# Messaging and Driving: An Empirical Analysis of Dynamic Message Signs in Virginia

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# Motivation

Traffic crashes and congestion represent two major transportation issues.

- ≈**1.4%** of all deaths in the US are traffic fatalities (40,000 deaths x VSL = 2% of US GDP)
- Drivers in Washington DC lost an average of **124 hours** (5 days) per commuter due to congestion (INRIX, 2019). ≈$3,700 in wages for median income.
- Economists have studied these issues for some time (Vickrey, 1969).
- The US Senate just passed a $1T infrastructure bill.

What can *DOTs* do about these issues?

# What Can DOTs Do?

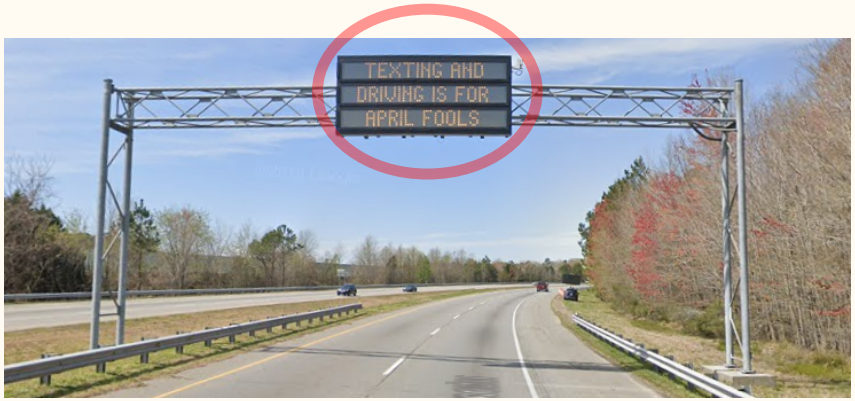
DOTs cannot change traffic laws or infrastructure.
DOTs try to alleviate crash risk and maintain speeds with Highway Signage

- Lessons from billboard advertisements: use simple, relevant, non-transitioning messages (Belyusar et al., 2016; Mollu et al., 2018; Harasimczuk et al., 2018; Reinolsmann et al., 2018).
- Non-traditional messages are most "effective" (Shealy et al., 2020).
- Some safety slogan messaging *increases* crashes (Hall and Madsen, 2021).

# Research Questions

1. What is the impact of general safety campaign slogans on crashes and speed?
2. Does the structure and/or content of the messages matter?

# Types of Dynamic Message Signs



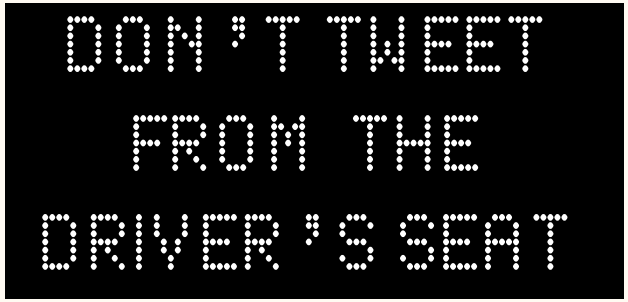

Stationary DMS ✓


Blankout DMS *X*


Portable DMS ✓


Travel Time DMS *X*

# Types of Messages - Safety Messages

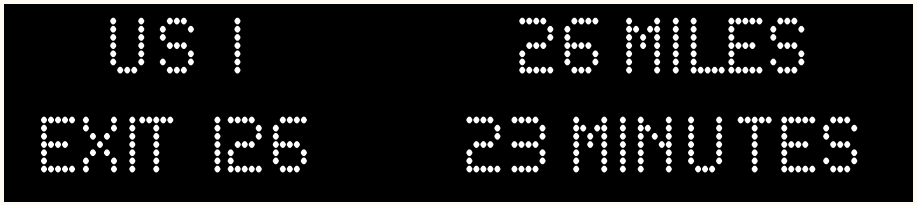



(a) Example 2


(b) Example 2

# Types of Messages - Number of Pages


(a) Single Page Message



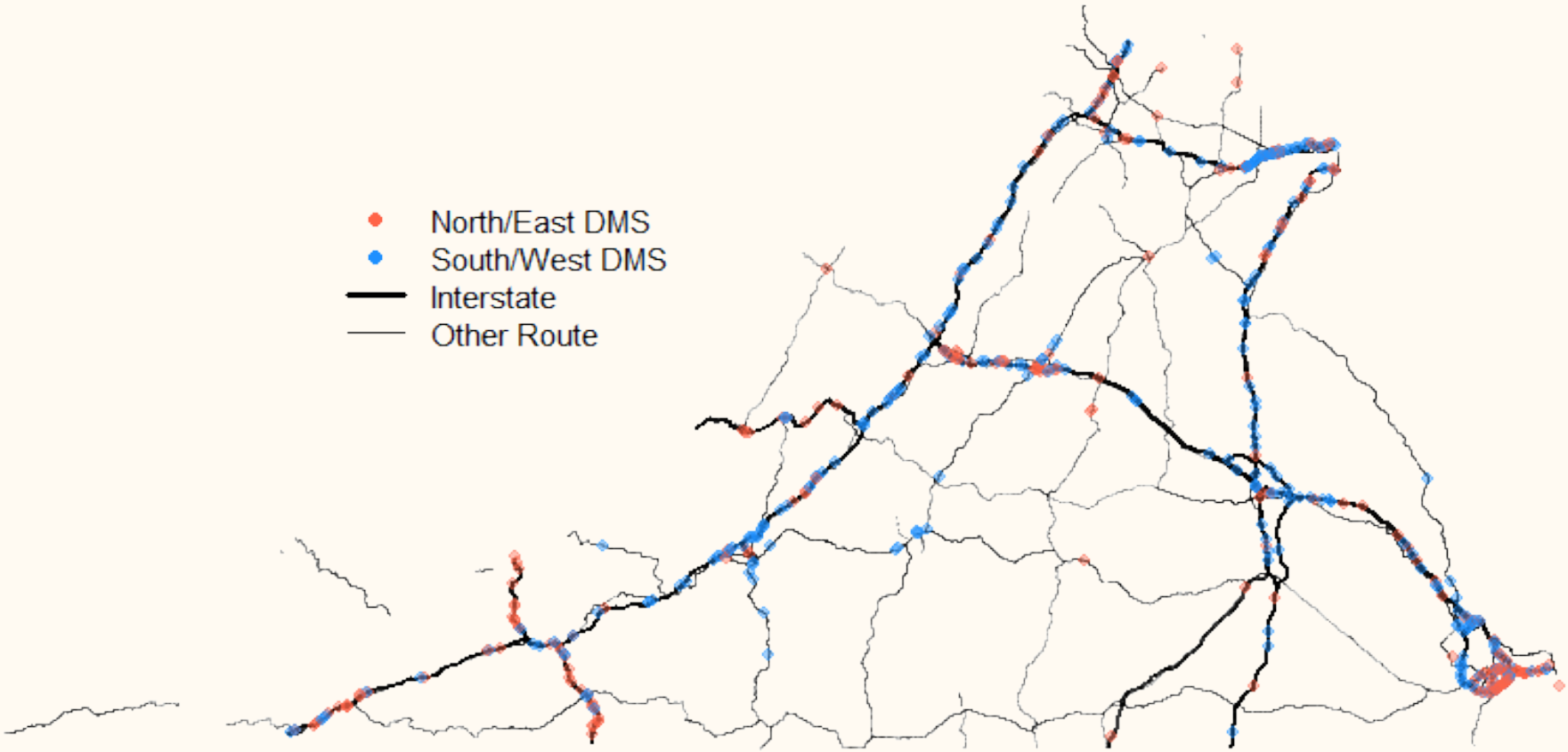

(b) Two Page Message

Example from a DMS on I-95N at mile marker 100

- Crash rates are ≈20% higher for the two page-version of this message
- Difference in average travel time ≈ 30 seconds

# Setting - Virginia

Data come from Virginia Department of Transportation (VDOT)



# Data Sources

Data from VDOT:

- Linear Referencing Location System
- Minute-level DMS logs
  - Timestamp
  - Sign identifier
  - Message text (including on/off status)
  - Location (lat/long)
- Universe of crashes (Police & 511)
  - Report time*
  - Location (mile marker, lat/long)

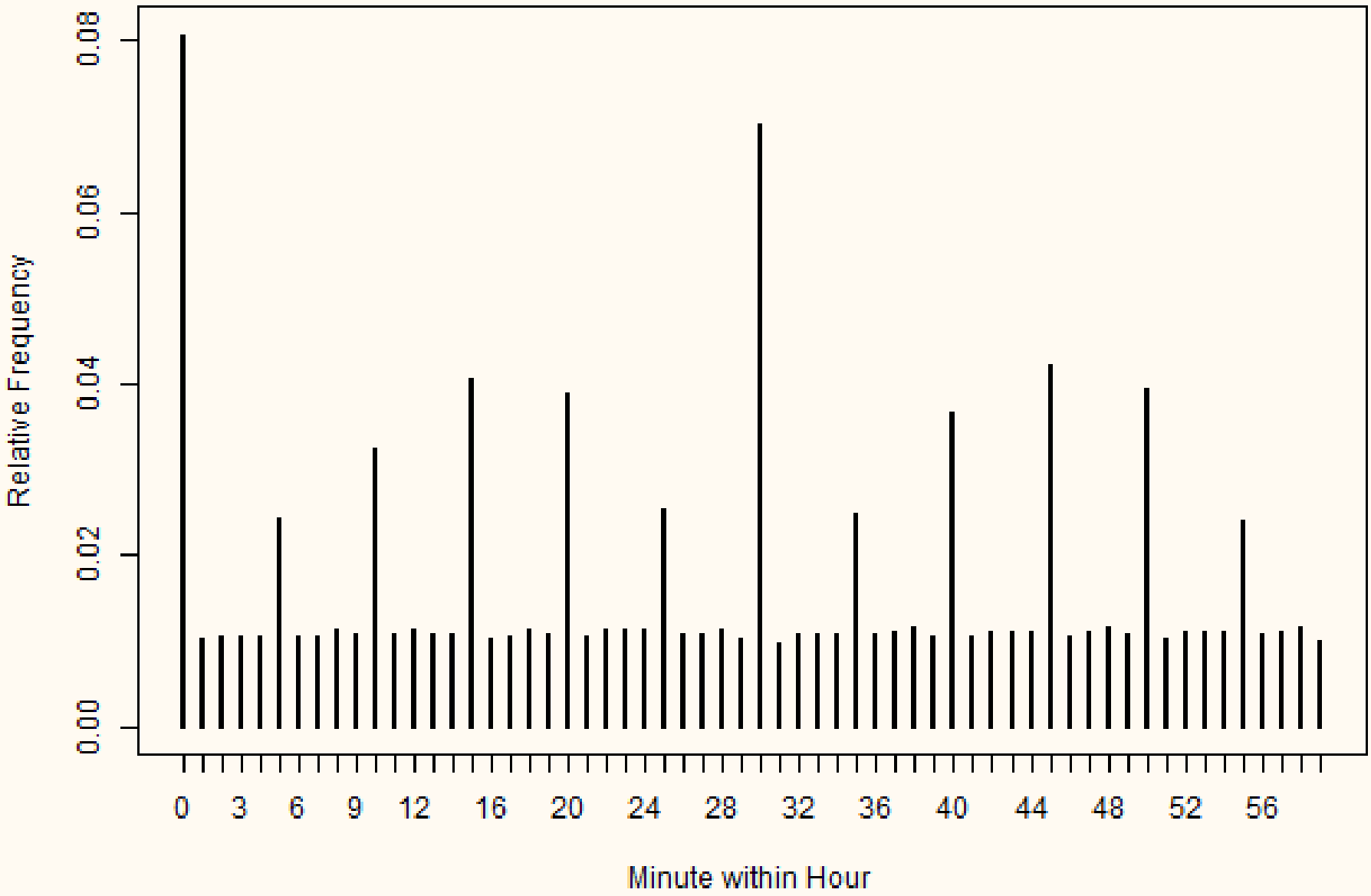
Data from INRIX:

- Hourly speed estimates by segment

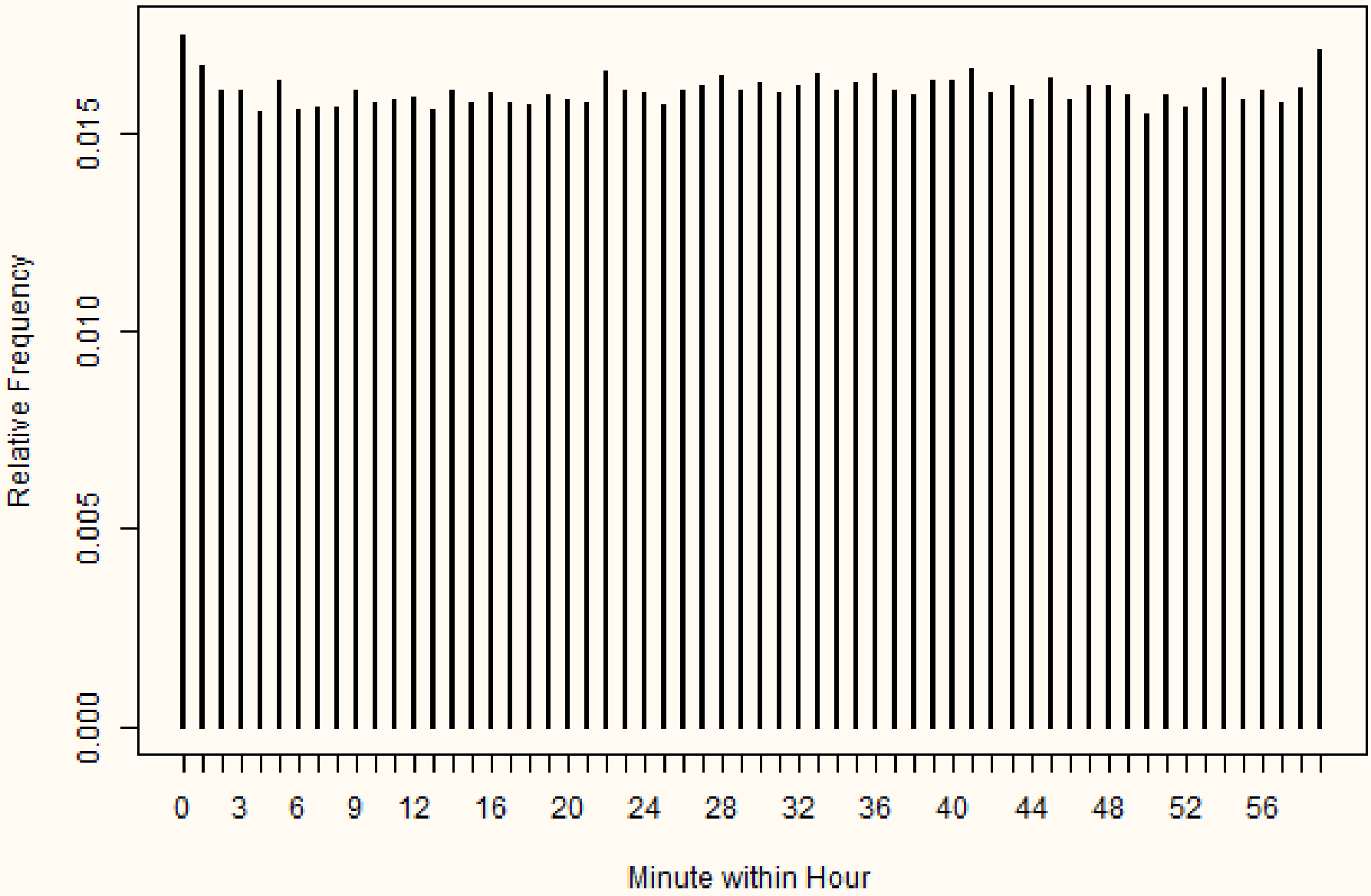
Unit of Analysis: hourly speed and crashes for 391 DMS locations

- Distance between DMS locations in km ($\mu = 14.2, \sigma = 36$) - comparable to Hall and Madsen (2021) ($\mu = 13.7, \sigma = 29$).

# Distribution of Crashes by Minute (DMV)



# Distribution of Crashes by Minute (511)



# Empirical Strategy

**Problem**: Messages, and therefore their characteristics, are not randomly assigned.

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**Solution 1**: Use pre-planned safety campaigns as exogenous variation.

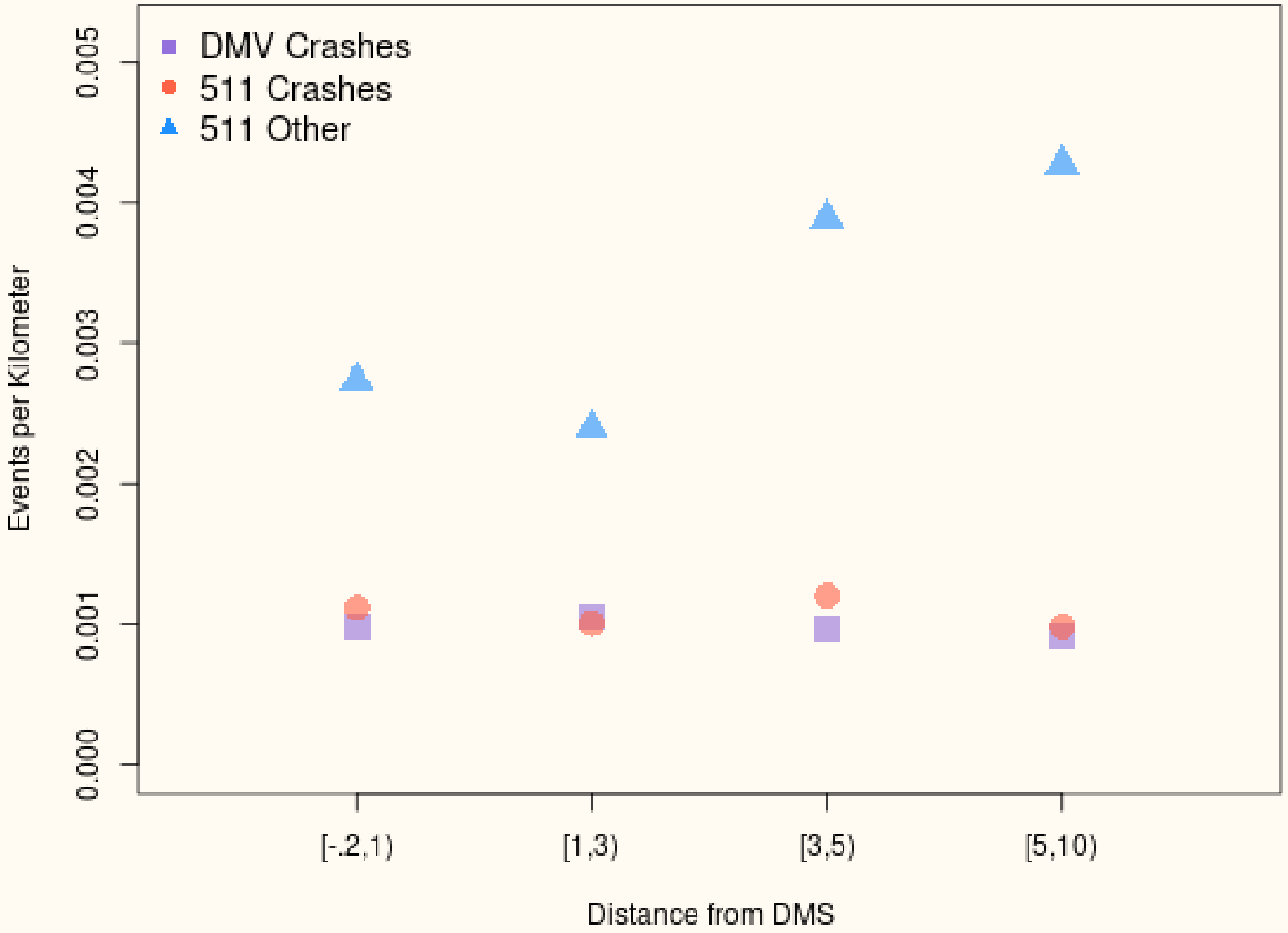
**Solution 2**: Consider DMS information at the *beginning* of an hour.

# Data Summary

| | Mean | St. Dev. | Min | Max |
|---|---|---|---|---|
| Number of DMS | 1.019 | 0.135 | 1 | 2 |
| Stationary DMS | 0.815 | 0.422 | 0 | 2 |
| Portable DMS | 0.204 | 0.408 | 0 | 2 |
| Safety Campaign Day | 0.164 | 0.370 | 0 | 1 |
| Speed at Location | 99.342 | 16.200 | 2 | 129 |
| Number of DMS On | 0.423 | 0.510 | 0 | 2 |
| Saftey Message Displayed | 0.026 | 0.160 | 0 | 2 |
| Crash Message Displayed | 0.030 | 0.172 | 0 | 2 |
| Pages | 0.633 | 0.825 | 0 | 6 |
| Characters | 16.796 | 22.329 | 0 | 156 |

N = 5,614,199

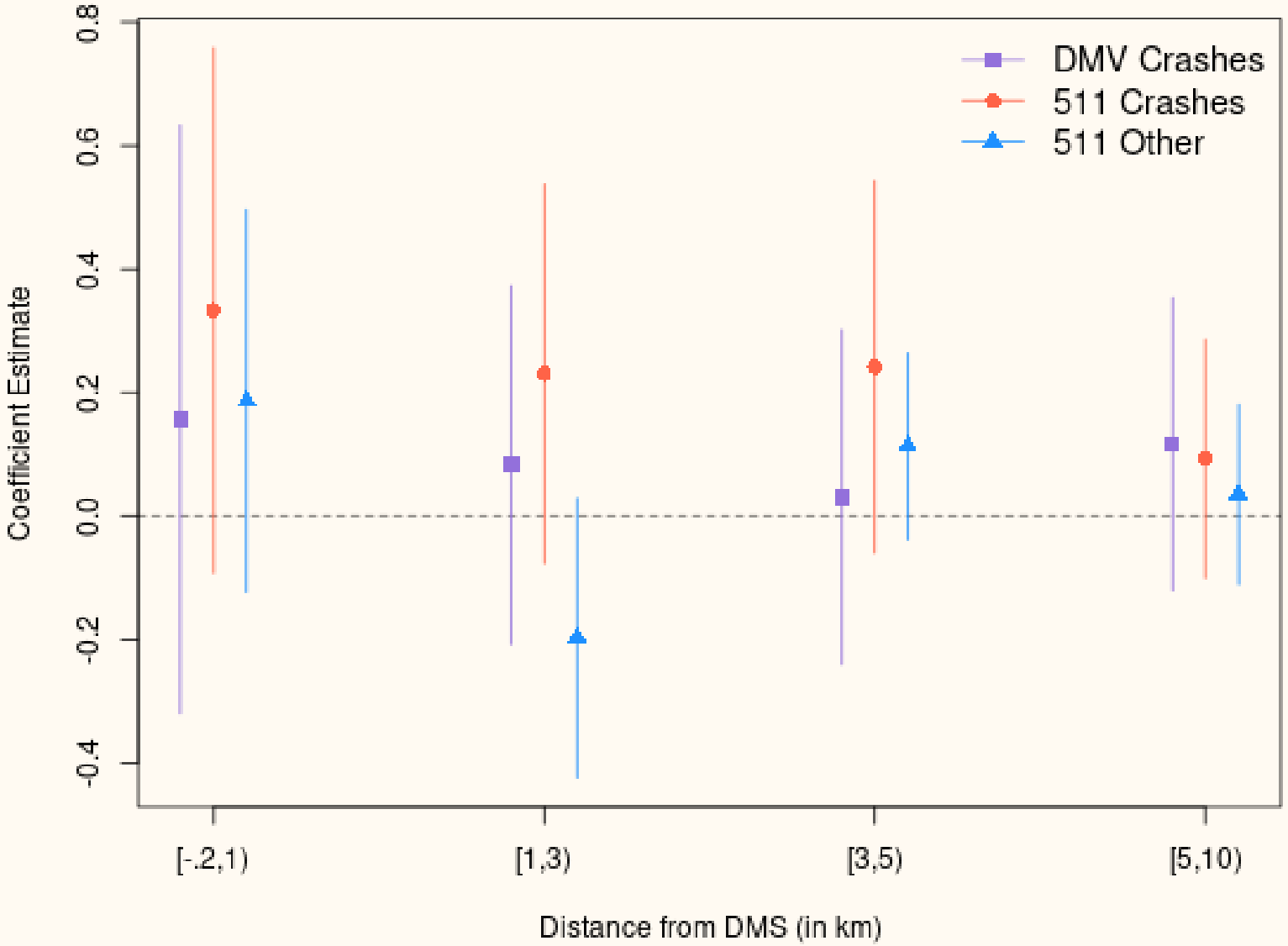
# Data Summary



# Model 1 - Safety Campaigns

$$
\begin{aligned}
Y_{s+k,t} = {} & \alpha \text{DMS On}_{s,t} + \beta_0 \text{Campaign}_t \\
& + \beta_1(\text{Campaign}_t \times \text{Off-Peak}_t) \\
& + \beta_2(\text{Campaign}_t \times \text{DMS On}_{s,t}) \\
& + \beta_3(\text{Off-Peak}_t \times \text{DMS On}_{s,t}) \\
& + \delta(\text{Campaign}_t \times \text{Off-Peak}_t \times \text{DMS On}_{s,t}) \\
& + \mu_{s,m(t),d(t),h(t)} + \tau_{y(t)} + \eta_{holiday} + \epsilon_{s+k,t}
\end{aligned}
$$

# Effect of Safety Campaigns on Incidents Over Space



# Model 2 - Safety Messages

$$
\begin{aligned}
Y_{s+k,t} = \alpha &\text{DMS On}_{s,t} \\
&+ \delta(\text{DMS On x Safety Msg})_{s,t} \\
&+ \beta_1(\text{DMS On x Crash Msg})_{s,t} \\
&+ \beta_2(\text{DMS On x Hazard Msg})_{s,t} \\
&+ \mu_{s,m(t),d(t),h(t)} + \tau_{y(t)} + \eta_{holiday} + \epsilon_{s+k,t}
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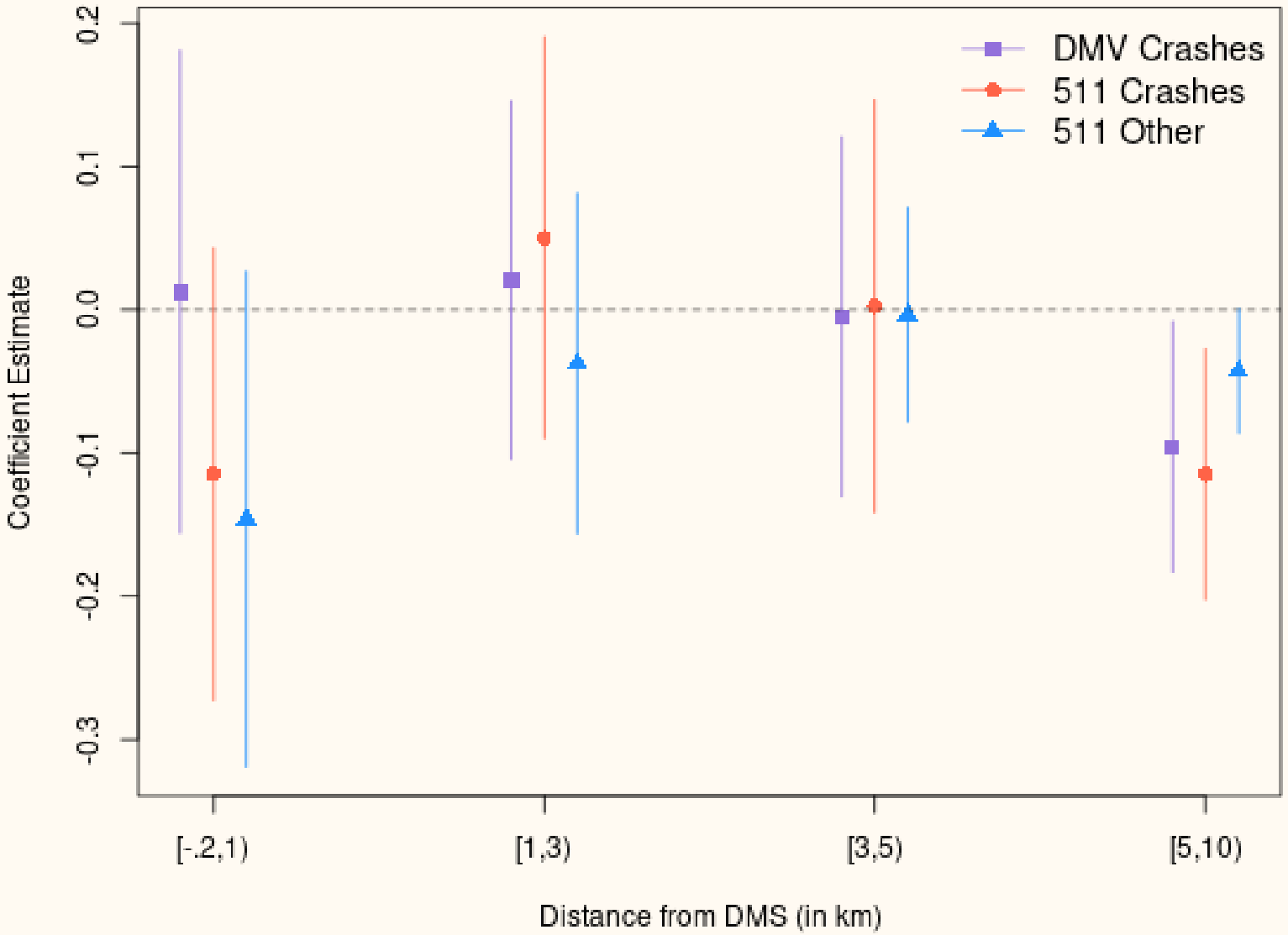
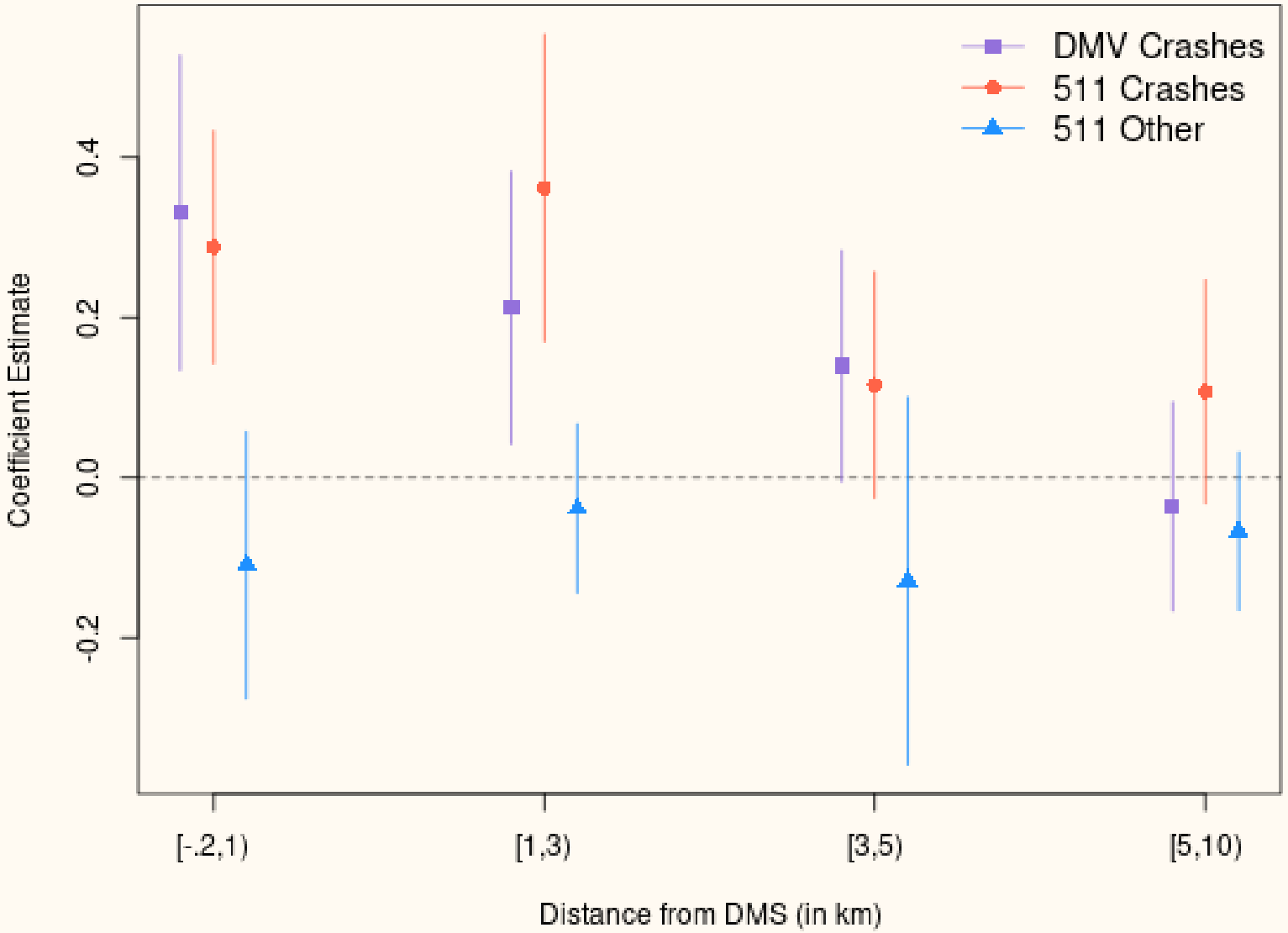


# Model 3 - Message Characteristics

$$
\begin{aligned}
Y_{s+k,t} = {} & \alpha \text{DMS On}_{s,t} \\
& + \delta(\text{DMS On}_{s,t} \times \text{Multi-Page}_{s,t}) + \beta \text{Char}_{s,t} \\
& + \mu_{s,m(t),d(t),h(t)} + \tau_{y(t)} + \eta_{holiday} + \epsilon_{s+k,t}
\end{aligned}
$$

# Effect of Multi-Page Messaging Over Space



# Results - Speed

| | Eq (1) | Eq (2) | Eq (3) |
|---|---|---|---|
| DMS On | -1.075*** | -0.665*** | -1.121*** |
| | (0.127) | (0.144) | (0.291) |
| $\text{Campaign}_t$ x $\text{Off-Peak}_t$ x $\text{DMS On}_s$ | -0.009 | | |
| | (0.140) | | |
| $\text{DMS On}_{s,t}$ x $\text{Safety Msg}_{s,t}$ | | 0.525*** | |
| | | (0.123) | |
| $\text{DMS On}_{s,t}$ x $\text{Multi-Page}_{s,t}$ | | | -1.352*** |
| | | | (0.228) |
| Num. Obs. | 5,583,114 | 5,583,114 | 5,583,114 |
| $R^2$ | 0.791 | 0.793 | 0.791 |
| *Note:* | | | * p $<$ 0.1, ** p $<$ 0.05, *** p $<$ 0.01 |

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  1.5% of *all* highway crashes
- 0.6% of all crashes result in a fatality $\implies$ 1 fatality per month

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  $\implies$ \$200 per driver
- \$200 $x$ 3.45M (2019 VA Employment) = \$700M
  $\implies$ 0.12% of VA's 2019 GDP

- Bento et al. (2020): WTP $>$ Beckerian Value of Time

# Discussion

- DOTs face a tradeoff between keeping drivers informed vs focused
- Updating information in a high stakes setting is (perhaps obviously) costly, in contrast to what DOTs might believe.
  - Decreased safety
  - Decreased speeds
- DOTs should be selective in the timing and formatting of messages to minimize negative externalities
- More research needs to be done on the impacts of DMS use – especially considering the results of Hall and Madsen (2021) and this study.

# Future Work

1. Tokenization of Message Text
   - Are certain words "worse"? If so, are they intense words, like in Hall and Madsen (2021)?
2. Investigating Route Changes
   - How effective are DMS at helping drivers find alternate routes when traffic levels are high?

# Contact Information

Questions or Comments?

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