted directly from the covariates. The table lists an interpretation if the predictor was significant in at least two different models.

Several of the significant patterns shown in Table 10 are consistent with trends from other studies. In particular, previous research has shown that factors such as older age, being male, having more traffic violations, perceiving driving unbelted as less risky, and having a higher BMI were associated with driving unbuckled on some or all trips (See Table 4). In addition, drivers who believed that driving without a seat belt posed a greater safety risk were also more likely to be consistent seat belt users. Finding the same basic patterns as previous studies provides validation that the sample in the current study has characteristics that overlap with the general driving population.

Table 10. Summary of driver models built to identify factors that predict consistent (groups A/B) versus occasional seat belt use (groups C2/D2/D3). See text for description of symbols.

Predictor	Chi-Square	Logistic Regression	Random Forest	LASSO	Compared to regular seat belt users, occasional seat belt users:
Weekday	*			*	
AnnualMiles		+			
AgeGroup	*	+	+		Are more likely to be 40 years old or older
Sex	*	*	*		Are more likely to be male
BMI		+	+		Are more likely to be overweight
MaritalStatus	*		*	*	Are more likely to be single
Income					
NumViolations	*	+		+	Have greater number of traffic violations
NoBelt_Is_Risky	*	*		-	Are less likely to perceive no seat belt as unsafe
RiskTakingScore	*		*		Are more likely to report engaging in risky driving behaviors
DrivingKnowledge	*	-		-	Have lower scores on a basic driving knowledge test
ClockDrawing	*		+	+	Have worse clock-drawing scores
ADHD_Confidence	*	+	+	*	Have higher ADHD confidence score
VisualAcuity		-			
Sensation Seeking					
SS_Disinhibition				+	
SS_ThrillSeeking				+	
BarkleyScore				+	
Left_Hand_Strength				-	
ShiftWork				*	
LifeStress				-	

Some significant predictors in the current study have not previously been examined in the context of seat belt use. Lower scores on a driving knowledge test comprised of common driver licensing questions and worse performance on clock-drawing scores predicted occasional seat belt use. These factors could be related to driver age or cognitive capabilities, but there is insufficient supplementary information to identify clear patterns. Higher ADHD confidence scores, which indicate potential symptoms of ADHD in adults, were also associated with occasional seat belt use. This factor has not been examined as a predictor of seat belt use, so it may warrant further attention in future studies.

The Reagan et al. (2012) investigation of occasional seat belt use did not find significant differences across the demographic factor examined. This is likely due to a small sample, particularly since the number of participants was inadequate to support testing several conditions. However, the study did find that occasional seat belt users scored higher on the Driver Stress Index (DSI) Aggressive Driving Scale, which measures drivers' attitudes and tendencies regarding thrill seeking, aggression, dislike of driving, fatigue proneness, and hazard monitoring (Matthews et al., 1997).

Table 11 shows results of modeling to identify predictors of the two types of occasional seat belt users in the current study. To increase the statistical power, the models included all group C drivers combined (part-trip unbuckled) and all group D drivers (full trip unbuckled) combined respectively.

Table 11. Summary of driver models built to identify factors that predict consistent type of occasional seat belt user: part-trip unbuckling (groups C1/C2) versus full-trip unbuckling (groups D1/D2/D3). See text for description of symbols.

Predictor	Chi-Square	Logistic Regression	Random Forest	LASSO	Among occasional seat belt users, drivers who typically are full-trip unbuckled:
Weekday				*	
AnnualMiles					
AgeGroup	*	-	*	-	Greater proportion of ages 16-24 and smaller proportion of ages 40-64
Sex					
BMI				+	
MaritalStatus	*	*	*		Are more likely to be single
Income				*	
NumViolations	*	+	+	+	Have greater number of traffic violations
NoBelt_Is_Risky					
RiskTakingScore	*	+	*		Have higher risk-taking scores
DrivingKnowledge	*			-	
ClockDrawing			+	+	Have worse clock-drawing scores
ADHD_Confidence				*	
VisualAcuity				*	
Sensation Seeking		+	+	*	Have higher sensation seeking scores
SS_Disinhibition		+	+	+	Have higher disinhibition scores
SS_ThrillSeeking		+	+	+	Have higher thrill-seeking scores
BarkleyScore				+	
Left_Hand_Strength	*	-	-	-	Have lower left-hand strength
ShiftWork			*	*	Are more likely to work evening or night shifts
LifeStress				*	

Age was a predictor for some ranges; the full-trip unbuckled group had a greater proportion of drivers 16 to 24 years old and smaller proportion of those 40 to 64. Some of the other predictors of full-trip unbuckling are typically associated with younger people, such as being single, and greater risk-taking and sensation-seeking. However, other significant predictors are typically associated with older people, such as worse clock-drawing scores and lower left-hand strength. Drivers who had engaged in more full-trip unbuckling also tended to have a higher number of violations and were more likely to work evening or night shifts.

Self-Reported Seat Belt Use

The continuous seat belt use data provides unique information that has not previously been available for examining seat belt use patterns. It provides an objective record of driver behavior that is unavailable through observational studies. Previously, researchers used self-report data to obtain this type of information. The SHRP2 driver assessment battery included a self-reported seat belt use question, which provided a unique opportunity to examine the accuracy of self-reported seat belt use.

Figure 6 below shows self-reported seat belt use as a function of actual seat belt use (i.e., percentage of fully buckled trips), with the data points coded by seat belt user type. The response scale ranged from “never” drive unbuckled to “often” drive unbuckled. Only three drivers (one each from groups AB, C2, & D2/3) reported “often” driving unbuckled, so these responses were combined with the “sometimes” drive unbuckled responses.

The distribution indicates that occasional seat belt users tended to underestimate the frequency of driving unbuckled. Most drivers reported “Never” driving without a seat belt; however, a substantial proportion of those drivers had less than 100% of their SHRP2 trips as fully buckled. This pattern suggests that many drivers responded in a socially desirable manner, which is implicit acknowledgment that they understand that driving unbuckled runs against social norms (e.g., Paulhus & Vazire, 2007). The “NA” category contains the seat belt use percentages of drivers who did not provide an answer to the self-report question. Although the distribution is similar to the one for the “Never” category, a higher proportion of low belt users declined to answer this question.

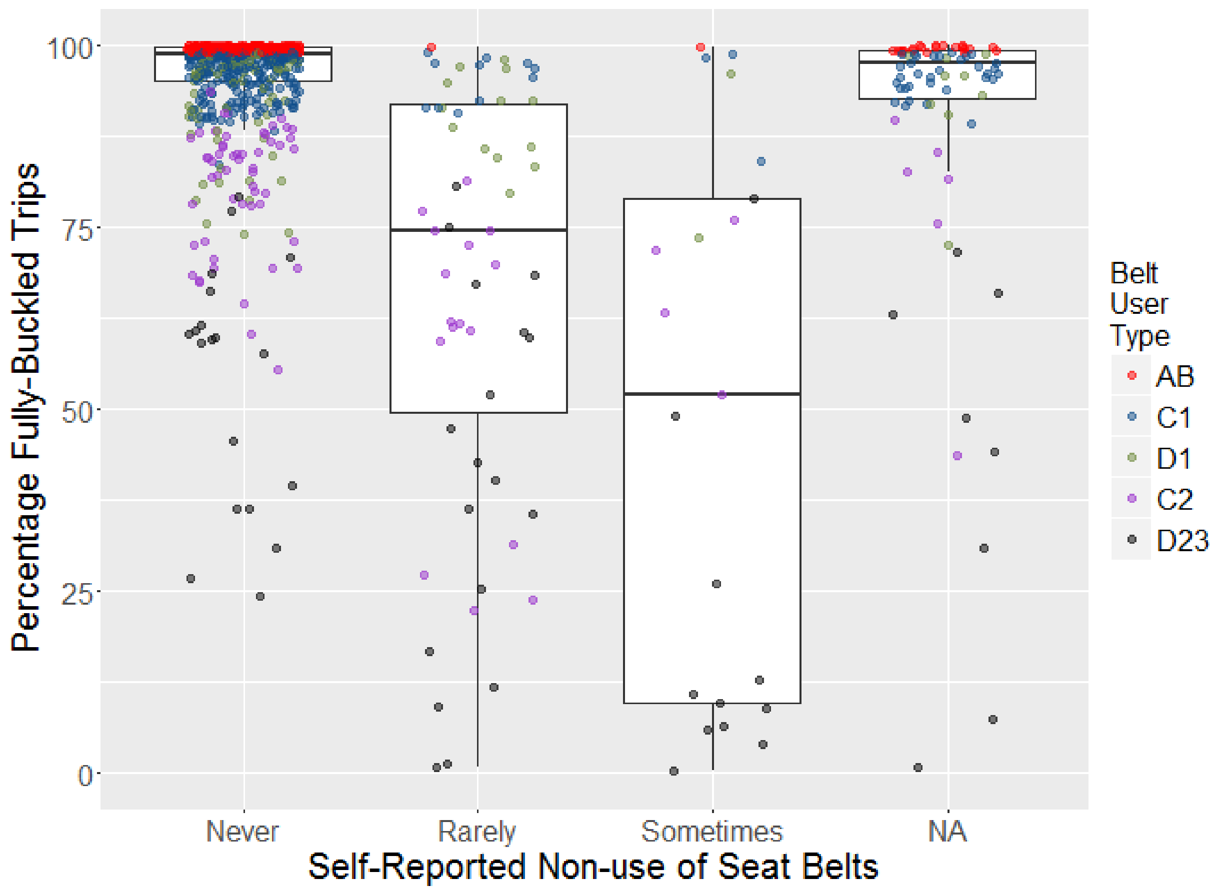

Figure 6. Percentage of fully buckled trips across self-reported frequency of seat belt use for individual drivers, color-coded by seat belt user type.

The analyses of driver-specific predictors in this chapter indicated that the sample displayed many of the same patterns that researchers have found in other seat belt use studies. This appeared despite the sample being restricted to SHRP2 drivers who had newer vehicles. Regarding the research objective of identifying driver-specific predictors of occasional seat belt use, the statistical modeling indicated that multiple factors differentiated drivers who were either primarily part-trip or primarily full-trip unbucklers. However, these driver-specific factors represent only one element of occasional seat belt use. The other key aspect involved situational factors about a trip or immediate driving conditions that may influence driver seat belt decisions. The next section explores these factors.

Situational Factors Associated With Occasional Seat Belt Use

This section describes systematic differences in the trips taken by drivers in the different seat belt use groups. The issue of occasional seat belt use highlights the notion that drivers are not governed by a simple internal behavior "policy" to either use or not use seat belts (i.e., Yates et al., 2011). In the current driver sample, 30% of drivers were neither consistent seat belt users nor non-users. Rather, most of these drivers seemed to decide to buckle or unbuckle at the trip outset or partway through the trip. Thus, certain situational factors must be influencing these driver decisions.

These situational factors are the focus of the current chapter, and particularly, the trip-wide and immediate situational aspects that may mediate driver decisions. The analyses in this chapter addressed the second research objective:

Do situational aspects before or during a trip affect belt-use decisions?

The research team used three approaches to investigate this question. First, they examined the trip summary data to identify trip-wide difference between the three types of seat belt use trips (fully buckled, partially unbuckled, fully unbuckled). Next, they focused on situational factors within trips. They divided partially buckled trips into buckled and unbuckled driving epochs and compared the two types of epochs to identify factors associated with buckled driving. Finally, they examined immediate driving conditions during the 30 seconds before and 30 seconds after a participant buckled/unbuckled. These three approaches examined situational factors across a range of levels, and it covered both pre-trip seat belt use decisions and factors that may have influenced mid-trip decisions.

Trip-wide Predictors of Seat Belt Use

Previous examinations of trip characteristics identified trip duration and average trip speed as factors associated with likelihood of seat belt use by occasional seat belt users (Reagan et al., 2012; Yates et al., 2011). In addition, Yates et al., (2011) found that occasional seat belt users were more likely to use seat belts on daytime than on nighttime trips.

The trip summary records in the SHRP2 dataset provided a way analyze the influence of these trip characteristics on seat belt use. Trip Summary records provided a single summary measure per trip for key variables such as start hour, duration, and average speed among other variables. In addition, each trip had a belt use type (fully buckled, partially unbuckled, and fully unbuckled) computed in earlier analyses. Over 1.26 million trips were available for the analyses. Table 12 shows the distribution of trip summary records across seat belt user type and trip type.

Table 12. Distribution of buckled, partially buckled, and fully unbuckled trips across the different seat belt user types.

	A	B	C1	C2	D1	D2	D3
Buckled	61,710	426,197	409,603	86,729	121,036	34,203	1,315
Partial	-	1,172	15,307	26,789	4,849	13,344	1,076
Unbuckled	-	5,922	7,117	2,934	5,415	21,705	19,061

Regression analyses examined the relationship between trip type and three trip-level variables, including trip start hour, distance, and average speed. Statisticians only included drivers from groups C and D because the focus was on occasional seat belt users. Participants in groups A and B had too few partially or fully unbuckled trips to analyze.

Separate logistic regression models (generalized linear mixed model) compared the different trip types. The analysis used data from 50,000 randomly selected trips from groups C and D for each comparison. Participant and site were random factors. The comparisons for all variables were statistically significant. Table 13 provides the model estimates and significance levels for trip-summary variables. Partially unbuckled and fully unbuckled trips were shorter and had lower average speeds than fully buckled trips, with fully unbuckled being the shortest and slowest overall. In terms of variable importance, the start hour variable was relatively less significant compared to the distance and average speed variables. The findings for the start hour variable are difficult to interpret and discussed in more detail in the next section. Overall, the high number of cases (i.e., n = 50,000 for each comparison) included in the variable led to a regression model that has enough power to make meaningless differences statistically significant. The next sections discuss the patterns for the three trip variables.

Table 13. Model estimates for the trip type comparisons.

	Fully Buckled vs. Unbuckled	Fully Buckled vs. Partially Unbuckled	Fully Unbuckled vs. Partially Unbuckled
Intercept	-1.89^{***}	-1.56^{***}	0.55^{***}
Distance	-0.07^{***}	-0.03^{***}	-0.07^{***}
Average Speed	-0.08^{***}	-0.03^{***}	-0.05^{***}
Start Hour	-0.01^{*}	-0.01^{**}	-0.01^{***}

$^{*}\ p < .05$, $^{**}\ p < .01$, $^{***}\ p < .001$

Time of Day

Previous research suggests that occasional seat belt users may be more inclined to use seat belts when they perceive a greater risk. One higher-risk situation involves driving at night. Previous research indicates that occasional belt users are more likely to use or report using seat belts at night than during the day (Yates et al., 2011). Although the regression modeling in the previous section indicated that trip start-time was a significant predictor, closer inspection of this variable suggests that the differences across trip type had no practical significance. Figure 7 shows the relative distribution of different types of buckling trips across start hour. Occasional seat belt users did not make proportionately fewer partially buckled or unbuckled trips at night. To the contrary, the reverse trend holds from 8 p.m. to 1 a.m.; however, the differences were trivial, at less than half of one percent.

Figure 7. Differences in the distribution of trip types across trip start hour.

Trip Distance

Figure 8 shows differences in trip distance across trip type for the different seat belt user groups. To simplify the comparison, trips were aggregated within driver, so each driver contributed a single point in each of the fully buckled, partially unbuckled, and fully unbuckled categories. The figure illustrates the trend from the previous regression modeling: trip distances dropped across trip type with fully unbuckled trips representing the shortest trips on average. Another notable pattern is that in the median trip distance on fully unbuckled trips was typically less than a couple miles for all groups except the D2/D3 drivers.[2]

[2] Trip distances are around 0.93 miles (1.5 km) longer on average than what are shown in the graphs because the variable distance removed for privacy-protection reasons are not included in the distance calculations.

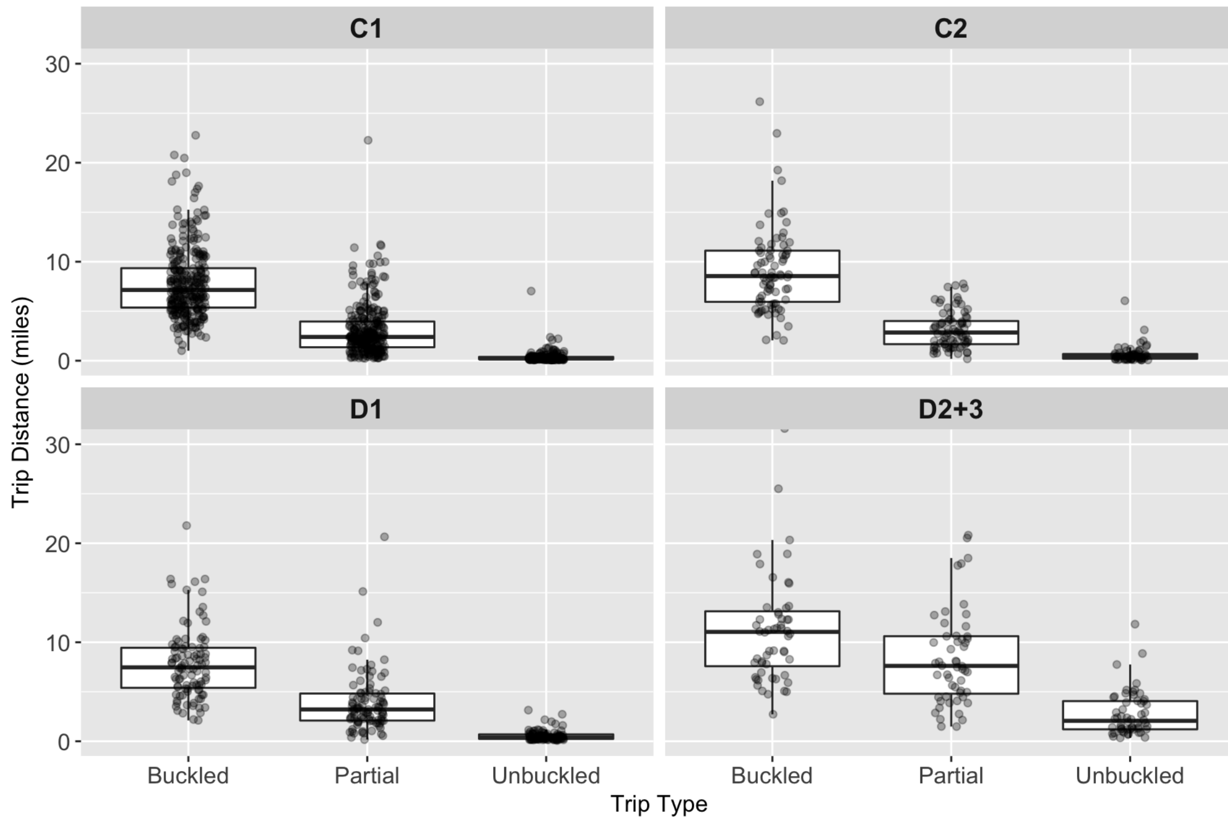

Figure 8. Box plot showing median trip distance for each type of trip by seat belt user type.

Trip Speed

Figure 9 shows average trip speed by trip distance aggregated for each driver. The trip distance calculated for each driver is the same as in Figure 8; however, it is shown as a function of average trip speed. Average speeds were lowest on fully unbuckled trips and highest on fully buckled trips. Note that average trip speed included time when the vehicle was getting up to speed or stopping. This starting and stopping makes up a higher proportion of those trips taken on lower-speed local roads with frequent traffic control devices, so overall speeds appear lower when aggregated.

Fully unbuckled trips were shorter and had lower average speeds for all seat belt user types. Similarly, most drivers tended to be fully buckled on longer trips with higher average speeds. The data patterns support the notion that occasional seat belt users were more likely to drive fully or partially unbuckled on trips they considered low risk—short trips on lower speed roads. However, this pattern was not as strong for drivers in the D2/D3 group, where there is more overlap between partially unbuckled and fully unbuckled trips.

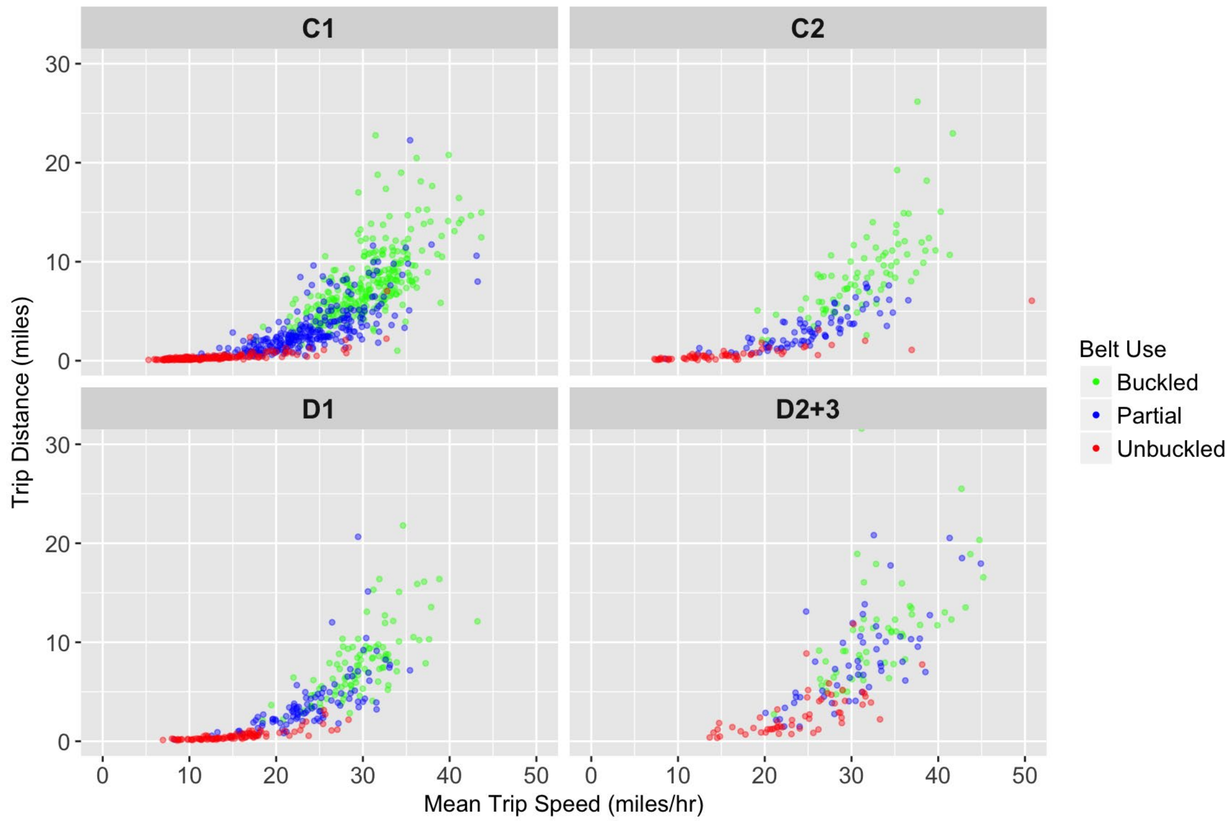

Figure 9. Scatter plot of trip distance and average speed aggregated within drivers from different seat belt user types.

The previous analyses examined factors that were applicable to entire trips. The data patterns regarding fully buckled and fully unbuckled trips can be interpreted in the context of pre-trip decisions. Drivers may have decided on some occasions to not buckle up if they were taking a short trip on lower speed roads. It is more difficult to interpret the data patterns from partially unbuckled trips. Partially unbuckled trips consistently fell in between the other two types of trips in terms of distance and average speed. However, these two characteristics provide no insight as to why drivers were buckling or unbuckling partway through these trips.

Situational Factors Associated With Partial Seat Belt Use Trips

The analyses in this section examined the situational factors that prompted some seat belt users to buckle or unbuckle partway through their trip. Analyses compared the buckled and unbuckled portions of partially unbuckled trips to identify systematic differences in factors that may have motivated seat belt use decisions.

Trip Epoch Data

Statisticians parsed trips into continuous "epochs" of buckled and unbuckled driving. They then calculated summary measures for each epoch within a trip (e.g., duration and average speed), which supported comparisons between buckled and unbuckled epochs from the same trip. Figure 10 illustrates how individual trips were divided into separate epochs depending on whether drivers were buckled or unbuckled. The summary measures were based on 1 Hz time-series recordings from the data acquisition system.

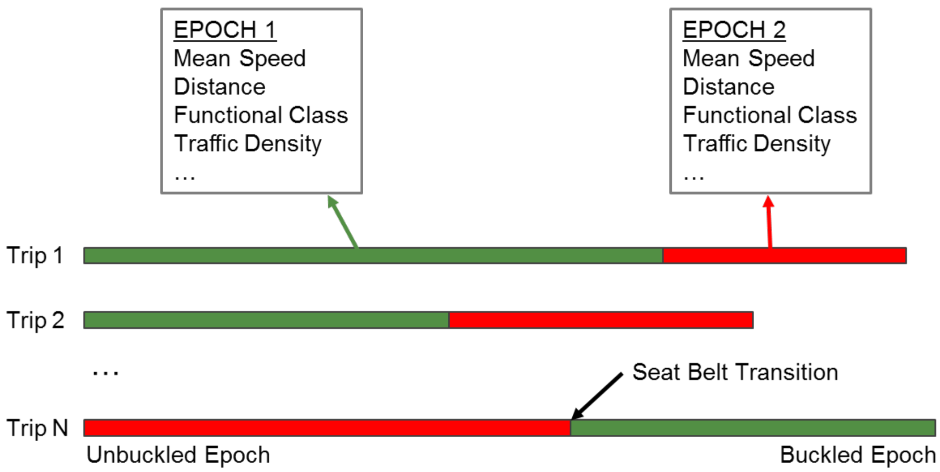

Figure 10. Segmentation of individual trips into unbuckled and buckled epochs.

Statisticians calculated seven summary measures from the time-series variables:

- *Average Speed*: Average speed during the epoch when the vehicle was in motion;
- *Log Duration*: The log of the total duration of the epoch. The positive skew and wide range of durations necessitated the log transformation;
- *Average Traffic Density*: Number of vehicles detected by the radar divided by the sum of their distances to the participant's vehicle in each sample, averaged over the epoch. This was a gross approximation of traffic density based on vehicles in the immediate area;
- *Minimum Functional Class*: The highest capacity roadway traveled during the epoch. This ranged from Interstate freeways (level 1) to residential roads (level 5);
- *Average Lux*: Ambient illumination as measured through the windshield;
- *Headlamp Use*: The percentage of the epoch in which the headlamps were on; and
- *Wiper Use*: The percentage of the epoch in which the wipers were on.

Statisticians conducted this analysis on a subset of partially unbuckled trips. A key limiting factor was that trips needed to have epochs that were long enough to reliably calculate the summary measures. This limitation was further complicated by the need to remove the beginning and end of each trips as a privacy protection measure, which eliminated substantial portions of useable data on shorter, lower-speed trips. The trip selection criteria included the following:

- Trips longer than 3.1 miles (5 km);
- Seat belt use between 25% and 75% so that there were sufficient data in each epoch of a trip;
- Trips could only have a single buckle/unbuckle event (i.e., 2 epochs) to simplify the comparisons and permit analysis of order effects; and
- Individual epochs had to be at least 30 seconds long.

A final concern about the time-series data was the inclusion of trips in which drivers parked their vehicle and unbuckled without turning off the ignition. In this case, the trip would continue even though the unbuckled driver may not even be in the vehicle at the time. To identify these instances, statisticians used the transmission mode variable to identify epochs in which the vehicle was parked. This included 4.0% of unbuckled epochs and 3.4% of buckled epochs. Examining only this subset of epochs, vehicles were in park an average of 54% of the time for unbuckled epochs and an average of 22% of the time for buckled epochs. While it is unlikely that drivers would leave the vehicle while parked when the seat belt was buckled, this is certainly possible during unbuckled epochs. Therefore, statisticians removed trips from the dataset that contained unbuckled epochs with any time with the vehicle in park.

Application of the selection criteria left 1,838 trips that were suitable for analysis.[3] Trips that began with the driver unbuckled were more common (1,588 from 101 drivers) than trips that began with the driver buckled (250 from 62 drivers). Table 14 shows the age and sex counts of the corresponding drivers. While sex was balanced across the sample, older drivers were more frequent than younger drivers. In the oldest age category (65+), males substantially outnumbered females.

Table 14. Age and sex of drivers included in the analyses of seat belt use epochs.

	16-24	25-39	40-64	65+	Total
Females	13	17	17	18	65
Males	8	15	18	27	68
Total	21	32	35	45	133

Analysis of Trip Epochs

Statisticians analyzed how drivers' behaviors changed between the buckled and unbuckled epochs of the trips. They ran mixed effects models with the different time-series variables (i.e.,

[3] All trips from a single outlier driver were removed because this driver took a large number of long, unbelted trips.

average speed, log duration) as the model response. All models included the following fixed effects as covariates:

- *Buckled*: Whether the driver was buckled during the epoch, which was compared to unbuckled epochs;
- *Buckling*: Whether the driver transitioned from unbuckled to buckled during the trip, which was compared to the reverse pattern, going from buckled to unbuckled; and
- *Second Epoch*: The second epoch in a trip, which was compared to the first epoch to capture order effects.

Since there is likely correlation between epochs on the same trip and by the same driver, statisticians included random intercepts for drivers and for trips within drivers, both of which were significant.

Covariates were significant in the models for average speed, log duration, average traffic density, and minimum functional class (see Table 15). Drivers were more likely to be belted during epochs in which they drove at higher speeds, for longer duration, in higher density traffic, and on higher-capacity roads as compared to unbuckled epochs. Trips in which the driver unbuckled during the trip tended to be at higher speed, for a shorter duration, in higher density traffic, and on higher-capacity roads than trips in which the driver started unbuckled and buckled mid-trip. The second epoch in all trips (regardless of whether drivers were buckled or unbuckled) tended to have a lower speed, longer duration, and lower traffic density than the first epoch.

None of the covariates were significant for average lux, headlamp use, and wiper use. Average lux was included to capture situations at night in which a driver may have driven unbuckled in well-lighted areas but buckled in dark unlighted areas. However, there was so little nighttime driving relative to daytime driving that there were probably insufficient cases for this pattern to emerge. Similarly, since weather and lighting conditions were similar for the duration of a trip, instances in which they varied between epochs were probably uncommon.

Table 15. Estimates for regression model covariates for buckled, buckling, and second epochs.

Responses	Intercept	Buckled		Buckling		Second Epoch	
Average Speed	21.22	7.46	***	8.08	***	-3.00	***
Log Duration	2.50	0.08	***	-0.15	***	0.05	***
Average Traffic Density	42.11	8.03	***	6.66	***	-6.08	***
Minimum Functional Class	3.62	-0.38	***	-0.17	***	0.08	*
Average Illumination	414.82	26.74	NS	34.51	NS	2.60	NS
Headlight Use	0.32	0.01	NS	-0.02	NS	0.01	NS
Wiper Use	0.07	0.02	.	0.05	NS	0.00	NS

Figure 11 uses the estimated coefficient values to show the nature of the simple interactions between buckling and unbuckling trips and the order of the epochs. Table 16 that follows, provides an explanation of the interaction patterns.

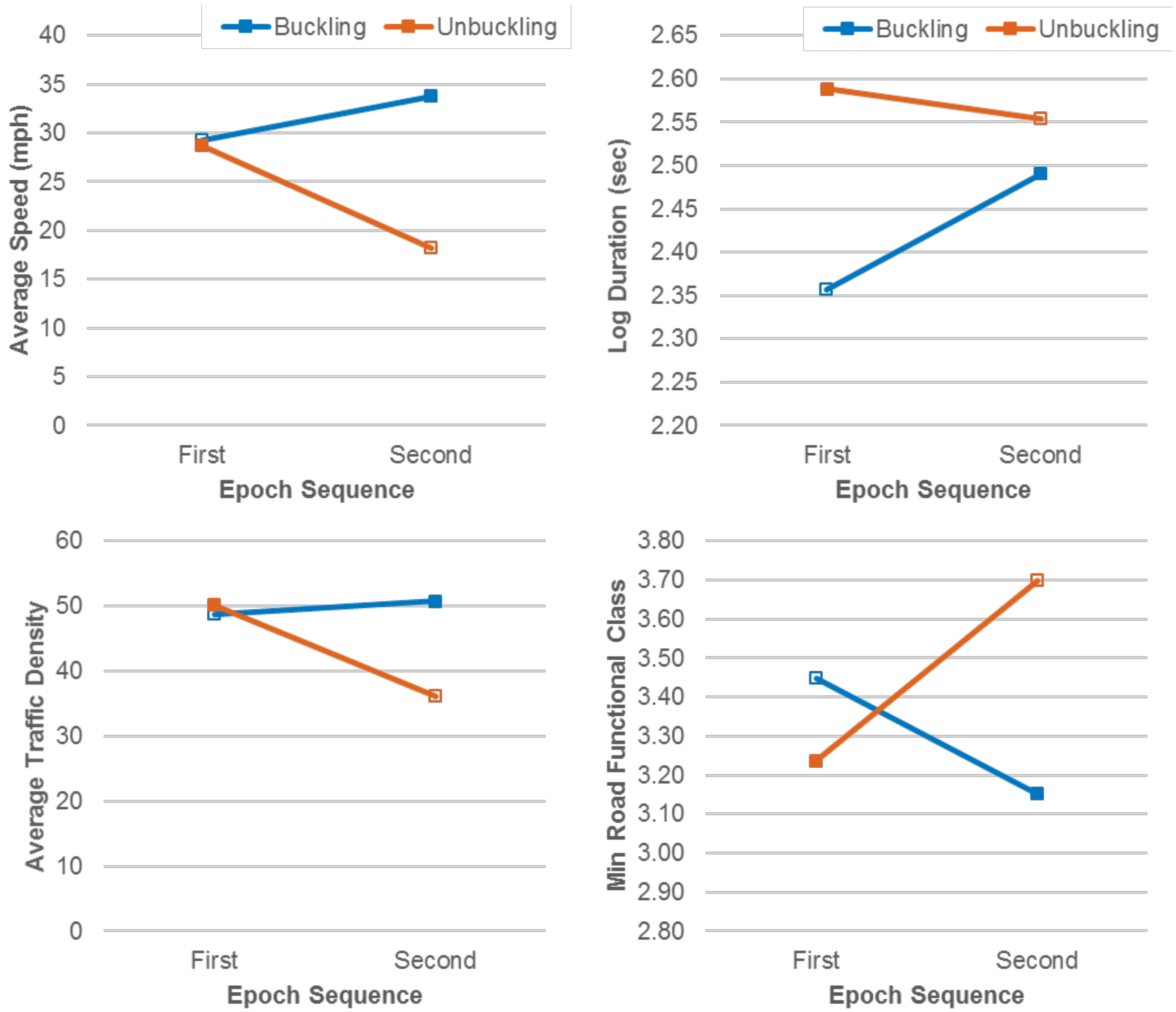

Figure 11. Estimated coefficient values from the regression model showing the simple interactions between buckling and unbuckling trips and the order of the epochs.

Table 16. Differences in epoch characteristics for different buckling and unbuckling trips.

Factor	Buckled as compared to unbuckled trips	Unbuckling as compared to buckling trips	Interaction
Average Speed	Higher average speeds	Lower average speeds	The difference between buckled and unbuckled speeds was only evident in the second part of the trip
Epoch Duration	Longer duration	Longer duration	The duration of buckled epoch was longer than unbuckled epoch if trip starts unbuckled, but there was no difference in epoch of trip that started buckled.
Traffic Density	Higher traffic density	Lower traffic density	Trips where drivers unbuckled had less traffic during the unbuckled part (second epoch)
Function Class	More travel on higher-capacity roads	More travel on higher-capacity roads	Buckling trips traversed higher capacity roads in the second epoch; the reverse pattern held for unbuckling trips

The results from the time-series epoch analyses are consistent with previous findings that drivers were more likely to use seat belts when safety risk was higher. The variables examined in the epoch analyses were indirect proxies for safety risk; however, all the significant variables were in directions that were consistent with this hypothesis.

Influence of Immediate Driving Conditions on Driver Buckling and Unbuckling

The previous analysis found that mid-trip buckling/unbuckling decisions coincided with global changes in driving conditions. A related question is if aspects of the immediate driving conditions triggered drivers' decision to buckle or unbuckle. The time-series data can provide some information about this, especially if the decision was triggered by traffic or weather conditions that the data collection equipment recorded.

A key benefit of the time-series data was that it recorded when a driver buckled or unbuckled during a trip. This facilitates comparing driving conditions within 30 seconds before the transition with those 30 seconds after to identify any differences in key variables that were reliably associated with buckling or unbuckling. The available variables included most of the ones from the previous analysis: average speed, average traffic density, minimum functional class, average illumination, and wiper use. Trip duration was excluded because it was the same for both comparison windows, and headlamp use was excluded due to missing data. A new variable, "percent time moving" represented the percentage of each 30-second window that the vehicle was in motion.

Descriptive Analysis

Statisticians conducted the analysis on partially unbuckled trips (the only trips that had changes in buckle status) in which the seat belt transition occurred at a point in the trip that could accommodate 30-second windows before and after the transition. The parking brake could not be active in either time window. Statisticians excluded both the before and after windows of trips that did not meet these requirements. This data filtering resulted in 1,741 pre/post pairs for buckling trips (where drivers started unbuckled) and 269 pairs for unbuckling trips (where drivers started buckled).

Figure 12 below shows the density plots for the different time windows across four key variables[4]. The solid lines on the graphs represent buckling trips, and the dashed lines represent unbuckling trips. Green lines indicate time windows when drivers were buckled, while red lines indicate time windows where drivers were unbuckled. The legend in Figure 12 organizes the time windows based on their order. Buckling-1 and unbuckling-1 are the time windows that occurred before the transition, and the buckling-2 and unbuckling-2 occurred after the transition on each type of trip, respectively.

Percent Time Moving: On buckling trips (solid lines), most of the time windows involved the vehicle being in motion 90 to 100% of the time. This suggested that many drivers buckled their seat belts while moving, which could be distracting if they had difficulty latching the buckle. On most unbuckling trips (dashed lines), the vehicle was moving 90 to 100% of the time while drivers were still buckled; however, the opposite pattern holds after drivers unbuckled. On about half of the unbuckled windows that followed transitions, the vehicle was stopped most of the time (moving 0 to 10% of the time). Note that during these unbuckled windows, the vehicles were not in park. Moreover, on 79% of these trips, drivers continued driving, so the stopped periods did not represent just the tail end of their trips. This suggests that some drivers may have stopped to do something that required unbuckling, and that they did not buckle up again once they continued with their trip.

Average speed: The average speed measure was strongly influenced by percentage of time moving, since speed was recorded as 0 mph when the vehicle was stopped. Consequently, 80% of the unbuckled windows on unbuckling trips (red dashed line) had an average speed below 6.2 mph (10 km/hr). These time windows were excluded from Figure 12 to more clearly show the data patterns. Average speeds in the pre-transition window on unbuckling trips (green dashed line) were low even though most vehicles were in motion most of the time. This is consistent with drivers slowing down prior to stopping or driving through low-speed areas, such as parking lots. On buckling trips, the distributions for average speed were almost the same for the pre- and post- transition windows, which is consistent with the notion that many drivers were buckling while the vehicle was moving. Overall speeds were moderate around these transitions, suggesting that they could have occurred on low-speed roads (i.e., with 25 to 30 mph posted speed limits) or higher-speed roads with traffic congestion.

[4] Statisticians excluded average illumination and wiper use because the plots lacked data in one or more conditions, or they showed no variation across conditions.

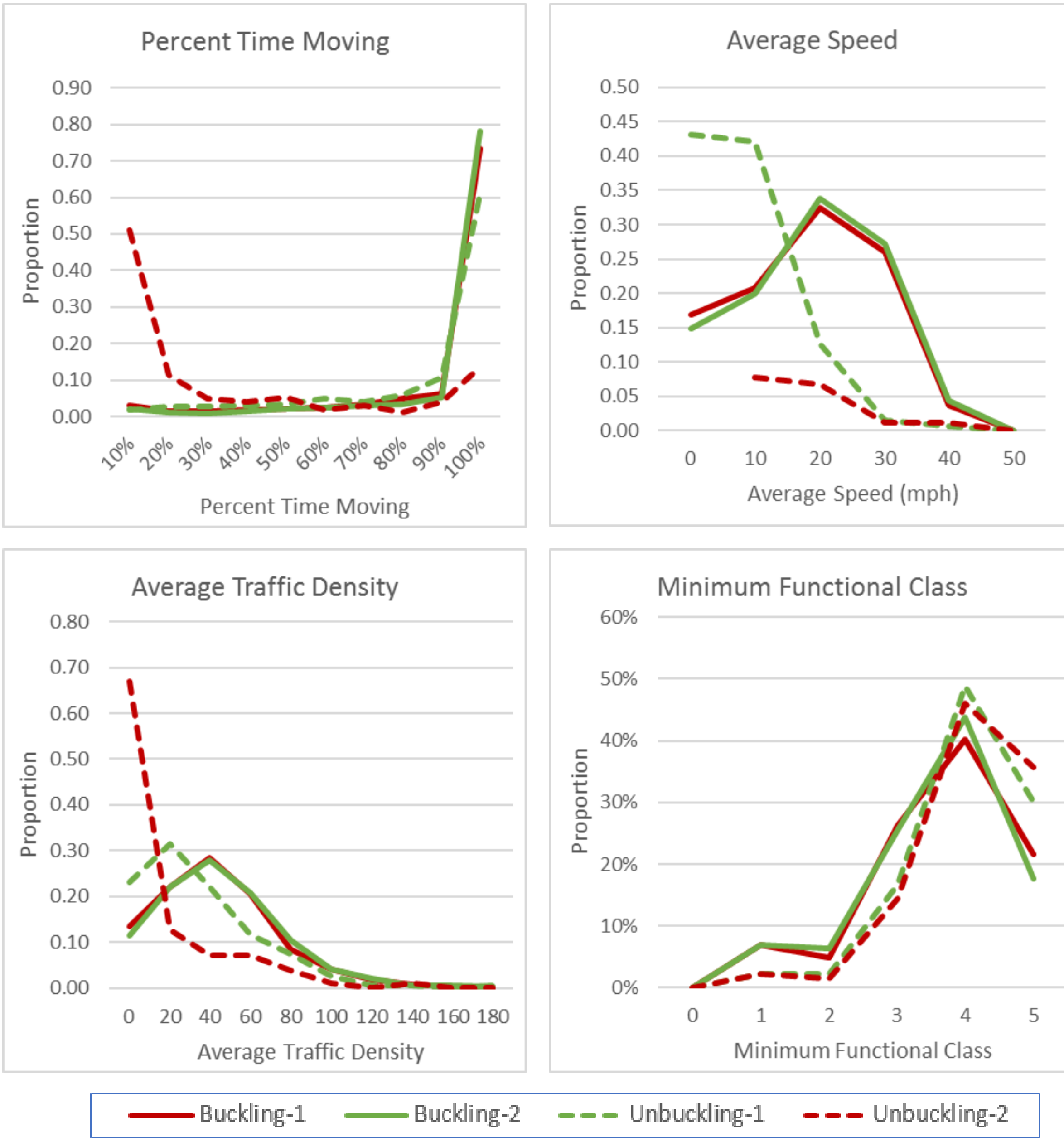

Figure 12. Density plots for the pre- and post-buckle transition windows on buckling and unbuckling trips across the variables: percent time moving, average speed, average traffic density, and minimum functional class.

Average traffic density: This variable was primarily a relative indicator of traffic density as described in the previous section; however, values of 60 generally correspond to following a single lead vehicle at normal headway at lower speeds. On buckling trips, the distributions for average traffic density were basically the same for the pre- and post-transition windows, which suggested that traffic conditions did not influence buckling. It also suggested that on most of the buckling trips, drivers were likely following a vehicle when they reached for the buckle and engaged latch, which could have posed a safety risk. Average traffic density was lower on unbuckling trips. This was especially true for the unbuckled windows, almost 70% of which had values less than 20. These low values likely represent being stopped in an open area with no nearby traffic or parked vehicles.

Minimum functional class: For this variable, differences between pre- and post- transition windows would imply that drivers may have been influenced by the riskiness of the road type (i.e., buckling before entering higher capacity roadways, or unbuckling after exiting these roads). However, there was minimal evidence for this pattern across the pre- and post-windows. There were slightly more instances of unbuckled driving on the lowest-capacity roads (i.e., residential roads) on both types of trips; however, the overall distributions were largely the same within trip type. Most travel surrounding the seat belt transitions occurred on class-4 roadways, which are collector-distributor roads that provide for a high volume of traffic movement at moderate speeds between neighborhoods. The primary difference between the trip types was that buckling trips were more common on class-1 and class-3 roadways (freeways and major arterials) and less common on the lower capacity roadways.

Case-control Analysis

Statisticians used a case-control methodology to examine if changes across the pre- and post-transition windows were statistically significant. They used the time-series data to compare the 60-second window around the transition point (which included both the 30-second pre- and 30-second post-buckle transition windows) versus a different 60-second control window from either before or after the transition window. In this case-control design, the transition window was the "case" and the comparison window was the "control." For each transition, there were either one or two control windows from the same trip. The number of controls and whether they occurred before or after the transition window, or both, depended on the position of the transition during the trip and the trip duration. Buckling transitions averaged 1.56 controls per trip, and unbuckling transitions averaged 1.68 controls per trip.

Statisticians examined the difference in the variables before and after the seat belt transition. For example, the average speed in the 30-second window before the transition was subtracted from average speed in the 30-second window after the buckle transition. In the control windows, average speed during first 30-second interval was subtracted from average speed during the second 30-second interval. Statisticians repeated this for all variables.

Statisticians built separate case-control models for buckling transitions and unbuckling transitions by adding one variable at a time. Figure 13 summarizes the results based on standardized coefficients. The blue dots in the figure indicate variables that had significantly different values immediately before and after the seat belt transition relative to a similar before-after comparison in the control window. Red dots indicate non-significant differences. The outcomes confirmed the descriptive findings from the density plots described above. The key data patterns are as follows:

Buckling trips: In the 30 seconds immediately after buckling, average speed was an average of 1.6 mph faster, traffic density was 2% higher, the functional class tended to be higher capacity, and drivers spent 1.5% more time moving. These effects were significant because of the large number of records; however, they do not translate to meaningful differences in roadway characteristics.

Unbuckling trips: In the 30 seconds immediately after unbuckling: average speed was 13 mph slower, traffic density was 30% lower, the functional class tended to be lower capacity, and drivers spent 53% more time stopped.

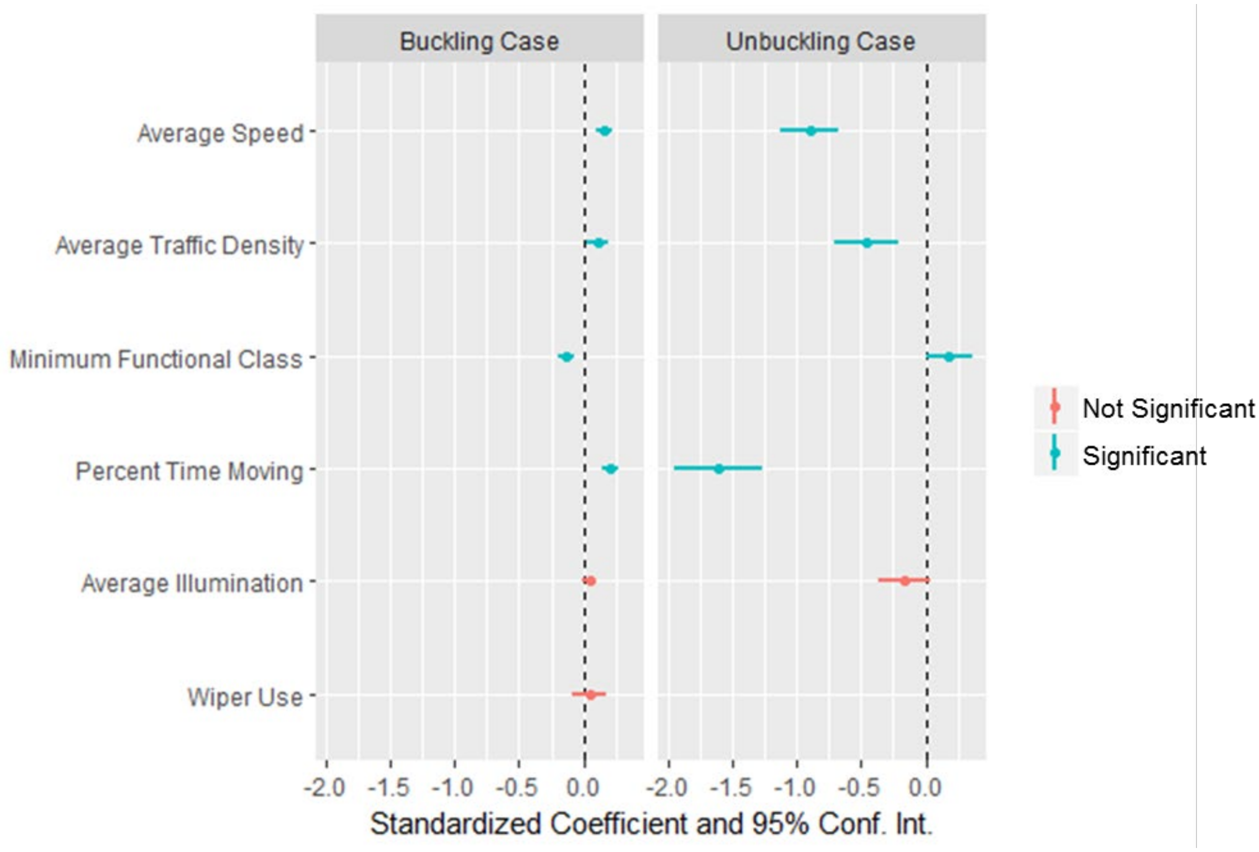

Figure 13. Standardized coefficients from the case-control modeling for separate buckling and unbuckling trip models.

The analyses conducted in this section identified the potential contribution of immediate driving conditions on driver decisions to buckle or unbuckle. The analyses had important limitations in that the variables were only indirect indicators of driver behavior, and the overall sample size was relatively small, particularly for unbuckling trips.

Despite these constraints, consistent and interpretable data patterns emerged from the analyses. There were clear differences in the immediate driving conditions associated with buckling and unbuckling transitions. The finding that most buckling events occurred at speed and in traffic was somewhat unexpected since reaching for and latching the buckle is easier and safer to accomplish while stopped. It is possible that buckling was motivated by events prompting an immediate response, such as drivers seeing a police vehicle, a possibility examined further in the next chapter.

The driving conditions during seat belt transitions on unbuckling trips were qualitatively different. A large proportion of these occurred while the vehicle was momentarily stopped but not parked. It is possible that some drivers may have stopped to do something that required unbuckling and that they did not buckle up again once they continued with their trip. This type of behavior could be targeted by countermeasures. Overall, the available trip-wide and situational predictors of occasional seat belt use point to the same key safety-focused factors as in some way motivating the behavior of drivers that are not consistent seat belt users.

GPS and Video Data Analysis

While the analyses of the aggregated data were useful for identifying easily quantifiable factors such as vehicle speed, accelerations, and trip duration that may be influencing part-time seat belt use, additional information was needed to assess whether other trip or situational factors may influence driver buckling behaviors. The coding and data analyses described in the sections that follow focused on a detailed examination of factors that appeared to influence driver buckling behaviors via a review of satellite imagery and videos of trips. The review and analysis process focused on several topics including the determination of factors related to:

1. Mid-trip buckles/unbuckles
    a. Single buckle/unbuckle trips
    b. Multiple buckle/unbuckle trips
2. Trips where the driver was fully buckled or fully unbuckled the entire trip
3. Driver buckling behaviors after experiencing a crash or near-crash
    a. Buckling immediately after the event
    b. Belt use rate after the event compared to before the event

Mid-Trip Buckles/Unbuckles

The preliminary analysis used GPS data to determine the type of roadway/location (e.g., interstate, local road, commercial, residential) where the vehicle was located when a driver buckled or unbuckled. This analysis indicated some definite patterns but also revealed a substantial number of unexplainable events. Given these findings, the study progressed to video information for the two minutes before and two minutes after the buckle/unbuckle to identify factors from the surrounding environment (e.g., passengers, law enforcement, traffic) that may have influenced driver behavior.

GPS Map Data Analysis

Analysts used Google Earth software to review a sample of trips that showed a mid-trip buckle/unbuckle. A total of 183 drivers had at least one trip that the SHRP2 system logged as having one or more mid-trip buckle/unbuckle event. Many trips were repeats of the same route for a given driver with the buckle/unbuckle happening at the same location. As such, analysts reviewed the map data for a sample of 1,860 trips out of the 2,795 that were available.

Mapping and Coding Procedure. Figure 14 provides an example of a single trip from an occasional seat belt user mapped in Google Earth. It shows the GPS coordinates for the two minutes before and the two minutes after the seat belt transition with location and belt status mapped once per second (120 samples before and 120 samples after the seat belt transition). White circles indicate that the belt was buckled, and purple circles indicate unbuckled. Researchers mapped the start (red circle labeled “S”) and end (red circle labeled “E”) points of the time series, which permitted assessments of the direction of travel and whether the transition was a buckle (purple to white) or unbuckle (white to purple) event. Coding the two minutes before and after the belt transition kept map file sizes manageable while still providing enough environmental information to identify factors that could have triggered buckling/unbuckling.

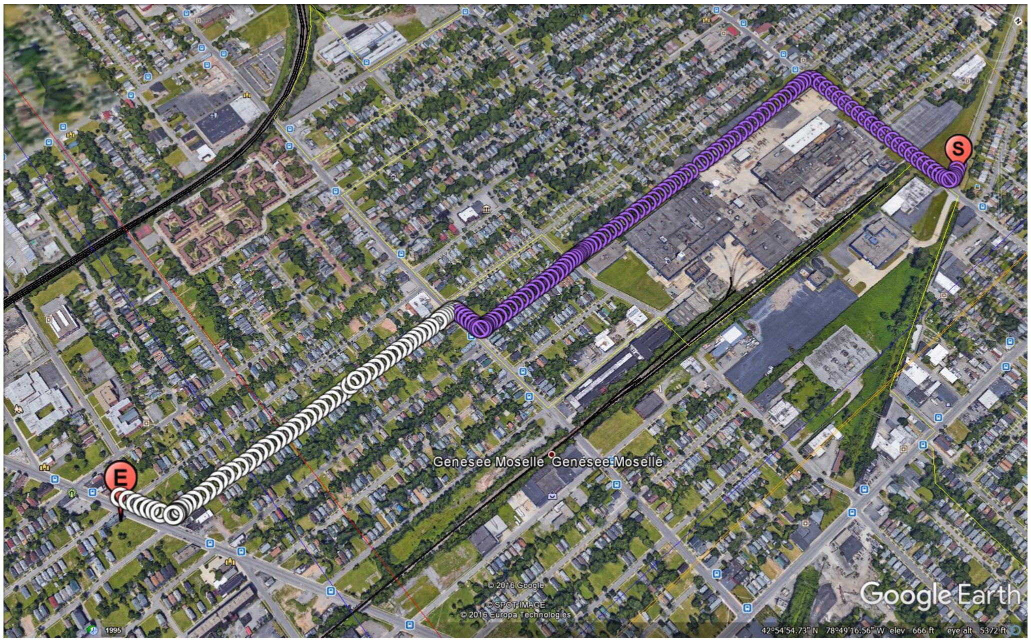

Figure 14. Example of a trip mapped in Google Earth.

When coding each transition, researchers documented transition type (buckle or unbuckle), location of transition (e.g., intersection, residential location, commercial location, freeway, or other active roadway), and speed. Approximately 10% of the coded trips (184 of the 1,860) either were missing data, contained an apparent GPS calibration error (e.g., trip was presented as being in the middle of an ocean), or were otherwise uninterpretable. The final dataset consisted of a total of 1,676 trips.

Findings

Table 17 presents the primary environmental characteristic categories that emerged from the map review. For most trips, the driver buckled/unbuckled while stopped on the roadway (e.g., at an intersection) or while stopped at a business or private residence. Some drivers buckled/unbuckled when entering or exiting a limited access highway. Still others buckled "late" as they exited a residence or business. For some trips, the map and speed data provided no explanation for the seat belt transition. This raised the possibility that factors internal or external to the vehicle influenced the buckle/unbuckle event, but it was not possible to make a determination based on the map data.

Table 17. Factors related to seat belt transitions based on the map review

Factor	Description
Intersection	Transitioned while stopped or slowed at intersection
Limited Access Highway On/Off Ramp	Transitioned while entering/exiting limited access highway
Commercial/Business Stop	Transitioned after stopping at a business (e.g., restaurant, bank/ATM, gas station)
Residential Stop	Transitioned after stopping at a private residence
Stopped On Roadway	Transitioned while stopped on a roadway
Late Buckle / Early Unbuckle	Buckled shortly after beginning or unbuckled before ending a trip
Unclear Transition	Transition due to an unclear influence

Figure 15 provides examples of two trips where a driver buckled (checkmark) or unbuckled (X) at an intersection. The blue arrow represents the direction of travel before the transition. Drivers were often stopped or proceeding very slowly when these intersection transitions took place.

Figure 15. Intersection transitions

Figure 16 provides two examples of transitions at on/off ramps on limited access highways. In the left example, the driver buckled just before merging onto the highway. In the right example, the driver unbuckled while exiting the highway.

Figure 16. Limited access highway on/off ramp transitions

Figure 17 shows two instances where the buckle/unbuckle took place in a parking lot at a commercial location before the driver exited the parking lot. The arrow represents the direction of travel. Researchers observed similar patterns at private residential locations where buckles/unbuckles generally took place in a driveway while the vehicle was stopped. These could be artifacts of the data collection system. For example, if a driver started the car unbuckled and sat in the driveway for a while before buckling, the action would have been logged as an unbuckled to buckled transition even though the person was buckled the whole time the vehicle was actually underway. Also, a person stopping to drop off or pick up someone could have been logged as a mid-trip buckle/unbuckle if they took off the seat belt while stationary with the vehicle running and then put it back on when underway again.

Figure 17. Transitions at commercial/business locations

Figure 18 shows two examples of seat belt transition points that occurred on limited access highways. In the picture on the left, the vehicle speed was zero miles per hour at the time of transition; the person was probably stopped in traffic or had pulled off the roadway. In the picture on the right, the driver was stopped at a toll booth during a seat belt transition.

Figure 18. Transitions when stopped on active roadways

A number of the transitions were characterized as late buckles where the driver buckled on an active roadway shortly after the start of a trip rather than at its origin. Figure 19 provides some examples of late buckles, which generally occurred after leaving a residential or business area.

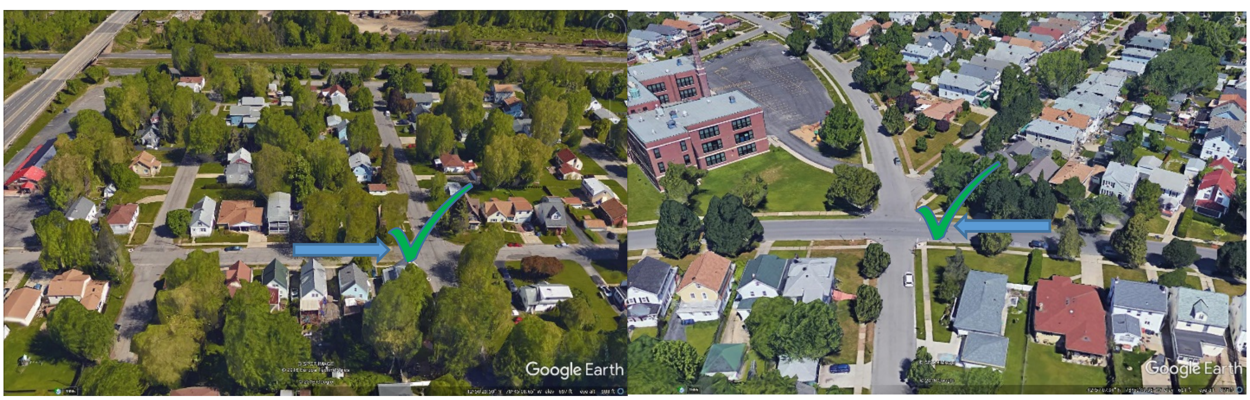

Figure 19. Late buckles

Finally, for some trips, the factors related to a seat belt transition were unclear. In both the left and right examples in Figure 20 below, the driver had a seat belt transition for no apparent reason while moving on an active roadway.

Figure 20. Unclear factors influencing transitions

The GPS coordinate data from the SHRP2 data files generally produced an acceptable representation of the two minutes before and after a seat belt transition. Researchers identified several factors that appeared to be related to the seat belt transition points. The multi-camera videos that were part of the SHRP2 data, however, were the only means to verify the observations from the map review and to determine if other factors were influencing driver buckle/unbuckle behaviors.

Analysis of Video Data

To obtain further insight regarding factors influencing these behaviors, researchers analyzed SHRP2 video data. The analyses focused on three objectives:

1. To confirm the environmental factors identified during map coding. Even though some of the behavior patterns identified were logical and predictable, such as habitual late buckling, other, more compelling factors may have either overridden the environmental ones or acted in combination with them.
2. To identify other factors not identified during the map coding, including in-vehicle factors such as the influence of passengers and the physical state of the driver, as well as external factors such as traffic, weather, or presence of law enforcement.
3. To determine whether peculiar patterns of buckling/unbuckling recorded by the system were data recording errors.

Video Data. The SHRP2 dataset included video information from multiple cameras focused on the forward and rear roadways, driver's face, driver's hands, and other aspects of the vehicle and the scene around it. Software permitted analysts to select a specific trip, to scan all or portions of the trip, and to examine synchronized views of multiple cameras and graphical displays of user-selected parameters such as speed.

During the video review, the researchers 1) verified data quality, 2) coded environment/roadway circumstance at time of seat belt transition, and 3) coded up to three factors that appeared to be related to the seat belt buckle/unbuckle. Table 18 shows the coding options for these variables.

Table 18. Coding scheme for characterizing factors influencing seat belt transitions.

Variable	Codes
Environment/roadway circumstance at time of seat belt transition	• Local road • Collector road • Limited access road • Commercial stop • Residential stop • Stop other • Start/End of trip • Missing data or uninterpretable • Unknown
Factors potentially related to the seat belt transition	• Enter/exit freeway, • Late buckle/early unbuckle • Law enforcement vehicle or emergency services vehicle • Exit/re-enter the vehicle • Commercial drive-thru (e.g., fast food, bank) • Distraction (e.g., cell phone use) • Intersection approach • Traffic • Passenger (e.g., presence of passenger apparently influenced driver belt use) • Reach for object in vehicle • Weather conditions (e.g., started raining) • Other person (e.g., a person outside of the vehicle influenced belt use) • Lighting (e.g., getting dark or light outside) • Toll booth • Unknown

The master list contained 3,921 trips from the 183 drivers. Each of these trips had a mid-trip buckle/unbuckle logged by the data system. Some drivers had only a single trip with a buckle/unbuckle event while others had hundreds of trips where they buckled/unbuckled. A number of the trips had bad seat belt data. The two most frequent types of bad data involved recording a buckle/unbuckle on the data file when the video clearly showed no change in the belt use state, and frequent buckle or unbuckle events when the video confirmed the driver's belt state was unchanged. Usually, but not always, all of the data for a driver were either good or bad. Occasionally a single trip, or even part of a trip, showed bad data while the rest of a driver's trips appeared valid. Forty-two of the 183 drivers had at least one trip containing bad data. Researchers coded videos for all 3,921 trips on the master list.

Descriptive Analysis of Video Data

The first objective of the video coding and analysis was confirmatory in nature. Researchers reviewed videos of trips in which environmental factors had been coded as influencing buckling/unbuckling based on the map data. All six factors were confirmed as prompting seat belt transitions. However, for a number of transitions where it was unclear from the previous analysis why the person may have buckled or unbuckled, video reviewers did not identify an influencing factor. The list below provides additional information on the original six factors:

Late Buckle / Early Unbuckle—Numerous drivers buckled shortly after a trip began. This appeared to be habitual buckling at a certain point such as reaching the edge of a residential neighborhood and turning on to a higher speed road. Others tended to unbuckle early just before reaching a destination such as a residence.

Commercial/Business Stops—A number of drivers who arrived at a stop midway through a trip unbuckled and then buckled again when they left; others arrived buckled and left unbuckled. These locations were usually drive-thru restaurants, ATMs, malls, or other commercial locations at which the person stopped with the vehicle ignition on to conduct some transaction or pick up a passenger. People who buckled after arriving unbuckled tended to remain buckled for the remainder of the trip. When a person arrived buckled but left unbuckled, there was a mixture of late re-buckling and never re-buckling on the trip. A number of these transitions were "false transitions" in which people were sitting in a driveway or parking lot with the engine on and had unbuckled while they performed a task or waited on another person to arrive. In these instances, the driver was in little to no danger and was not on an active roadway. For instance, a person may have unbuckled to give money to an employee at a fast food drive-thru but re-buckled before moving the vehicle. In other instances, a driver started the vehicle but sat unbuckled in the parking lot for an extended time before buckling.

Residential Stops—Many of these buckles/unbuckles involved a driver sitting in their own driveway for extended periods. The systems logged buckles/unbuckles while the vehicle was stationary. In some instances, a person arriving at a residence and picking up a passenger unbuckled while waiting for the passenger to enter the vehicle. The residential stop did not generally appear to be the main cause for a valid seat belt transition. It is important to note, however, that numerous late buckles and early unbuckles were observed near residences. A number of drivers did not buckle until they had backed out of the driveway while others remained unbuckled much longer while driving in the neighborhood.

Intersections—The videos confirmed that many drivers buckled up when arriving at an intersection. On many occasions, drivers buckled up as they slowed down when approaching lines of traffic stopped at an intersection. Other times they buckled after they were at a complete stop. Often, the intersection itself, or the act of approaching an intersection, appeared to be the only factor influencing the decision to buckle. Unbuckles at intersections were less common but did occur for apparent reasons described later.

Limited Access Highway On/Off Ramp—Several drivers consistently buckled when entering a limited access highway while others unbuckled upon exiting. Only one driver consistently unbuckled on entrance ramps to limited access highways. In these instances, it was clear the person was buckling or unbuckling solely because of the entering or exiting of the limited access highway.

Stopped on Active Roadway—There were a few instances of a person stopping on an active roadway and unbuckling or buckling when stopped. This usually involved people who left the vehicle running when they stopped to help a stranded motorist or when their own cars had broken down. Others stopped on the side of the road to put out or retrieve signs for a business. In one instance, a person stopped to remove a turtle from the road.

The second objective of the video coding involved identifying additional factors that motivated buckling or unbuckling during a trip. Common factors included the following:

Presence of Law Enforcement Vehicles—Many drivers buckled in response to seeing a law enforcement vehicle or emergency services vehicle. Drivers apparently interpreted flashing lights as law enforcement even though many were other emergency services vehicles. Their reactions were different than a normal response to an approaching emergency vehicle with flashing lights. These drivers reacted rapidly with an obvious look of distress as they attempted to put on the seat belt with a sense of urgency in response to the flashing lights. The videos showed that drivers often checked the rear and side view mirrors when they saw a law enforcement vehicle with lights on, even when the vehicle was going in the opposite direction. The same reaction was also observed when a police vehicle was in sight without lights on.

Passengers—A number of videos showed that passengers influenced driver seat belt use. On some trips, the driver arrived unbuckled and then buckled up after picking up a passenger. Either the passenger influenced the buckling decision or cued it. Likewise, when passengers were dropped off drivers often buckled/unbuckled after the stop.

Work Related—Multiple drivers appeared to operate ride-share or taxi services. These drivers typically drove unbelted, received a telephone call, buckled up, and proceeded to pick up a passenger. These drivers then stayed buckled for the remainder of the trip.

Distraction—Numerous people drove while distracted, and many unbuckled to answer a phone that was in a pocket. Other distractions associated with unbuckling included retrieving cigarettes or other items from pockets, reaching for objects in the car, eating, or taking off clothing. Sometimes these drivers re-buckled but often they did not.

Spontaneous—A number of drivers appeared to buckle or unbuckle without any apparent influence. Several drivers unbuckled on high speed roadways. These drivers did this consistently after driving on the roadway for a period of time and reaching a high speed. Others would buckle for no apparent reason after driving for extended periods.

Improper use and faking—Not surprisingly, some drivers wore the seat belt improperly. This resulted in the data system indicating the driver was buckled when the shoulder belt was behind the driver. Several drivers also pulled the shoulder belt strap over but did not engage the buckle in a likely attempt to appear belted to law enforcement.

The third objective, identifying data patterns that likely represented inaccurate data, was the simplest to address. Researchers identified at least two patterns of inaccurate seat belt data.

In most instance, the bad data were comprised of buckles/unbuckles occurring at consistent intervals (e.g., 6 seconds, 30 seconds) that were clearly not related to driver behavior based on their frequency and consistency. The cause of this particular failure may have been either malfunctioning of the data recorder or the vehicle sensors. Nevertheless, the patterns were easy to detect and these trips were excluded from analyses.

The other pattern was random signal loss within a trip that caused the indication of a buckle/unbuckle. These were consistent with a sensor or switch “sticking” occasionally. While this type of data failure could be discriminated through the use of the videos, it could not be detected from the network data alone. The rate at which these dropouts occurred could not be estimated. They were, therefore, noise that must be accepted in any analysis of SHRP2 seat belt data that does not use the videos to confirm belt buckles/unbuckles.

Statistical Analysis of Video Data

While reviewing the videos, it became obvious that trips with single buckles/unbuckles were very different from those in which there were multiple buckles/unbuckles. In particular, when a person had only a single buckle/unbuckle, the buckle state remained the same for the remainder of the trip. Trips with multiple buckles/unbuckles often involved multiple stops or some other type of trip that was very different from the single transition trips. As such, the data for the single and multiple buckle/unbuckle trips were analyzed separately.

Trips With a Single Buckle/Unbuckle. This section presents results for trips during which the driver changed seat belt state (i.e., buckled to unbuckled or unbuckled to buckled) only a single time. Table 19 provides the type of location where the seat belt buckle/unbuckle took place. As can be seen in the table, there were statistically significant differences in the locations where buckles or unbuckles took place ($\chi^2(5, N = 1826) = 388.34$, $p < .001$). For each location, a z-test of the column proportions was performed to determine if the proportions were statistically different. Statistically significant differences are denoted by an asterisk in the table. Most notably, drivers were more likely to buckle than unbuckle on a local road or collector road. Drivers were more likely to unbuckle at commercial or residential stops or when on a limited access road/ramp. Most of the limited access road/ramp unbuckles were drivers unbuckling just before an exit or on the exit ramp. There were, however, a few instances of drivers unbuckling on a limited access road entrance ramp or when actively driving on the limited access road.

Table 19. Locations of single buckles or unbuckles

	Type of Transition	
	Unbuckled % (n = 354)	Buckled % (n = 1,472)
Local Road	3.7	14.8*
Collector Road	7.9	53.1*
Limited Access Road or Ramp	39.3*	18.2
Commercial Site Stop	25.1*	6.4
Residential Site Stop	22.3*	7.0
Other Site Stop	1.7*	0.5

*Significantly higher by z-test, $p < 0.05$.

Table 20 provides the observed factors at the time of a buckle/unbuckle when only a single seat belt use transition occurred during a trip. Multiple situations could have been coded for each transition if two factors appeared simultaneously (e.g., law enforcement was visible when a driver approached an intersection). As such, summing the percentages will lead to values greater than 100% within the buckled or unbuckled categories. As can be seen in the table, there were differences in the reasons for buckled and unbuckled transitions. For each factor, a separate chi-square test was performed to see if drivers buckled or unbuckled with the same frequency in association with the respective factor. Statistically significant differences in factor frequency for unbuckled and buckled transitions are noted in the table. Intersections and the presence of law enforcement (or other emergency vehicles with similar lights) were the two most frequent reasons for drivers buckling. Not surprisingly, drivers exiting the vehicle was the most frequent reason for an unbuckle. It is important to note that a substantial proportion of both buckle and unbuckle events were categorized as having an "unknown" factor influencing the behavior. In these instances, researchers could not determine why a person buckled/unbuckled.

Table 20. Factors influencing single buckles/unbuckles

	Type of Transition	
	Unbuckled % (n = 354)	Buckled % (n = 1472)
Intersection	3.1	24.2*
Traffic	4.5	3.6
Law Enforcement	0.0	15.8*
Exit/Re-enter Vehicle	38.1*	5.9
Late Buckle/Early Unbuckle	2.5	6.2*
Enter/Exit Freeway	0.3	3.7*
Commercial Drive-thru	7.3*	2.0
Reach for Object in Vehicle	2.3*	0.3
Distraction	6.2*	0.9
Other Person	1.4	0.5
Weather Conditions	0.0	0.4
Toll Booth	0.8	0.2
Lighting	0.0	0.1
Passenger	0.6	3.2*
Unknown	36.4	39.8

*Significantly higher by chi-square test, $p < 0.05$.

Trips With Multiple Buckles/Unbuckles. This section presents results for trips during which the driver had more than one buckle/unbuckle on a trip. Table 21 provides the observed factors at the time the buckles/unbuckles took place. Each buckle/unbuckle on a trip was coded as an independent event. As can be seen in the table, there were differences in the locations where buckles or unbuckles took place ($\chi^2(5, N = 707) = 47.74$, $p < .001$). For each location, a z-test of the column proportions was performed to determine if the proportions were statistically different. Statistically significant differences are denoted by an asterisk in the table. As shown in the table, buckles were more likely to take place on local roads, collector roads, and limited access roads/ramps. Unbuckles were more likely to take place at commercial and residential stops. A large proportion of buckles also took place at commercial and residential stops. These were usually a driver re-buckling after having unbuckled to leave the vehicle or interact with someone at a business (e.g., fast food drive-thru).

Table 21. Locations of buckles/unbuckles when multiple changes on a single trip.

	Type of Transition	
	Unbuckled % (n = 338)	Buckled % (n = 369)
Local Road	4.7	11.4*
Collector Road	6.5	17.6*
Limited Access Road or Ramp	5.9	11.7*
Commercial Site Stop	49.4*	36.3
Residential Site Stop	30.2*	21.1
Other Site Stop	3.3	1.9

*Significantly higher by z-test, $p < 0.05$.

Table 22 provides the observed factors at the time of a buckle/unbuckle when multiple changes occurred during a trip. Each buckle/unbuckle on a trip was coded as an independent event. Again, multiple situations could occur simultaneously, so the percentages will sum to greater than 100% within the buckled or unbuckled categories. For each factor, a separate chi-square test was performed to see if drivers buckled and unbuckled with the same frequency in association with the respective factor. Statistically significant differences are noted in the table. Drivers were more likely to buckle at intersections. Law enforcement was again associated with buckling. The great majority of unbuckles occurred when a driver exited the vehicle while a lesser percentage of buckles were associated with re-entering the vehicle. Drivers were more likely to have a late buckle when leaving the trip origin than they were to have an early unbuckle when arriving at a destination.

Table 22. Factors influencing buckles/unbuckles with multiple transitions on a single trip.

	Type of Transition	
	Unbuckled % (n = 338)	Buckled % (n = 369)
Intersection	3.6	11.1*
Traffic	0.6	1.4
Law Enforcement	0.0	8.1*
Exit/Re-Enter Vehicle	61.8*	33.9
Late Buckle/Early Unbuckle	6.5	27.6*
Enter/Exit Freeway	0.3	1.9
Commercial Drive-Thru	14.2*	6.5
Reach for Object in Vehicle	6.5*	1.4
Distraction	3.6*	1.1
Other Person	2.1	0.8
Weather Conditions	0.0	0.5
Toll Booth	0.3	0.0
Lighting	0.0	0.0
Passenger	0.3	1.9*
Unknown	5.9	16.3*

*Significantly higher by chi-square test, $p < 0.05$.

Entire Trips Buckled/Unbuckled

This portion of the study involved coding videos of trips during which the driver was either fully buckled or fully unbuckled for the entire trip. A convenience sample of unbuckled trips of at least five minutes in duration were selected for review along with a matched set of buckled trips for the same drivers. To the extent possible, the trips were matched on duration, length, and speed. Some drivers had only one trip on which they were completely unbuckled while others had hundreds.

A small sample of brief (less than 5 minutes) fully buckled and unbuckled trips were examined separately. As with the trips above, every brief unbuckled trip was matched with a brief buckled trip based on the approximate trip duration, length in miles, and speed variables.

The data coding and analysis focused on identifying environmental, roadway, and other factors that may be related to a decision to drive fully buckled or unbuckled on a trip. The variables coded are presented in Table 23 below.

Table 23. Variables coded for fully buckled/unbuckled trips.

Variable	Levels
Trip origin/destination (each coded separately)	Residential, Commercial, Leisure, Unknown
Passenger at origin, picked up, dropped off (each coded separately)	Yes-Child, Yes-Adult, No
Interstate driving	Yes/No
Non-interstate 55 mph+	Yes/No
Precipitation	Yes/No
Darkness/twilight	Yes/No
Visible police	Yes/No
Trip demand (driver workload)	Extreme, High, Average, Low
Driver condition	Highly Alert, Average, Compromised
Driver control (vehicle motion/stability)	Smooth, Some Instability, High Instability

Descriptive Analysis

This section presents descriptive results comparing fully buckled or unbuckled trips for the same drivers. The list below provides information on the factors that emerged as clearly being related to fully buckled or unbuckled trips:

Passengers — The presence of passengers appeared to influence full trip belt use. A number of drivers buckled for the entire trip when passengers were present in the vehicle, but did not buckle when driving alone. A few young drivers tended to not wear a belt when peers were present but did buckle when driving alone.

Trip Demand — Some drivers did not buckle when the trip demand or workload was low. Low demand trips generally had little to no traffic and relatively low speeds. Often, these were brief trips in a neighborhood or other non-commercial location. Trips with average to higher demands (e.g., heavier traffic, around commercial locations) appeared to be associated with higher belt use.

Difficulty Putting on Belt or General Comfort — Coders used the open comments field to note that it was obvious some drivers had difficulty putting on the seat belt or showed signs of discomfort when wearing a belt. A number of instances were observed with the driver attempting to put on the belt but failing due to clothing interfering, apparent mobility issues, or obesity. Many instances of improper use were observed, often by females placing the shoulder belt under the arm.

Statistical Analysis
Results are presented separately for trips longer than five minutes and those less than five minutes. Given the nature of the data coding for this portion of the study, results for each factor that appeared to be related to fully buckled/unbuckled trips are presented in separate tables.

Trips Longer than Five Minutes
Trip origin/destination. Table 24 provides the type of trip origin for fully unbuckled and buckled trips. There were statistically significant differences in the locations where buckled or unbuckled trips began ($\chi^2(3, N = 2074) = 29.91$, $p < .001$). Unbuckled trips were more likely to originate from a residential location while buckled trips were more likely to originate from commercial locations.

Table 24. Percentage of fully buckled/unbuckled trips starting from each origin.

	Trip Belt Status	
	Unbuckled % (n=1037)	Buckled % (n=1037)
Residential	46.6*	37.0
Commercial	44.6	56.5*
Leisure	2.1	1.5
Unknown	6.8	4.9

*Significantly higher by z-test, $p < 0.05$.

Table 25 provides the type of trip destination for fully unbuckled and buckled trips. There were statistically significant differences in the trip destination locations where buckled or unbuckled trips ended ($\chi^2(3, N = 2074) = 57.13$, $p < .001$). Unbuckled trips were more likely to end at a residence while buckled trips were more likely to end at a commercial location.

Table 25. Percentage of fully buckled/unbuckled trips ending at each destination.

	Trip Belt Status	
	Unbuckled (n=1037)	Buckled (n=1037)
Residential	55.3*	38.9
Commercial	42.4	58.8*
Leisure	1.6	1.6
Unknown	0.7	0.7

*Significantly higher by z-test, $p < 0.05$.

Passengers. Table 26 provides the type of passenger (if any) in the vehicle at the start of fully unbuckled and buckled trips. As evident from the table, there were statistically significant differences in both the presence and type of passenger as the trip began ($\chi^2(2, N = 2074) = 63.23$, $p < .001$). Buckled trips were more likely to have an adult passenger in the vehicle at the origin while unbuckled trips were more likely to have the driver alone in the vehicle at the origin.

Table 26. Percentage of fully buckled/unbuckled trips with passenger at origin.

	Trip Belt Status	
	Unbuckled (n=1037)	Buckled (n=1037)
Yes, child	6.3	8.0
Yes, adult	16.4	30.3*
None	77.3*	61.7

*Significantly higher by z-test, $p < 0.05$.

Trip demand. Table 27 provides data on the rated trip demand for fully buckled and unbuckled trips. As shown in the table, there were statistically significant differences in trip demand for buckled and unbuckled trips ($\chi^2(3, N = 2074) = 213.38$, p <.001). Buckled trips were more likely to have average or higher trip demands while unbuckled trips were much more like to be low demand.

Table 27. Percentage of fully buckled/unbuckled trips with each trip demand.

	Trip Belt Status	
	Unbuckled (n=1037)	Buckled (n=1037)
Extreme	0.1	0.7*
High	6.0	8.2*
Average	59.2	82.6*
Low	34.7*	8.5

*Significantly higher by z-test, $p < 0.05$.

Results for the factors that did not distinguish among fully buckled and unbuckled trips can be found in Appendix A.

Trips Less than Five Minutes

Trip origin/destination. Table 28 provides the trip origin location for fully unbuckled and buckled brief trips. Due to an insufficient number of leisure and unknown origin trips in the sample, these trips were excluded from the analysis. As can be seen in the table, there were statistically significant differences in the locations where fully buckled or unbuckled brief trips began ($\chi^2(1, N = 104) = 3.87$, $p = .049$). Unbuckled trips were more likely to originate from a residential location. Many drivers never left the residential neighborhood during these trips. Buckled trips tended to originate more from commercial locations.

Table 28. Percentage of fully buckled/unbuckled brief trips starting from each origin.

	Trip Belt Status	
	Unbuckled (n=57)	Buckled (n=57)
Residential	50.9*	33.3
Commercial	40.4	57.9*
Leisure	3.5	1.8
Unknown	5.3	7.0

*Significantly higher by z-test, $p < 0.05$.

Table 29 provides the trip destination location for each fully unbuckled and buckled brief trips. Again, due to an insufficient number of leisure and unknown destination trips, these trips were excluded from the analysis. As shown in the table, there were statistically significant differences in the brief trip destination locations where fully buckled or unbuckled trips ended ($\chi^2(1, N = 113) = 3.98, p = .046$). Unbuckled trips were more likely to end at a residential location while buckled trips were more likely to end at commercial locations.

Table 29. Percentage of fully buckled/unbuckled brief trips ending at each destination.

	Trip Belt Status	
	Unbuckled (n=57)	Buckled (n=57)
Residential	63.2*	45.6
Commercial	35.1	54.4*
Leisure	1.8	0.0
Unknown	0.0	0.0

*Significantly higher by z-test, $p < 0.05$.

Passengers. Table 30 provides the type of passenger in the vehicle at the start of fully unbuckled and buckled brief trips. Overall the results do not indicate statistically significant differences in the presence and type of passenger as the trip began at the 0.05-level ($\chi^2(2, N = 114) = 5.16, p = .08$). However, an unbuckled trip was more likely to have the driver alone in the vehicle at the trip origin than a buckled trip.

Table 30. Percentage of fully buckled/unbuckled brief trips with passengers at origin.

	Trip Belt Status	
	Unbuckled (n=57)	Buckled (n=57)
Yes, child	12.3	24.6
Yes, adult	7.0	14.0
None	80.7*	61.4

*Significantly higher by z-test, $p < 0.05$.

Precipitation. Table 31 provides whether precipitation occurred during fully buckled and unbuckled brief trips. Trends with respect to precipitation were evident, $\chi^2(1, N = 114) = 3.81$, p =.05, with buckled trips tending to occur more often with precipitation falling than unbuckled trips.

Table 31. Percentage of fully buckled/unbuckled brief trips with precipitation.

	Trip Belt Status	
	Unbuckled (n=57)	Buckled (n=57)
Yes	1.8	10.5
No	98.2	89.5

No statistically significant differences by z-test.

Trip demand. Table 32 provides drivers' workloads for each fully buckled and unbuckled brief trip. As evident from the table, only one brief trip was coded as high demand. This trip, on which the driver was fully buckled, was grouped with the average trip demand cases for purposes of the chi-square analysis. Results of this chi-square analysis revealed statistically significant differences in demand for buckled and unbuckled brief trips ($\chi^2(1, N = 114) = 15.41$, p <.001). Buckled trips were much more likely to have average trip demand while unbuckled trips were much more likely to be low demand trips.

Table 32. Percentage of fully buckled/unbuckled brief trips with each trip demand.

	Trip Belt Status	
	Unbuckled (n=57)	Buckled (n=57)
Extreme	0.0	0.0
High	0.0	1.8
Average	47.4	80.7*
Low	52.6*	17.5

*Significantly higher by z-test, $p < 0.05$.

Results for the factors that did not distinguish among fully buckled and unbuckled brief trips can be found in Appendix A:.

Seat Belt Use after a Crash or Near-Crash

The SHRP2 vehicle data collection systems identified "events" where there was some form of sudden deceleration or other g-force exceedance that indicated a person may have had a crash or near-crash experience. As part of the original SHRP2 project, coders reviewed the events and coded a variety of factors including the seat belt use of the driver. The current study focused on events where the driver was coded as "unbelted." A total of 245 events were originally coded by SHRP2 reviewers as having an unbelted driver. After reviewing these events, the research team found several miscoded events in which the driver was either fully belted or partially belted (e.g., lap belt only). Removing these miscoded events led to a final sample of 178 events with an unbelted driver. The research team also judged the severity of the events and the driver reactions to the events to allow for an exploration of how these factors may have impacted subsequent belt use. These scales are listed below.

Severity of crash:

- No contact (e.g., sudden braking, light curb strike, brief run off road)
- Minor (e.g., contact made with very minor damage possible)
- Moderate (e.g., contact with another vehicle or object that likely led to moderate damage to vehicle)
- High severity (e.g., heavy damage to vehicle or injury)

Drive Reaction:

- No reaction (e.g., no observable response to supposed event)
- Minor (e.g., some reaction, but continues driving without issue)
- Moderate (e.g., obvious emotional and physical reaction to event)
- Severe (e.g., severe emotional and physical reaction; likely stops vehicle or shows prolonged emotional reaction)

Two separate research questions were then addressed through additional review of the event videos and other trips of interest. The research questions were:

1. How often do unbelted drivers buckle immediately after experiencing an "event"?
2. Did experiencing an event lead some unbelted drivers to increase their belt use after the event compared to before the event?

To answer the first research question, the research team members watched each event video all the way to the end of the trip to determine if the person buckled up immediately, or shortly after, the event. If a person turned off the ignition after the event (e.g., to exit the vehicle to check damage), the researchers then pulled up the next video in the sequence to determine if the person buckled at the start of that video which was a continuation of the event trip. No vehicles or data collection systems were damaged to the point where this second video was not available. As such, coders could determine belt use after the event for all 178 trips.

To answer the second research question, seat belt use on the 10 trips before and 10 trips after the events were coded. Given the amount of time needed to review 20 full trips and code seat belt use, a sample of drivers was selected based on the severity of their reaction to the event. The sample was heavily weighted towards events in which the driver had a moderate to severe reaction (n = 71) as these events likely had the most potential for changing driver behavior. For comparison purposes, a smaller sample of events in which drivers had no or minor reaction to the event were selected out of those that remained.

Coders reviewed each trip in its entirety and coded driver belt use when the vehicle was underway. Belt use was coded as "fully belted," "partially belted," or "fully unbelted." To be coded as fully belted, a driver had to wear the seat belt properly for the entire time the vehicle was on an active roadway. To be coded as partially belted, the driver had to have a seat belt transition from buckled to unbuckled, or vice versa and drive the vehicle while in the different belt state. Fully unbelted trips were those in which the driver never wore the seat belt. Improper use was coded as unbelted. Some drivers had more than one event, and separate belt use rates were calculated before and after each event. Coders attempted to code 10 trips before and after the event, but some of the selected trips were not trips of interest (e.g., driving in parking lot; driving a very short distance to a neighbor's house) and were excluded from the analyses.

Belt Use Immediately after Crash or Near-Crash

Given the design of this analysis, all drivers were unbelted at the time of the crashes or near-crash events. A total of 40 drivers (22.5%) buckled immediately/shortly after the events. In every instance where a driver buckled, it was very clear the buckle was directly related to the crash/near-crash experience.

Belt use was explored by the rated severity of the event and the driver reaction to the event. Given the small sample size, event severity levels were condensed to "no contact" and "minor to moderate contact/severity" to provide enough power for a statistical comparison. No events were coded as severe. As shown in Table 33, the difference in the percentage of drivers buckled when an event was rated as minor/moderate and when an event was rated as no contact was not statistically significant, ($\chi^2(1) = 2.58$, $p = .108$). Driver reaction levels were condensed to "none to minor reaction" and "moderate to severe reaction" to provide enough power for a statistical comparison. A higher percentage of drivers buckled when the driver reaction was rated as moderate to severe than when the reaction was rated as none to minor ($\chi^2(1) = 8.19$, $p = .004$).

Table 33. Percentage of drivers buckling immediately after events.

Event Severity		Driver Reaction	
No Contact % (n = 133)	Minor/Moderate % (n = 45)	None/Minor % (n = 106)	Moderate /Severe % (n = 72)
19.5	31.1	15.1	33.3*

*Significantly higher by chi-square test, $p < 0.05$.

Of the 40 drivers who belted immediately after events, 37 (92.5%) remained belted until the end of the trip. Of the 138 drivers who did not buckle after the event, two (1.4%) buckled by the end of the trip.

Belt Use Rate for Trips Before and After Crashes or Near-Crashes

Table 34 shows the average belt use for each category (fully unbelted, partial belt use, fully unbelted) for the drivers before and after the events. For this analysis, percentage of belt use in each category was calculated for each driver and then averaged across the 96 drivers sampled. As can be seen in the table, drivers were unbuckled for a lower percentage of trips on average after events ($t(95) = 2.46$, $p = .02$). There was a statistically significant increase in partial seat belt use for trips after events ($t(95) = 2.01$, $p = .047$). No statistically significant difference in full seat belt use was found from before to after events ($t(95) = 1.20$, $p = .23$).

Table 34. Average belt use rate for trips before and trips after events.

	Trips Before Event % (n = 96) M (SD)	Trips After Event % (n = 96) M (SD)
Fully Unbelted	62.0 (33.2)*	56.5 (35.4)
Partial Belt Use	16.4 (18.6)	20.0 (21.7)*
Fully Belted	21.6 (27.6)	23.6 (27.3)

*Significantly higher by paired samples t-test, $p < 0.05$.

Table 35 shows the average belt use rate for drivers for the trips before and after events with no contact and events with minor/moderate severity to determine if more severe events led to greater buckling after. Drivers with no contact during the event were unbuckled for a lower percentage of trips on average after events ($t(65) = 2.43$, $p = .018$). There was no statistically significant difference in average partial seat belt use ($t(65) = 1.94$, $p = .06$), or full seat belt use ($t(65) = 1.51$, $p = .14$) in trips after the safety events. There was no statistically significant difference in belt use among drivers with minor to moderate crash severity (unbelted, $t(29) = .67$, $p = .51$, partial belt, $t(29) = .65$, $p = .52$, full belt, $t(29) = .15$, $p = .87$).

Table 35. Average belt use rate before and after events by crash severity.

	No Contact (n = 66) M (SD)		Minor/Moderate (n = 30) M (SD)	
	Trips Before Event %	Trips After Event %	Trips Before Event %	Trips After Event %
Fully Unbelted	64.4 (34.3)*	57.3 (35.0)	56.9 (30.4)	54.6 (37.0)
Partial Belt Use	16.2 (18.9)	20.7 (22.7)	16.7 (18.2)	18.5 (19.6)
Fully Belted	19.4 (25.8)	22.0 (26.6)	26.4 (30.9)	27.0 (29.2)

*Significantly higher based on paired samples t-test, $p < 0.05$.

Table 36 shows the average belt use rate for drivers for trips before and after events with no to minor driver reactions and moderate to severe driver reactions. Drivers with a minor reaction to the event had a statistically significant higher percentage of fully belted trips after the event, ($t(24) = 2.67$, $p = .013$). There was no statistically significant difference in unbelted trips, ($t(24) = 1.26$, $p = .22$) or partial belted trips, ($t(24) = .24$, $p = .81$) before and after the event. Drivers with a moderate to severe reaction to the event were unbelted significantly less often, ($t(70) = 2.10$, $p = .039$) and partially belted significantly more often, ($t(70) = 2.77$, $p = .007$) after the events. There was no statistically significant difference in full belt use before and after the event for this reaction category.

Table 36. Average belt use rate before and after events by driver reaction.

	None to Minor (n = 25) M (SD)		Moderate to Severe (n = 71) M (SD)	
	Trips Before Event %	Trips After Event %	Trips Before Event %	Trips After Event %
Fully Unbelted	63.2 (34.4)	56.9 (36.8)	61.6 (33.0)*	56.3 (35.2)
Partial Belt Use	23.2 (21.5)	22.2 (24.8)	14.0 (16.9)	19.2 (20.7)*
Fully Belted	13.6 (25.0)	20.9 (27.7)*	24.4 (28.0)	24.5 (27.4)

*Significantly higher based on paired samples t-test, $p < 0.05$.

Table 37 shows the average belt use rate for drivers for before and after events for drivers who buckled and those who did not buckle after the event. For drivers who buckled after the events, there was a statistically significant decrease in the average of unbelted trips after the events, ($t(39) = 2.28$, $p = .028$). There was not a statistically significant difference in the average partial belt use, ($t(39) = 1.82$, $p = .08$) or full belt use ($t(39) = .97$, $p = .34$) on trips before and after the events. For drivers who remained unbuckled after the event, there was no statistically significant difference between average unbelted trips, ($t(55) = 1.38$, $p = .17$), partial belted trips, ($t(55) = 1.15$, $p = .25$), or belted trips, ($t(55) = .73$, $p = .47$) before and after the events. While neither group appeared to have a meaningful increase in fully belted trips after events, those drivers who buckled appear to be more likely overall to be fully or partially belted compared to those who did not buckle.

Table 37. Average belt use rate by buckle action after event.

	Driver Buckled (n = 40) M (SD)		Driver Remained Unbuckled (n = 56) M (SD)	
	Trips Before Event %	Trips After Event %	Trips Before Event %	Trips After Event %
Fully Unbelted	47.5 (32.5)*	40.2 (33.9)	72.4 (29.8)	68.1 (32.0)
Partial Belt Use	23.0 (19.0)	27.7 (22.4)	11.6 (16.9)	14.5 (19.6)
Fully Belted	29.5 (31.5)	32.1 (30.3)	16.0 (23.0)	17.4 (23.4)

*Significantly higher based on paired samples t-test, $p < 0.05$.

The trip mapping and coded videos provided a rich data set that supplemented the earlier data analysis. Several factors were related to driver buckling/unbuckling behaviors. Many of the findings, such as buckling with passengers and after encountering law enforcement, were confirmatory in nature and expected. Another common theme that is consistent with the earlier analysis is that seat belt use varied based on the driver's perception of the riskiness of the driving situation. Many people either unbuckle mid-trip, or never buckle at all, on "low demand/risk" trips or portions of trips, such as unbuckling when exiting high speed limited access roads or on neighborhood roads. These behaviors imply some active assessment of risk by drivers with a conscious decision to either buckle or unbuckle based on the perceived risk on a given trip or segment of a trip.

Another novel aspect of this study was the review of how unbuckled drivers behaved after experiencing a crash or near-crash event. Interestingly, only about a fifth of the unbelted drivers who experienced events put the seat belts on for the remainder of the trips after the events. Event severity did not appear to be a major factor as drivers involved in some of the most severe events did not buckle after experiencing what should have been frightening incidents. Other drivers experienced much less severe events but responded by immediately buckling. Those drivers who did buckle after their events, however, tended to have higher belt use rates (either partial belt use or full belt use) both before and after the events than those who did not buckle. This suggests the event served as a reminder to wear a seat belt for these people who already tended to wear seat belts more often. In general, however, experiencing a crash or near-crash event tended not to lead to substantially higher belt use after the event.

Summary and Conclusions

The current study provided a unique opportunity to expand on previous studies that examined occasional seat belt use in real world driving conditions (Regan et al. 2012; Yates et al., 2011). Overall, the findings from the present study indicate that SHRP2 naturalistic study data can provide useful insights regarding driver belt use behavior. The in-depth analyses of driver behavior across entire trips confirmed that occasional seat belt use is a real behavior that a small proportion of drivers engage in regularly. By categorizing trips based on seat belt status, researchers also confirmed the existence of two types of occasional belt users:

1. Occasional seat belt users that make predominately pre-trip buckling decisions
2. Occasional seat belt users that make predominately within-trip buckling decisions

The primary analyses addressed two research objectives covering driver-specific predictors of seat belt use and situational factors affecting belt use on individual trips. These objects are discussed in the sections below.

Research Objective 1: Identify individual differences that differentiate user groups

Analyses of driver-specific factors indicated that occasional belt users have different characteristics than consistent belt users. While the behavioral-based measure in the current study differed from self-report, citation, and other measures from previous studies, the current findings were consistent with the existing literature (See Table 4). The key factors that differentiated regular seat belt users from occasional seat belt users in the current study are listed below. Findings that matched previous studies are indicated by an asterisk. As compared to consistent users, occasional seat belt users:

- Were more likely to be 40 years old or older;*
- Were more likely to be male;*
- Were more likely to be overweight;*
- Were more likely to be single;*
- Had more traffic violations;*
- Were less likely to perceive driving with no seat belt as unsafe;*
- Were more likely to report engaging in risky driving behaviors;*
- Had lower scores on a basic driving knowledge test;
- Had worse clock-drawing scores; and
- Had higher indication of ADHD.

Some key predictors from previous studies were not related with seat belt use in the current study; however, methodological differences likely explain these differences (see Table 1). Income and education attainment were skewed towards the high end in the current study because the availability of seat belt status on a trip was limited to newer, more expensive vehicles. Additionally, race and ethnicity were excluded from the analyses because almost all available drivers were non-Hispanic whites.

The consistency between the current findings and previous studies indicates the SHRP2 data captured belt use behavior that matches established patterns. This provides some degree of validation for extending the analyses into the topic of "occasional seat belt use" as defined by observed behavior within trips.

The findings support the existence of two types of occasional belt users: 1) those that made pre-trip decisions to buckle on some trips but not others, and 2) those that made buckle/unbuckle decisions during a trip. Additionally, the inferential analyses indicated that these two types of occasional belt users differ in several ways. Specifically, compared to drivers that make mid-trip decisions, drivers that made pre-trip decisions:

- Consisted of a greater proportion of age 16 to 24 and smaller proportion of 40 to 64,
- Were more likely to be single,
- Had more traffic violations,
- Had higher risk-taking scores,
- Had worse clock-drawing scores,
- Had higher sensation seeking scores,
- Had higher disinhibition scores,
- Had higher thrill-seeking scores,
- Had lower left-hand strength, and
- Were more likely to work evening or night shifts.

The data also permitted researchers to examine the accuracy of self-reported seat belt use. Occasional belt users greatly over-estimated their seat belt use. These drivers were also less likely to report that driving unbuckled posed a much greater safety risk.

The analyses of driver-specific predictors indicated that the sample displayed many of the same patterns that researchers have found in other seat belt use studies. This was true despite the sample being restricted to SHRP2 drivers who had newer vehicles. Regarding the research objective of identifying driver-specific predictors, the statistical modeling indicated that being an occasional seat belt user was associated with several measures related to risk taking or risk acceptance, especially for drivers who tended to make pre-trip decision about using belts.

Research Objective 2: Identify the impact of *situational* factors in seat belt use patterns of occasional seat belt users

Researchers examined the potential effect of situational factors by analyzing trip time series data and video coding of select trips.

Analysis of Trip Time-Series Data

Trip-Wide Predictors of Seat Belt Use: Logistic regression analyses indicated that the trip types (fully buckled, partially unbuckled, and fully unbuckled) differed significantly in terms of trip distance, average speed, and start-time. Partially unbuckled and fully unbuckled trips were shorter and had lower average speeds than fully buckled trips, with fully unbuckled being the shortest and slowest overall. There was a clear relationship indicating that "riskier" trip characteristics were associated with more consistent seat belt use. However, this pattern was not as strong in the lowest belt-use D2/3 group, which suggested that these drivers may have been motivated by different factors than the other seat belt user groups.

Situational Factors Associated with Partial Seat Belt Use Trips: Drivers were more likely to be belted during driving epochs in which they drove at higher speeds, for longer duration, in higher density traffic, and on higher-capacity roads as compared to unbuckled epochs. These patterns are consistent with the notion that drivers are more likely to use a seat belt in riskier driving conditions. There was also an asymmetry in trip characteristics based on whether drivers began buckled or unbuckled. Trips in which the driver unbuckled during the trip tended to be at higher speed, for a shorter duration, in higher density traffic, and on higher-capacity roads than trips in which the driver started unbuckled and buckled mid-trip.

Influence of Immediate Driving Conditions on Driver Buckling and Unbuckling: There were clear differences in the immediate driving conditions associated with buckling and unbuckling transitions. The finding that most buckling events occurred at speed and in traffic was somewhat unexpected since reaching for and latching the buckle is easier and safer to accomplish while stopped. It is possible that buckling was motivated by events prompting an immediate response, such as drivers seeing a police vehicle, which researchers observed repeatedly during the video analysis. The driving conditions during seat belt transitions on unbuckling trips were different. A large proportion of these occurred while the vehicle was momentarily stopped but not parked. It is possible that some drivers may have stopped to do something that required unbuckling and that they did not buckle up again once they continued with their trip.

Overall, the available trip-wide and situational predictors of occasional seat belt use point to the same key safety-focused factors as in some way motivating the behavior of drivers that are not consistent seat belt users.

Analysis of GPS and Video Data

The trip mapping using GPS and coding of videos provided a rich data set that supplemented the overall data analysis. Several factors were related to driver buckling behaviors. Many of the findings were confirmatory in nature and expected. For example, drivers simply buckling late or not buckling until they reached a road with traffic was not surprising. Similarly, the presence of passengers tending to lead to more buckling was not a new finding. The study confirmed that some younger drivers did not buckle when peers are in the car but they did buckle when alone. There was also evidence that drivers unbuckled when distracted by a cell phone that was in a pocket, while reaching for objects, or doing other distracting things like changing clothes while driving.

The impact of law enforcement on seat belt use was also confirmed with numerous part-time belt users immediately buckling at any indication of encountering a law enforcement vehicle. The frequency and strength of the reactions of motorists to flashing lights of passing law enforcement or emergency services vehicles provides support for the effectiveness of longstanding, high-visibility enforcement in creating general deterrence. Importantly, these drivers almost always remained buckled for the remainder of the trip.

Another common theme was that many people either unbuckled mid-trip, or never buckled at all, on “low demand/risk” trips or portions of trips. Several drivers repeatedly unbuckled when exiting high speed limited access roads while others never buckled at all when the trip was on local or neighborhood roads. These behaviors imply some assessment of risk by drivers, who made a conscious decision to either buckle or unbuckle based on the perceived risk on a given trip or segment of a trip.

Perhaps most surprising was the amount of buckling as drivers approached an intersection or line of traffic at an intersection. In most cases, there was no apparent reason for buckling at these times other than the approach and stop at the intersection. Most of the time the buckling behavior was very casual, as if the driver had simply forgotten to buckle and the intersection cued the buckling behavior. Perhaps the perception of the physical forces associated with the act of slowing or stopping were significant enough that the driver realized the seat belt was not engaged, or the thought of interacting with crossing of traffic was enough to increase perceived risk to the point that drivers buckled. This phenomenon certainly warrants further research to determine why drivers would buckle at intersections and how the finding can be utilized for countermeasure development.

The notion of drivers forgetting that they were not buckled partially explains the findings from the analyses of seat belt use following safety-critical driving events. Specifically, event severity did not appear to be a major factor as drivers involved in some of the most severe events did not buckle after experiencing what should have been a frightening incident. However, some drivers who experienced much less severe events responded by immediately buckling. These drivers tended to have higher belt use rates (either partial belt use or full belt use) both before and after the events than those who did not buckle. This suggests the event served as a reminder to wear a seat belt for these people who already tended to wear seat belts more often.

Conclusions

A common theme across multiple analyses in this study was the role of driving risk in occasional seat belt use. Occasional belt users generally scored higher on risk taking measures and were more likely to believe that driving unbelted did not pose a greater safety risk. However, their behavior on individual trips indicates that, overall, these drivers tended to use seat belts when driving in riskier situations.

It is important to note that across most of the trips reviewed, when a person buckled or unbuckled for a reason other than entering or exiting the vehicle, they generally stayed in the same buckled state until the end of the trip. As such, persistent and attention-grabbing belt reminders may be an effective way to get drivers to buckle up and remain buckled. The same reminder would need to activate when a person unbuckles to get them to buckle again. Other countermeasures may include educational or media materials that reinforce that the driver should wear a seat belt on every trip even if the perceived risk or demand is low, signs at limited access road exit ramps, or signs at commercial stops where drivers exit the vehicle and may forget to buckle again. The study results also suggest that a proportion of the population simply refuses to buckle, even after experiencing an event that should have prompted the driver to put on a seat belt. It is not clear if anything other than the most incessant reminder or an interlock would prompt these drivers to wear seat belts.

Overall, the SHRP2 dataset proved to be a useful source of information about occasional seat belt use. Although there were limitations regarding the availability of continuous seat belt status information across the full sample, the data examined in the current study were sufficient to support a wide range of analyses. These analyses confirmed expected trends among key predictor variables and situational factors, and they broadened our understanding of how these factors influence occasional seat belt use.

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Appendix A: Comparison of Network and Non-Network SHRP2 Vehicles

This appendix provides an overview of differences between network and non-network vehicles in the SHRP2 dataset. Figure A-1 provides a density plot showing distribution of vehicle model years. Network vehicles were substantially newer than non-network vehicles

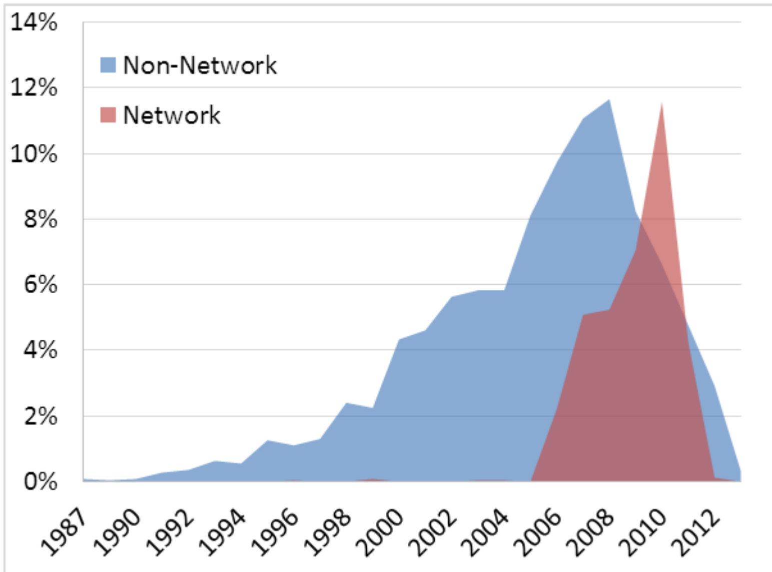

Figure A-1: Density plot showing distribution of vehicle model years. Network vehicles were substantially newer than non-network vehicles.

Table A-1 provides the output of univariate ANOVAs that statisticians conducted to examine differences between network and non-network vehicle drivers for key demographic variables.

Table A-1: Differences in driver-specific predictors between network and non-network vehicle drivers.

Characteristic	Relative to non-network vehicles, network vehicles had:	*p*-value
Age group	Fewer 16-24 and more 25-46	$p < 0.0001$
Gender	No difference	$p = 0.106$
Education Level	More with college and advanced degrees	$p < 0.0001$
Income	More earning over $100K	$p = 0.0001$
Marital Status	Fewer single and more married	$p < 0.0001$
Race	No difference	$p = 0.455$
Ethnicity	No difference	$p = 0.655$
Site	Fewer in NC and WA, and more in NY	$p = 0.0003$
Vehicle Type	More SUVs and crossovers	$p = 0.0007$

Appendix B: Supplementary Data Tables

The data tables in this appendix provide supplemental trip information for the tables from analysis of video data. The appendix tables summarize trip information for the trips in the main report. The additional information includes:

- Mean trip distance (miles),
- Mean trip duration (minutes),
- Mean of the maximum speed recorded on each trip (mph), and
- Mode of trip start hour.

Note that the table numbering has been changed so that it corresponds to the table numbering in the analysis. For example, “Table B-19” provides additional trip statistics to Table 19 in the main report.

Table B-19. Trip characteristics of single buckles/unbuckles by locations.

Buckle					**Unbuckle**				
	Distance (mile)	Total duration (min)	Max speed (mph)	Start hour		Distance (mile)	Total duration (min)	Max speed (mph)	Start hour
Collector road	10	20.6	58.7	17	Collector road	11.8	25.6	61	19
Commercial stop	17	36.5	59.4	12	Commercial stop	10.1	28.1	56.2	6
Limited Access Road	16.3	26.1	71.2	12	Limited Access Road	23.9	39.6	72.6	8
Local Road	11.3	24.5	54.8	15	Local Road	10.9	24.6	53.8	10
Residential stop	11	27.3	57.7	17	Residential stop	12.1	31.4	57.5	17
Stop Other	11	41.1	59.7	18	Stop Other	12	19.9	64.6	11

Table B-20. Trip characteristics of single buckles/unbuckles by influencing factors.

Buckle					**Unbuckle**				
	Distance (mile)	Total duration (min)	Max speed (mph)	Start hour		Distance (mile)	Total duration (min)	Max speed (mph)	Start hour
Distraction	6.7	19.6	58.4	18	Distraction	16.6	27.6	63.1	17
Drive-Thru	9	23.3	59.7	14	Drive-Thru	12.4	30.7	59.2	14
Enter/exit Freeway	12.9	23.5	72	12	Enter/exit Freeway	203.3	199.7	89.1	13
Exit/Re-enter Vehicle	20.2	39.6	61.1	12	Exit/Re-enter Vehicle	12	29.4	57.4	6
Intersection	10.1	20.4	57.9	11	Intersection	9.5	26.1	58.4	16
Late/early	10.6	28.7	57.4	12	Late/early	12.4	31.6	50	18
Law Enforcement	12.7	26	60.1	15	Law Enforcement	NA	NA	NA	NA
Lighting	3.5	13.4	38.5	21	Lighting	NA	NA	NA	NA
Other Person	7.8	23.9	55.6	8	Other Person	19.8	42.5	64	11
Passenger	11.2	28.4	57.1	17	Passenger	13.1	40.5	57.7	13
Reach	11	22.1	54.9	12	Reach	12.7	29.3	58.1	19
Toll Booth	16	22.1	75.3	18	Toll Booth	26.6	48.8	70	21
Traffic	11.5	20.9	66.2	7	Traffic	19.7	39.6	72.1	7
Unknown	11.6	21.9	61.1	12	Unknown	19.8	35.4	70.6	8
Weather	32.1	42.6	72.8	13	Weather	NA	NA	NA	NA

Table B-21. Trip characteristics of buckles/unbuckles when multiple changes on a single trip by locations.

Buckle					**Unbuckle**				
	Distance (mile)	Total duration (min)	Max speed (mph)	Start hour		Distance (mile)	Total duration (min)	Max speed (mph)	Start hour
Collector road	18	39.6	61.6	15	Collector road	23.4	50.8	63.5	13
Commercial stop	17.8	49.7	58.1	9	Commercial stop	23.3	54.9	59.1	14
Limited Access Road	49.7	68.2	73	11	Limited Access Road	68.4	75.8	79.9	13
Local Road	19.3	52.3	60.8	11	Local Road	19.8	57.8	63.4	11
Residential stop	15.9	47.2	59.5	9	Residential stop	16.5	45.4	59.5	17
Stop Other	16.6	53.2	68	16	Stop Other	33.3	63.8	66.5	11

Table B-22. Trip characteristics of buckles/unbuckles with multiple transitions on a single trip by influencing factors.

Buckle					**Unbuckle**				
	Distance (mile)	Total duration (min)	Max speed (mph)	Start hour		Distance (mile)	Total duration (min)	Max speed (mph)	Start hour
Distraction	37	39.8	85.2	11	Distraction	60.1	80.2	74.7	15
Drive-Thru	19.2	47.1	58.1	16	Drive-Thru	10.9	34.2	52.7	9
Enter/exit Freeway	54.3	80.4	72	11	Enter/exit Freeway	24	48.3	77.5	12
Exit/Re-enter Vehicle	18.3	53	60.4	18	Exit/Re-enter Vehicle	21.7	55	60.8	11
Intersection	14.9	38.3	61.5	17	Intersection	35.1	75.6	66.2	15
Late/early	19.6	49.4	57.6	9	Late/early	37.8	60.5	64.8	13
Law Enforcement	26.1	51.1	62.8	16	Law Enforcement	NA	NA	NA	NA
Other Person	16.7	44.9	58.9	15	Other Person	17.2	50.2	58.7	15
Passenger	14.4	52.4	67.1	16	Passenger	18.2	53.4	78	14
Reach	10.3	33.7	61.6	12	Reach	20.2	47.7	64.8	13
Traffic	31.6	47.2	68.8	12	Traffic	14.2	33.7	61.5	7
Unknown	28.4	49.4	65.2	12	Unknown	55.4	64.6	70.1	13
Weather	53.9	81.7	72.5	21	Weather	NA	NA	NA	NA
Toll Booth	NA	NA	NA	NA	Toll Booth	16.9	43.2	68.1	13

Table B-24. Trip characteristics of fully buckled/unbuckled trips by trip origins.

Buckle					**Unbuckle**				
	Distance (mile)	Total duration (min)	Max speed (mph)	Start hour		Distance (mile)	Total duration (min)	Max speed (mph)	Start hour
Commercial	4.2	12.5	40.6	6	Commercial	3.3	11.8	38.4	5
Leisure	5	13.5	29	25	Leisure	1.6	10.6	26.8	25
Residential	5	12.8	44.1	10	Residential	3.3	12	36.4	8
Unknown	6	12.9	43.3	10	Unknown	3.5	9.8	41.6	4

Table B-25. Trip characteristics of fully buckled/unbuckled trips by trip destinations.

Buckle					**Unbuckle**				
	Distance (mile)	Total duration (min)	Max speed (mph)	Start hour		Distance (mile)	Total duration (min)	Max speed (mph)	Start hour
Commercial	4.2	12.2	40.3	5	Commercial	3.7	12.4	38	5
Leisure	4.3	13.9	35.4	10	Leisure	5.9	15.7	28.8	10
Residential	5.3	13.4	44.6	9	Residential	2.8	11.1	37.3	8
Unknown	1.7	8.6	35.1	6	Unknown	4.2	17.1	34.5	6

Table B-26. Trip characteristics of fully buckled/unbuckled trips by passenger at origins.

Buckle					**Unbuckle**				
	Distance (mile)	Total duration (min)	Max speed (mph)	Start hour		Distance (mile)	Total duration (min)	Max speed (mph)	Start hour
None	3.3	10.9	41.4	6	None	2.9	11.3	37.2	8
Yes, adult	7.7	16.3	43.4	5	Yes, adult	5.4	14.3	38.7	5
Yes, child	3.3	12.1	39.9	10	Yes, child	2.1	10.5	36.8	10

Table B-27. Trip characteristics of fully buckled/unbuckled trips by trip demands.

Buckle					**Unbuckle**				
	Distance (mile)	Total duration (min)	Max speed (mph)	Start hour		Distance (mile)	Total duration (min)	Max speed (mph)	Start hour
Average	4.8	12.7	42.7	5	Average	4.6	12	45.6	3
Extreme	3.8	18.5	34.5	24	Extreme	1.2	13.8	20.4	24
High	6.8	15.7	50.8	10	High	6.8	17.5	56.6	10
Low	0.9	9.1	25.8	11	Low	0.4	10.3	20.2	5

Table B-28. Trip characteristics of fully buckled/unbuckled brief trips by trip origins.

Buckle					**Unbuckle**				
	Distance (mile)	Total duration (min)	Max speed (mph)	Start hour		Distance (mile)	Total duration (min)	Max speed (mph)	Start hour
Commercial	0.8	3.2	35.7	4	Commercial	0.9	2.9	38	7
Leisure	0.2	3.1	12.2	5	Leisure	0.6	3.1	24.3	12
Residential	1.2	3.4	39.5	6	Residential	0.6	2.5	30.3	11
Unknown	1.2	2.9	42.7	11	Unknown	1.1	3	36.1	15

Table B-29. Trip characteristics of fully buckled/unbuckled brief trips by destinations.

Buckle					**Unbuckle**				
	Distance (mile)	Total duration (min)	Max speed (mph)	Start hour		Distance (mile)	Total duration (min)	Max speed (mph)	Start hour
Commercial	1	3.4	36.3	4	Commercial	0.9	2.9	37.9	11
Leisure	NA	NA	NA	NA	Leisure	0.8	3.5	24.8	12
Residential	0.9	3	37.9	10	Residential	0.6	2.6	31.4	7

Table B-30. Trip characteristics of fully buckled/unbuckled brief trips by passenger at origins.

Buckle					**Unbuckle**				
	Distance (mile)	Total duration (min)	Max speed (mph)	Start hour		Distance (mile)	Total duration (min)	Max speed (mph)	Start hour
None	1	3.1	38.6	4	None	0.8	2.6	33.7	7
Yes, adult	0.9	3.5	38.9	14	Yes, adult	0.5	2.7	24.3	3
Yes, child	0.7	3.2	32.1	8	Yes, child	0.8	3.4	37.6	11

Table B-31. Trip characteristics of fully buckled/unbuckled brief trips by precipitations.

Buckle					**Unbuckle**				
	Distance (mile)	Total duration (min)	Max speed (mph)	Start hour		Distance (mile)	Total duration (min)	Max speed (mph)	Start hour
No	0.9	3.2	36.5	6	No	0.7	2.7	33.6	7
Yes	1.2	3.6	41.7	14	Yes	0.4	2.8	30.5	5

Table B-32. Trip characteristics of fully buckled/unbuckled brief trips by trip demands.

Buckle					**Unbuckle**				
	Distance (mile)	Total duration (min)	Max speed (mph)	Start hour		Distance (mile)	Total duration (min)	Max speed (mph)	Start hour
Average	1.1	3.5	40.5	4	Average	1.1	3.3	43.2	7
High	0.7	4	33.2	22	High	NA	NA	NA	NA
Low	0.3	1.9	21.6	6	Low	0.4	2.2	24.8	11

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