

Alyssa Peck

Department of Mathematical Sciences
Montana State University

May 3, 2014

A writing project submitted in partial fulfillment
of the requirements for the degree

Master of Science in Statistics

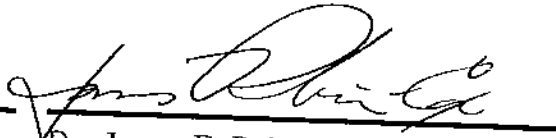
APPROVAL

of a writing project submitted by

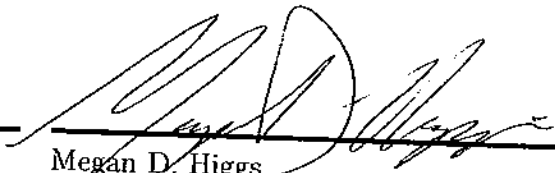
Alyssa Peck

This writing project has been read by the writing project advisor and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the Statistics Faculty.

4/24/2014
Date


Dr. James F. Robison-Cox
Writing Project Advisor

4/24/2014
Date


Megan D. Higgs
Writing Projects Coordinator

Evaluating the Effectiveness of Occupant Protection Programs

Alyssa Peck

May 2014

Abstract

It is widely accepted that vehicle seat restraints save lives, however, motorists do not use seat belts every time they operator a vehicle. Montana Department of Transportation (MDT) invests heavily in programs aimed at increasing seat restraint usage and saving lives. However, recent increases in traffic fatalities and decreases in overall seat belt compliance have required MDT to question the effectiveness of these programs. Here, we conduct a preliminary analysis of program impacts. The National Highway Transportation and Safety Administration (NHTSA) requires state departments to conduct annual seat belt usage surveys. The survey design in Montana consists of 120 sites in which binomial responses on seat belt use are collected and used as the response for 2010, 2011, and 2012. Covariate data, including demographic, highway, and weather conditions, as well as MDT program variables were obtained from MDT and public sources. We used logistic regression to model seat belt compliance as a function of the covariates. The fitted model showed increased compliance after MDT's media campaign, as well as a decrease in compliance when media advertisement were used in conjunction with Buckle Up Montana Coalitions when compared with no Buckle Up Montana Coalitions. Weak evidence of change in compliance was found for Driver's Education rates, media dollars spent in absence of Buckle Up Montana Coalitions, and Selective Traffic Enforcement Program efforts. Follow-up analyses suggested a saturating relationship between media expenditures and seat belt use rates, though this finding merits further investigation. We provide MDT with recommendations for future data collection methods to isolate the effects of the individual programs as well as a power analysis suggesting a sample size of approximately 900 samples at each site to detect a shift in seat belt compliance from 80% to 85%.

Contents

| | | |
|-------|--|----|
| 1 | Introduction | 3 |
| 2 | Methods | |
| 2.1 | Data Collection | 4 |
| 2.2 | Complete vs. Incomplete Data Sets | 4 |
| 2.3 | Analysis | 5 |
| 3 | Results | 8 |
| 4 | Discussion | |
| 4.1 | Interpretation of Findings | 9 |
| 4.2 | Data Limitations | 9 |
| 4.3 | Recommendations for Future Data Collection | 10 |
| 4.3.1 | Isolating STEP Effects | 11 |
| 4.3.2 | Isolating Media Effects | 11 |
| 4.3.3 | Isolating Driver's Education Effects | 11 |
| 4.3.4 | Isolating BUMT Effects | 12 |
| 4.3.5 | Power Analysis | 12 |
| 4.4 | Data Collection Discussion | 13 |
| A | Acknowledgements | 15 |
| B | Bibliography | 15 |
| C | Code | 16 |

List of Figures

| | | |
|---|---|----|
| 1 | Intensity map | 3 |
| 2 | Sampling map | 4 |
| 3 | Complete versus incomplete county information | 6 |
| 4 | Model Estimates | 7 |
| 5 | Added Variable Plot | 8 |
| 6 | Comparison of Media Subset Model Effects | 10 |
| 7 | Power Curve | 13 |

List of Tables

| | | |
|---|--|----|
| 1 | Selected model covariates | 7 |
| 2 | Model Estimates (no curvature) | 9 |
| 3 | Model Estimates (media subset including curvature) | 10 |

1 Introduction

Seat belt use is widely accepted as the best means for preventing deaths in vehicular accidents (Houston & Richardson, 2005). Therefore, federal agencies have imposed criteria and have offered incentives for state transportation departments to increase seat belt usage as a method for reducing traffic fatalities (NHTSA, 2001, 2002). State transportation departments aim to increase occupant protection by employing the use of seat belt education, outreach, and enforcement programs primarily funded by the National Highway Transportation and Safety Administration (NHTSA).

States further increase seat belt compliance through police enforcement using either primary or secondary laws. Law enforcement may ticket a motorist for not wearing a seat belt in states with a primary law; while in secondary law states, motorists will only receive a ticket for not wearing a seat belt if pulled over for another offense. Montana has maintained a high seat belt use given that it has a secondary enforcement law, with rates exceeding 80%. However, recent declines in overall seat belt use (from 79.2 to 78.9) along with increased traffic fatalities (from 189 to 209) from 2010 to 2011 prompted further investigation of the efficacy of the occupant protection programs being conducted by the Montana Department of Transportation (MDT) at the request of NHTSA.

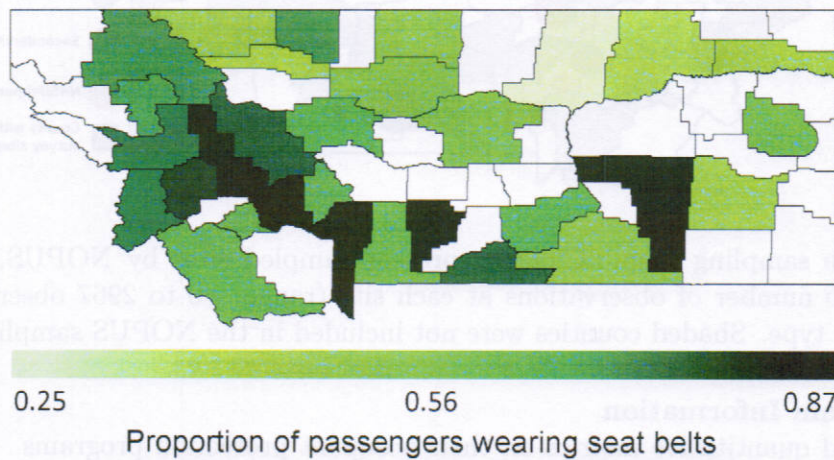


Figure 1: Intensity map shaded by proportion of drivers and front passengers wearing seat belts by county.

The team conducted a thorough evaluation for MDT's occupant protection programs, specifically targeting the extent to which programs are effective at increasing seat belt use. Administrative evaluations of individual programs are routinely conducted, but this analysis seeks to also understand the relationship between programs operating simultaneously in the same jurisdiction so MDT can allocate funding to have the greatest impact on increasing seat belt compliance across the state.

NHTSA requires states to collect yearly buckle rate information for occupants of front seats as part of the National Occupant Protection Usage Survey (NOPUS). This analysis relies on NOPUS data along with MDT program information and other covariate data to evaluate the effectiveness of the occupant protection programs conducted by MDT from 2010 to 2012.

2 Methods

2.1 Data Collection

NOPUS Seat Belt Use Data

Response data obtained from NOPUS consisted of seat belt usage data for drivers and their front seat passengers at pre-specified sites annually. Montana conducts the survey twice each year. The first sampling event occurs in late April and the second during June at the same site; between these sampling events, the MDT conducts a major media campaign aimed at improving seat restraint usage at some sites. We selected the three years (2010, 2011, and 2012) of NOPUS data available in electronic form for the analysis. Covariate data available for each NOPUS site include road type (with possible values of “Interstate”, “County/Secondary road”, “City road”, and “Highway/Primary road”) as well as the name of the data collector, time and day of each sampling, and duration of sampling. Figure 2 shows the spatial representation of the sampling sites and the number of observations during the three years considered for the analysis.

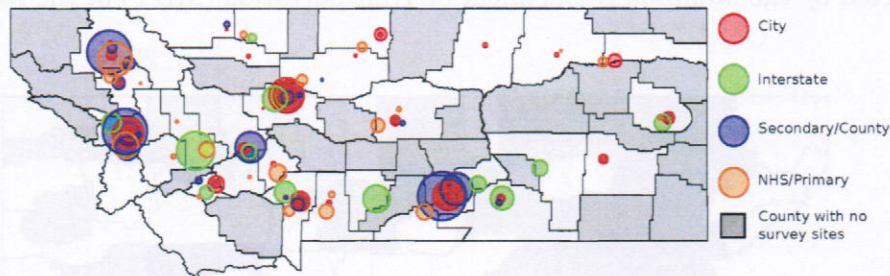


Figure 2: Site sampling map. Circles represent sampled sites by NOPUS, diameter of circle corresponds to number of observations at each site (range: 80 to 2967 observations), and color indicates road type. Shaded counties were not included in the NOPUS sampling design.

MDT Program Information

MDT provided quantitative metrics on their occupant protection programs. The four programs of interest are Driver’s Education, Selective Traffic Enforcement Programs (STEP), Media advertisements, and Buckle Up Montana (BUMT).

Driver’s Education: Driver’s education is available to all Montana high schools through an application process, and nearly all proposals are granted funding through the state Office of Public Instruction. Along with basic traffic laws, these courses provide students with information on the importance of seat belt usage. If these seat belt usage components work as intended, then students who attend the driver’s education courses will have a higher seat restraint usage rate than those who do not attend. Quantitative measures were obtained for this program by averaging the cost per student in each school district that corresponded to a NOPUS sample site.

Selective Traffic Enforcement Programs (STEP): STEP is conducted in conjunction with MDT and the Department of Justice Highway Patrol. Programs consist of employing additional policing efforts at specific locations and are typically conducted around major events (such as New Year’s and county fairs). City, county, and larger jurisdictions can

apply for funding, so the spatial levels vary across the state. MDT provided the number of additional officer hours planned for each event and the size of the enforcement area for each. Planned hours were converted to a standardized measure of effort by dividing the number of STEP hours planned by the population and size of the jurisdiction to facilitate comparisons across spatial areas.

Media: MDT purchases broadcast media time for advertisements promoting seat belt usage. MDT conducts its major campaign between sampling events each year, and consists of TV, radio, cable, and on-line components. Total media costs within each county represents the media effort for each sampling site.

Buckle Up Montana (BUMT): BUMT Coalitions operate in particular funded counties or cities and provide seat belt usage information through physical displays, booths, and activities. These programs are similar to media efforts in that they are public information displays, but differ in that they are much more hands-on than traditional media campaigns. An indicator for BUMT Coalition presence/absence at each site serves as the measure of effort for the model since no information regarding effort (dollars spent, hours allocated, etc.) was available.

Demography

Previous research suggests population density and socioeconomic status are somewhat predictive of seat belt usage (Morgan, 1967; Robertson *et al.*, 1972; for Disease Control, 1986; Hansell & Mechanic, 1990; Piana & Schoenborn, 1993; Nelson *et al.*, 1998; Schoenborn, 1988; Colgan *et al.*, 2004). Total population and median income estimates were obtained from the 2010 U.S. Census data (Bureau, n.d.) for all Montana counties in the NOPUS sampling space.

Weather Condition Information

Other literature suggests that weather is also a potential predictor of seat belt use. This information was gathered from on-line weather resources (weatherunderground.com) by querying the nearest city or weather station to the sampling location for the day of sampling. Total daily precipitation and mean temperature were recorded for each NOPUS sampling event.

2.2 Complete vs. Incomplete Data Sets

Sampling events with missing MDT program covariate information were removed from the initial data analysis. Omission of these 19 sites resulted in the removal of seven counties from the analysis. Complete and incomplete counties (see Figure 3) were compared in a follow-up analysis to assess whether covariates were missing systematically or at random. In general, the removed counties were rural and had a smaller population than the counties with complete data. However, some rural counties with small populations contained all covariates and contributed to the analyses.

2.3 Analysis

Binary response data are typically analyzed through logistic regression approaches. These models use an inverse logit link to relate the linear combination of predictors to the probability of success (seat belt use). Multilevel modeling was used to account for the hierarchy of sites nested within counties and observed multiple times each year. Likelihood ratio tests were conducted to determine

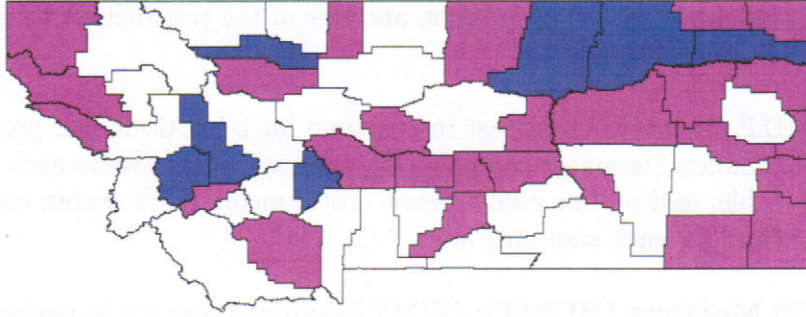


Figure 3: Complete versus incomplete county information. Pink shading represents the 26 counties with complete information, blue shading represents the seven counties removed from the analysis due to missing covariate information, and no shading represents the 23 counties not included in the sampling plan.

the hierarchical structure of the model, followed by likelihood ratio tests to determine the fixed effects structure.

Table 1 shows the selected covariates and their structure for the initial model including hierarchical terms. This model was used to estimate the probability of seat restraint usage given demography, MDT programs as well as highway and condition predictors. All continuous predictors were standardized ((observation - median)/standard deviation) to facilitate model convergence. Its structure is of the form:

$$P(y_{ijk} = 1) = \text{logit}^{-1}(\mathbf{X}_{ij}\beta + \mathbf{Z}_i\mathbf{b}_i + \mathbf{Z}_{ij}\mathbf{b}_{ij})$$

$$i = 1, 2, \dots, 23 \text{ counties and } j = 1, 2, \dots, 120 \text{ sites}$$

y_{ijk} = number of seat belts used in vehicle k at site j in county i

\mathbf{X}_{ij} = values associated with site and county level predictors

\mathbf{Z}_i = values associated with county random effects

\mathbf{Z}_{ij} = values associated with site (within county) random effects

Coefficients estimates from the model (with 50% and 95% confidence intervals) are shown in Figure 4. MDT programs showed weak evidence for impacting the odds of seat belt use. Program effects were further investigated using a model excluding MDT covariates. The residuals from this reduced model were plotted against the metric quantifying each programs' activity (see Figure 5). Figure 5 shows that the selected model missed apparent curvature between the residuals of the

| Covariate | Effect | Description |
|----------------------|--------|---|
| Stratum | Fixed | Categorical variable with four levels; Interstate, City, Primary roads, Secondary/County Roads |
| Precipitation | Fixed | Quantitative; daily precipitation for each sampling event in inches |
| Year | Fixed | Categorical variable with three levels (2010, 2011, 2012) indicating year of sampling event |
| Mean Temperature | Fixed | Quantitative; average daily temperature for each sampling event in degrees Fahrenheit |
| Population | Fixed | Quantitative; county population for each site (per 2010 US Census data) |
| Median Income | Fixed | Quantitative; county median county income for each site (2010 US Census data) |
| Driver's Education | Fixed | Quantitative; average student driver's education completion rate for the nearest school district to the sampling site (if applicable) |
| Media | Fixed | Quantitative; total media dollars spent in the county for each sampling site per year |
| BUMT Coalition | Fixed | Categorical; two levels representing presence or absence of a Buckle Up Montana Coalition in the county of each sampling site |
| STEP | Fixed | Quantitative; Selective Traffic Enforcement Program planned hours standardized by area and population of jurisdiction |
| County | Random | Intercept adjustment for county-level seat belt usage |
| Site (within County) | Random | Intercept adjustment for site-level (within county) seat belt usage |

Table 1: Selected model covariates for analysis on entire data set (not subsetted). Includes fixed or random definition, and description of each variable and how it is measured.

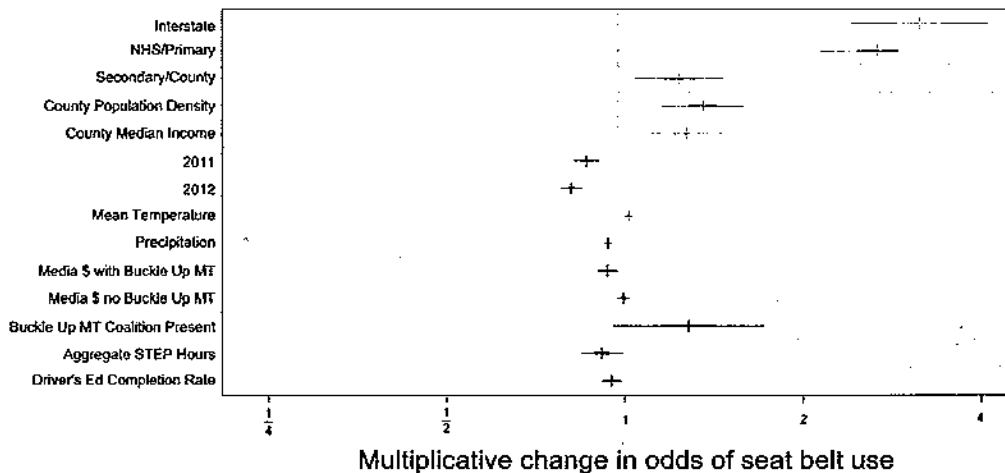


Figure 4: Model estimates (vertical line) with 50% and 95% confidence intervals for the multiplicative change in odds of seat belt use over baseline (City roads and 2010).

reduced model versus the total media cost and STEP hours metrics. Past research suggests a saturation effect of marketing where after listening to monotonous advertisement, an individual will begin to block it out, allowing no additional effects of the marketing tool.

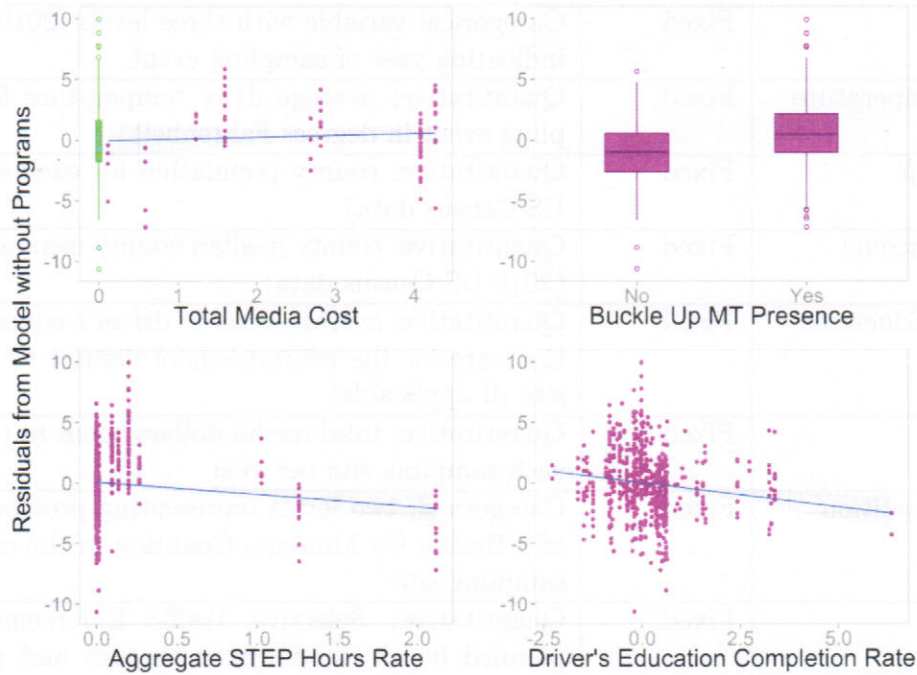


Figure 5: Added variable plot. Vertical axis represents residuals from the reduced model (no MDT program measures), and the horizontal axis represents the quantitative measure for each of the four MDT programs of interest in this analysis.

New models were fit on the Media presence (at least some media effort) and absence (no media effort) subsets of the data excluding any interactions with the BUMT indicator. The new models included quadratic effects for STEP hours, and the model subsetted on media presence also included the quadratic effect for media effort. Only one city (Billings) had a BUMT Coalition without any media effort which prevented estimation of the effects of BUMT from being estimated in the media presence model. The resulting coefficient estimates (with 50% and 95% confidence intervals) for both models are displayed in Figure 6.

3 Results

Odds of seat belt compliance increased for interstates (estimate = 3.23, p-value < 0.01), highways/primary roads (estimate = 2.74, p-value < 0.01), and county roads (estimate = 1.27, p-value = 0.01) when compared to city roads. County level demographic predictors—county median income and county population density—were also associated with increased compliance (estimates = 1.39 and 1.30 (respectively), p-values < 0.01). Indicators for 2011 (estimate = 0.88, p-value < 0.01) and 2012 (estimate = 0.83, p-value < 0.01) were associated with decreased compliance over 2010. Odds of seat belt use increased with mean daily temperature (estimate = 1.04, p-value < 0.01), and decreased with increased precipitation (estimate = 0.96, p-value < 0.01). Increased media effort (dollars spent, standardized) was associated with a slight (not statistically significant)

increase in seat belt compliance when conducted in the absence of a Buckle Up Montana Coalition (estimate = 1.02, p-value = 0.08). Odds of compliance decreased for media effort when conducted in presence of a Buckle Up Montana Coalition (estimate = 0.94, p-value < 0.01). Buckle Up Montana Coalitions on average were associated with a large (but statistically insignificant) increase in odds of seat belt use (estimate = 1.31, p-value = 0.07). Aggregate STEP hours and Driver’s Education Completion Rate were both associated with small, but non-significant decreases in odds of seat belt compliance (estimates = 0.94 and 0.97, p-values = 0.11 and 0.18, respectively).

| | Estimate | Std. Error | z value | Pr(> z) |
|-------------------------------------|----------|------------|---------|----------|
| (Intercept) | 1.36 | 1.14 | 2.41 | 0.02 |
| Interstate | 3.23 | 1.14 | 8.67 | 0.00 |
| NHS/Primary | 2.74 | 1.12 | 8.68 | 0.00 |
| Secondary/County | 1.27 | 1.09 | 2.66 | 0.01 |
| Precipitation (std.) | 0.96 | 1.01 | -5.02 | 0.00 |
| 2011 | 0.88 | 1.03 | -4.91 | 0.00 |
| 2012 | 0.83 | 1.02 | -9.00 | 0.00 |
| Mean Temp. (std.) | 1.04 | 1.01 | 4.53 | 0.00 |
| County Population Density (std.) | 1.39 | 1.09 | 4.01 | 0.00 |
| County Median Income (std.) | 1.30 | 1.07 | 3.81 | 0.00 |
| Driver’s Ed. Completion Rate (std.) | 0.97 | 1.02 | -1.35 | 0.18 |
| Total Media Cost– No BUMT (std.) | 1.02 | 1.01 | 1.75 | 0.08 |
| BUMT Coalition Present | 1.31 | 1.16 | 1.81 | 0.07 |
| Aggregate STEP Hours Rate (std.) | 0.94 | 1.04 | -1.58 | 0.11 |
| Total Media Cost– With BUMT (std.) | 0.94 | 1.02 | -4.13 | 0.00 |

Table 2: Coefficient estimates, standard errors, z-values, and p-values for model on total data set.

The model subsetted on media presence (at least some media effort) suggests evidence for a curvature effect of media dollars (estimate = 0.77, p-value = 0.01). Figure 6 shows the estimates with 50% and 95% confidence intervals for the two media subsetted models (some media and no media expenditures). These results show disagreement between the model estimates, indicating either correlations between covariates, and/or the need for better data to better estimate the effects.

4 Discussion

4.1 Interpretation of Findings

The results from the analysis suggest a decreased effect on seat belt compliance for areas co-conducting media campaigns and BUMT coalitions. Therefore, MDT should consider separating the media and BUMT campaigns in all counties (the level which these programs are funded) in order to most efficiently allocate funding and save more lives. There is evidence of quadratic effects for media expenditures, potentially indicating an effect of diminishing marginal returns on media investment.

The results suggest strong evidence for an increase in the odds of seat belt compliance for interstate, highway, and secondary/county roads over the baseline of city roads. These results are

| | Estimate | Std. Error | z value | Pr(> z) |
|--|----------|------------|---------|----------|
| (Intercept) | 1.06 | 2.28 | 0.07 | 0.95 |
| Secondary/County | 0.84 | 1.17 | -1.13 | 0.26 |
| Precipitation (std.) | 0.99 | 1.02 | -0.71 | 0.48 |
| Mean Temp. (std.) | 1.11 | 1.04 | 2.79 | 0.01 |
| County Population Density (std.) | 1.32 | 1.15 | 1.95 | 0.05 |
| County Median Income (std.) | 0.96 | 1.08 | -0.60 | 0.55 |
| Driver's Ed Completion Rate (std.) | 0.56 | 1.10 | -6.31 | 0.00 |
| Total Media Cost (std.)- linear | 3.14 | 1.80 | 1.94 | 0.05 |
| Total Media Cost- squared | 0.77 | 1.11 | -2.44 | 0.01 |
| Aggregate STEP Hours Rate (std.)- linear | 1.12 | 1.63 | 0.24 | 0.81 |
| Aggregate STEP Hours Rate- squared | 0.98 | 1.06 | -0.41 | 0.68 |

Table 3: Coefficient estimates, standard errors, z-values, and p-values for model subsetted on media presence, and includes estimates for curvature in media cost and STEP hours.

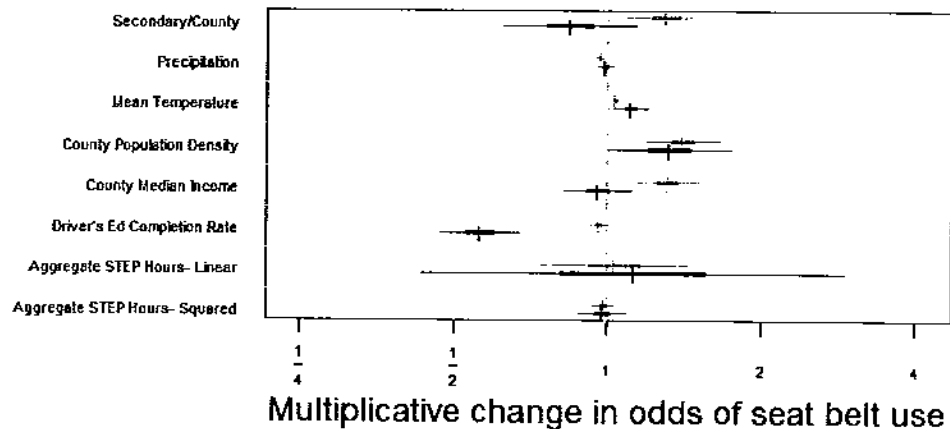


Figure 6: Comparison of model coefficients for models on the no media subset and at least some media subset. Light lines show estimates with 50% and 95% confidence intervals for the no media subset model, and black lines show estimates and 50% and 95% confidence intervals for the at least some media subset.

consistent with previous research. Higher county population density and county median income were associated with increased seat belt compliance. It was also found that 2011 and 2012 were associated with decreased odds of seat belt compliance when compared to the baseline of 2010, and is consistent with MDT's concern for decreasing state-wide seat belt use over the three years considered in the analysis. Finally, the analysis suggested strong evidence for increased odds of seat belt use with higher mean daily temperature and decreased odds for increased daily precipitation (rain and snow).

4.2 Data Limitations

Differences between the effects of BUMT on seat belt compliance in sites with media versus sites without media could not be estimated since only one site (Billings) had a BUMT Coalition and no media expenditures. Further data collection is required for sites with varying media expenditures

and BUMT presence/absence if the goal of MDT is to estimate BUMT's effect across different media allocation.

The estimates and standard errors shown in Figure 6 suggest evidence of interactions between predictors. The effect of county median income on the odds of seat belt compliance potentially depends media effort presence/absence. The estimates suggest increased odds of compliance for county median income in no media sites and decreased odds of compliance in the sites with at least some media. Future analyses should account for these potential interactions between predictors to help MDT fully understand the effects of their programs on seat belt compliance.

The estimated effect of BUMT coalitions on seat belt compliance was relatively large but not statistically significant. A better estimate of the effect of these coalitions could be achieved through a more precise measure of its effort rather than through the use of an indicator variable. MDT may consider measuring this through hours expended at each event, dollars spent on each event, or number of individuals participating. A better measure of BUMT effort could result in a more precise estimate of its effect and smaller confidence intervals.

4.3 Recommendations for Future Data Collection

Correlations exist between covariates, and were identified in preliminary analyses (not discussed in this document). The correlations between covariates (such as income and media effort) provide difficulties in identifying the major contributors of changes in seat belt compliance. The NOPUS design is unable to provide estimates of individual program effects in the absence of all other MDT intervention programs. We provide examples of designs aimed at isolating each program's effect on compliance to provide MDT with information on how effective each program is at influencing seat belt compliance. The designs considered next are for illustrative purposes, and MDT should fully consider the expected returns on conducting any of these designs.

4.3.1 Isolating STEP Effects

Selective Traffic Enforcement Program showed weak evidence for increasing seat belt compliance in the analyses discussed previously. However, detecting its effect from the study design may be difficult due to the infrequent occurrence of STEP effort. To better quantify the effect of these programs, we recommend conducting a separate study from the NOPUS design. A potential study design is to randomly sample sites and times which STEP efforts are being conducted, and record the number of drivers (and passengers) wearing and not wearing seat restraints. Sampling events for this design would occur both before passing and after passing the officer employed through STEP. Data collection distance before the officer should be far enough away to be potentially independent of the STEP effort (far enough away so a vehicle occupant cannot see the officer, but close enough to likely pass the officer and be recorded again). The second sampling event should be close enough to the officer as to maximize the likelihood of observing the same drivers as the first event.

4.3.2 Isolating Media Effects

Effects of media effort on seat belt compliance showed weak support for increased seat belt compliance. MDT may be interested in the individual effects of each type of media allocation on seat

belt compliance. This type of design would inform MDT which media programs have the highest (or lowest) impact so they can allocate media funding most efficiently.

- **Billboards**

Isolating the effects of billboard media campaigns may be conducted similar to the proposed STEP study design. Again, sampling could occur before and after a billboard that suggests seat belt usage, ensuring the same vehicles are likely to be measured twice (before and after the media). However, billboards may be unlikely to affect immediate seat belt compliance. MDT may consider conducting a follow-up survey questioning motorists on their likelihood to change their behavior given they saw a billboard promoting seat belt usage.

- **TV/Radio**

Television and radio broadcasts reach a large number of people, but it is nearly impossible to know who received their information while conducting observational data collection methods as in the NOPUS design. Therefore, a more effective tool for understanding their impact may be the use of survey data. In this way, (preferably) randomly selected individuals could complete a survey asking whether or not they heard a TV or radio advertisement for seat belt usage, and if that advertisement influenced their seat belt compliance. Although this design may introduce new sampling bias, it would potentially provide better estimates of individual media campaign efforts.

- **Internet**

Internet advertisement may reach the largest number of people (especially in urban areas of the state) at the lowest cost. However, like TV and radio campaigns, it is difficult to measure the effect they have on influencing seat belt usage. Unlike TV and radio, Internet advertisements are unique in their ability to obtain immediate feedback. For example, if exposed to on-line advertisement, a simple radio-button questionnaire could be prompted for the viewer to opt in for answering. Similar issues to the other media campaigns for bias are introduced, especially response bias with users being more likely to opt out given the ease of which to do so.

4.3.3 Isolating Driver's Education Effects

The upcoming changes to Driver's Education programs should prompt a study to evaluate program effectiveness for the Office of Public Instruction. MDT should consider the questions they would like to address before designing the sampling scheme. For example, if the goal is to estimate the effectiveness of Driver's Education on seat belt use for high school students, they may consider sampling outside of a high school parking lot before and after the Driver's Education course is conducted. Although this sampling design would not allow the surveyor to detect which sampled units (drivers/passengers) were actually enrolled in Driver's Education, it would better isolate the impacts of the program on the individuals most likely enrolled (i.e. high school students).

4.3.4 Isolating BUMT Effects

Isolating the effects of the Buckle Up Montana campaigns on seat restraint compliance is difficult from the NOPUS data alone given the displays are not necessarily conducted around the sampling events. Therefore, MDT may consider evaluating the BUMT coalitions' effect in two possible methods; request questionnaires to be filled out by participants inquiring on their previous seat

belt usage, and their likelihood to change their behavior after participating, or collect seat belt usage data before and after the event at which the display is being conducted. The first method may introduce sampling bias (response bias for questionnaire), and the effects of the campaign in the second method may be correlated with the event at which the display was present.

4.3.5 Power Analysis

We conduct a power analysis to estimate the sample size required to detect a specified shift in compliance for each program. This analysis was modeled for the designs aimed at isolating each individual program effect in a single targeted location (described previously). The samples in each design will depend on the type of program effect to be tested. For example, the samples for testing STEP effects would be vehicles (pre- and post- intervention program), and surveys for testing broadcast media effects. We want to detect a 5% increase in compliance over 80% (a typical state-wide compliance rate for Montana).

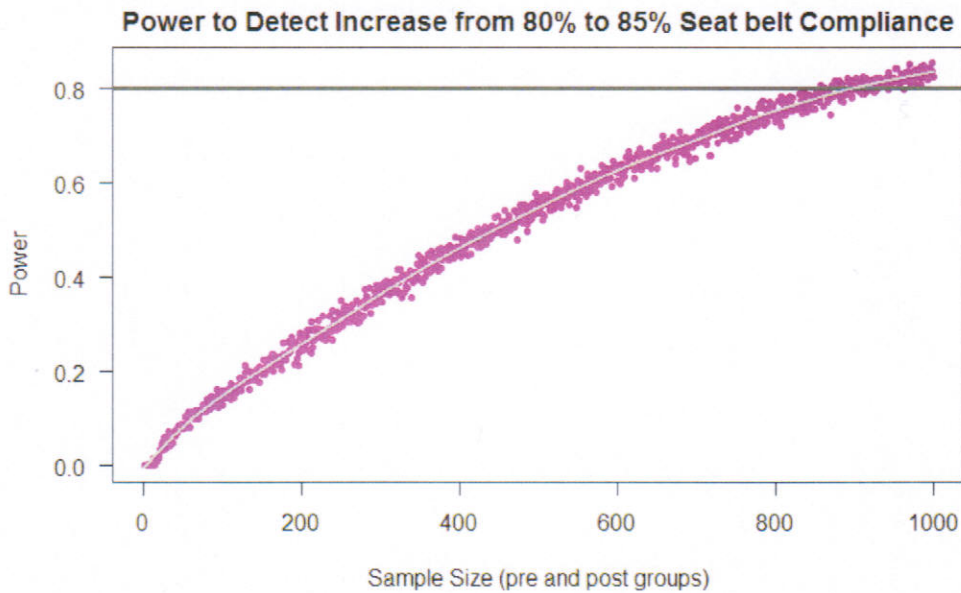


Figure 7: Power curve for isolation of MDT program effects. Horizontal line drawn at a power level of 0.80, suggesting a sample size of approximately 900 samples to detect a 5% increase in compliance over 80%.

The model for this analysis is assumed to be $P(y_i = 1) = \text{logit}^{-1}(\beta_0 + \beta_1 x_i)$ where β_1 represents the effect of the MDT seat belt intervention program. A Wald's test for this effect is conducted on simulated data, and the rejection rate is recorded for multiple sample sizes. For this analysis, the power was specified at 0.80, the significance (α - level) at 0.05, and we want to detect an increase in seat belt use from 80% to 85%. The plot in Figure 7 suggests a sample size of approximately 900 or more for the pre- and post- program measures to obtain a power of approximately 0.80.

4.4 Data Collection Discussion

MDT expressed interest in understanding the individual effects of each program along with the aggregate effects of multiple programs operating in a given jurisdiction (city, county, etc.). The

previously proposed study designs would not allow for estimation of effects of multiple programs, but would give MDT a clearer idea of how each program effects compliance individually. This would be especially interesting if the curvature in the media expenditures was apparent after isolating its effects from the other programs. This type of design could lend itself to future data collection methods to more fully understand the impacts of conducting multiple programs in a single jurisdiction. If results such as the interaction of media expenditures and BUMT (resulting in a decrease in odds of compliance when conducted together versus separated), MDT could alter the domain of the programs and achieve higher seat belt compliance with fewer resources used. Discovering the most efficient allocation of resources heavily depends on the quality of data collection employed by MDT, and this should be heavily considered as MDT moves forward in promoting seat belt use as a way to save lives from vehicular accidents.

A Acknowledgements

Kezia R. Manlove, MS. Ph.D. Candidate– Pennsylvania State University
Dr. James F. Robison-Cox, Ph.D. Associate Professor– Montana State University
Laura M. Stanley, Ph.D., CPE. Assistant Professor– Montana State University
Western Transportation Institute– Bozeman, MT
Montana Department of Transportation
Kris Christensen
Montana NASA EPSCoR
Montana State University Department of Mathematical Sciences
American Statistical Association Section for Statistical Programmers and Analysts

B Bibliography

References

- Bureau, U.S. Census. *American Community Survey 2010*.
- Colgan, F., Gospel, A., Petrie, J., Adams, J., Heywood, P., & White, M. 2004. Does rear seat belt use vary according to socioeconomic status? *Journal of Epidemiology and Community Health*, **58**, 929–930.
- for Disease Control, Centers. 1986. Seat belt use - United States. *Morbidity and Mortality Weekly Report*, **35**, 301–304.
- Hansell, S., & Mechanic, D. 1990. Parent and peer effects on adolescent health behavior. *Health Hazards in Adolescence*, 43–65.
- Houston, D., & Richardson, L. 2005. Getting Americans to Buckle Up: The Efficacy of State Seat Belt Laws. *Accident Analysis and Prevention*, **37**, 1114–1120.
- Morgan, J. N. 1967. Who uses seat belts? *Behavioral Science*, **12**, 463–465.
- Nelson, D. E., Bolen, J., & Kresnow, M. 1998. Trends in safety belt use by demographics and by type of state safety belt law, 1987 through 1993. *American Journal of Public Health*, **88**, 245–249.
- NHTSA. 2001. Achieving a High Seat Belt Use Rate: A Guide for Selective Traffic Enforcement Programs. *DOT Report*, **HS 809(244)**.
- NHTSA. 2002. Evaluation of Click It or Ticket Model Programs. *DOT Report*, **HS 809(498)**.
- Piana, A., & Schoenborn, C. 1993. Health promotions and disease prevention, United States, 1990. *Vital and Health Statistics Series*, **10(185)**.
- Robertson, L. S., O'Neill, B., & Wixom, C. W. 1972. Factors associated with observed safety belt use. *J Health Soc Behav*, **13**, 18–24.
- Schoenborn, C. A. 1988. Health promotion and disease prevention: United States, 1985. *Vital and Health Statistics Series*, **10(163)**.

C Code

```
# Read in shape files to build GIS
# "Drill down" through GIS layers to extract site-specific covariates using <>

# Transform covariates
# standardize: standardizedcovariate <-
#                   (covariate - median(covariate))/sd(covariate)
# create indicator variables (BUMT)

# Use glmer to build mixed effects models
# model selection via AIC/LRTs on appropriate maximum likelihood structure

# Power analysis

power.fun <- function(reps, beta0, betal, alpha, ngroup){

  # create vectors to be filled
  yrep <- rep(NA, 2*ngroup)
  pvals <- rep(NA, reps)
  rejectvec <- rep(NA, reps)

  # simulate group membership and response
  pred <- c(rep(0,ngroup), rep(1,ngroup))
  resp <- beta0 + betal*pred

  # simulate data
  for(i in 1:reps){
    for(k in 1:(2*ngroup)){
      yrep[k] <- rbinom(1,1,prob=invlogit(resp[k]))
    }

    # fit generalized linear model
    fit <- glm(cbind(yrep, abs(1-yrep)) ~ pred, family=binomial(link="logit"))

    # extract p-value from coefficient of interest
    pvals[i] <- summary(fit)$coefficients[2,4]

    # store wald's test results
    rejectvec[i] <- ifelse(pvals[i] < alpha, 1, 0)
  }

  # find proportion of wald test rejections
  powout <- sum(rejectvec)/reps
  return(list(powout))
}

# sample sizes considered
```

```
ngroups <- 1:1000

# make vector to store
powervec <- rep(NA, 100)

# loop over number in each group (sample size)
for(j in 1:length(ngroups)){
  powervec[j] <- power.fun(reps = 1000, beta0=1.386294, beta1=0.3483067,
                          alpha=.05, ngroup=ngroups[j]) [[1]]
}

plot(powervec)

## Using a built-in function to compute power:
power.prop.test(p1= .8,p2= .85,sig.level= 0.05,power= 0.8)
```