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

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January 10th, 2022

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't** DOTs Do?

Crashes - Beckerian Model:

- Enforce current traffic laws. (DeAngelo and Hansen, 2014; Gallagher and Fisher, 2020)
- Enact new traffic laws. (Cohen and Einav, 2003; Dee, 2009; Van Benthem, 2015)

Congestion - Fundamental Law of Road Congestion (Duranton and Turner, 2011)

- VMT/VKT increase proportionately with lane miles/kilometers.
- Dynamic Tolling (Bento et. al, 2021)

What Can DOTs Do?

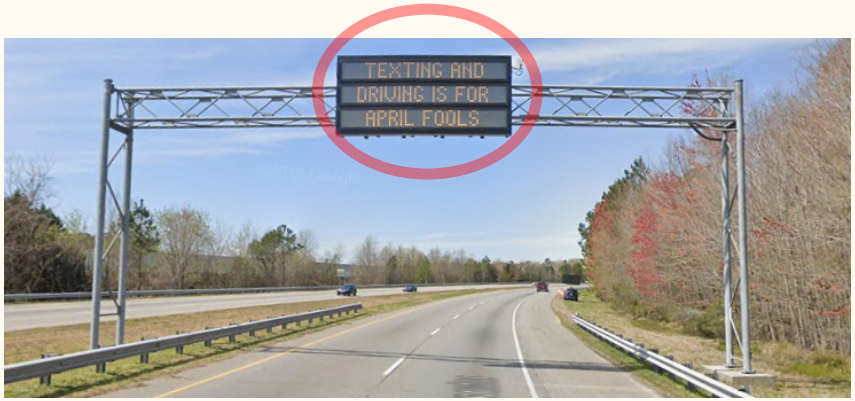
DOTs try to alleviate crash risk and maintain speeds with Highway Signage

- 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



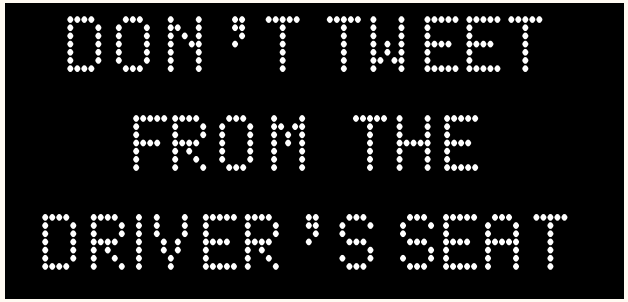
Stationary DMS ✓

Blankout DMS *X*

Portable DMS ✓

Travel Time DMS *X*

Types of Messages - Safety Messages

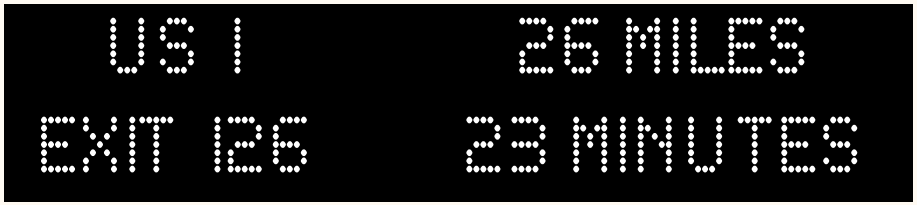


(a) Example 2

(b) Example 2

Types of Messages - Number of Pages

(a) Single Page Message



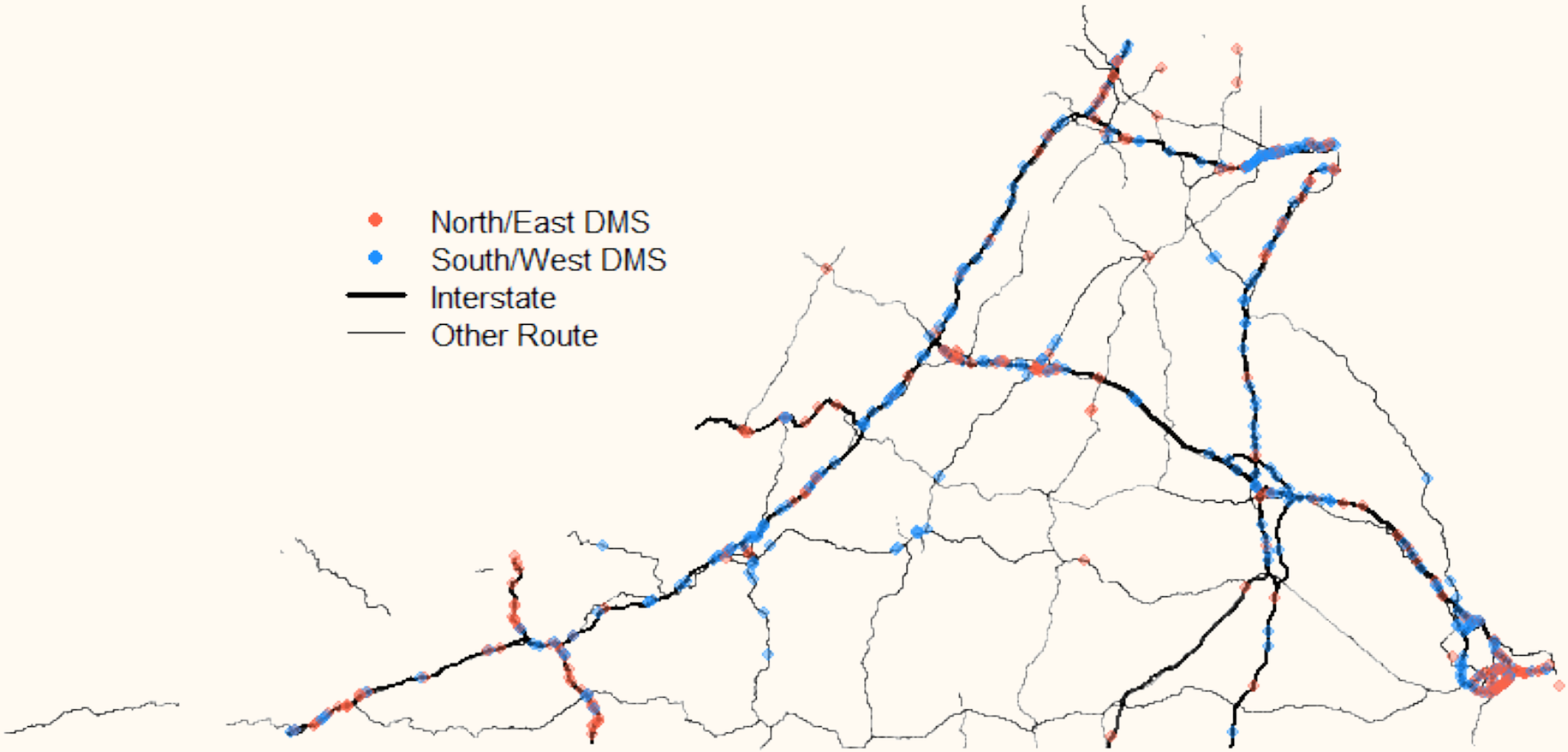
(b) Two Page Message

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)

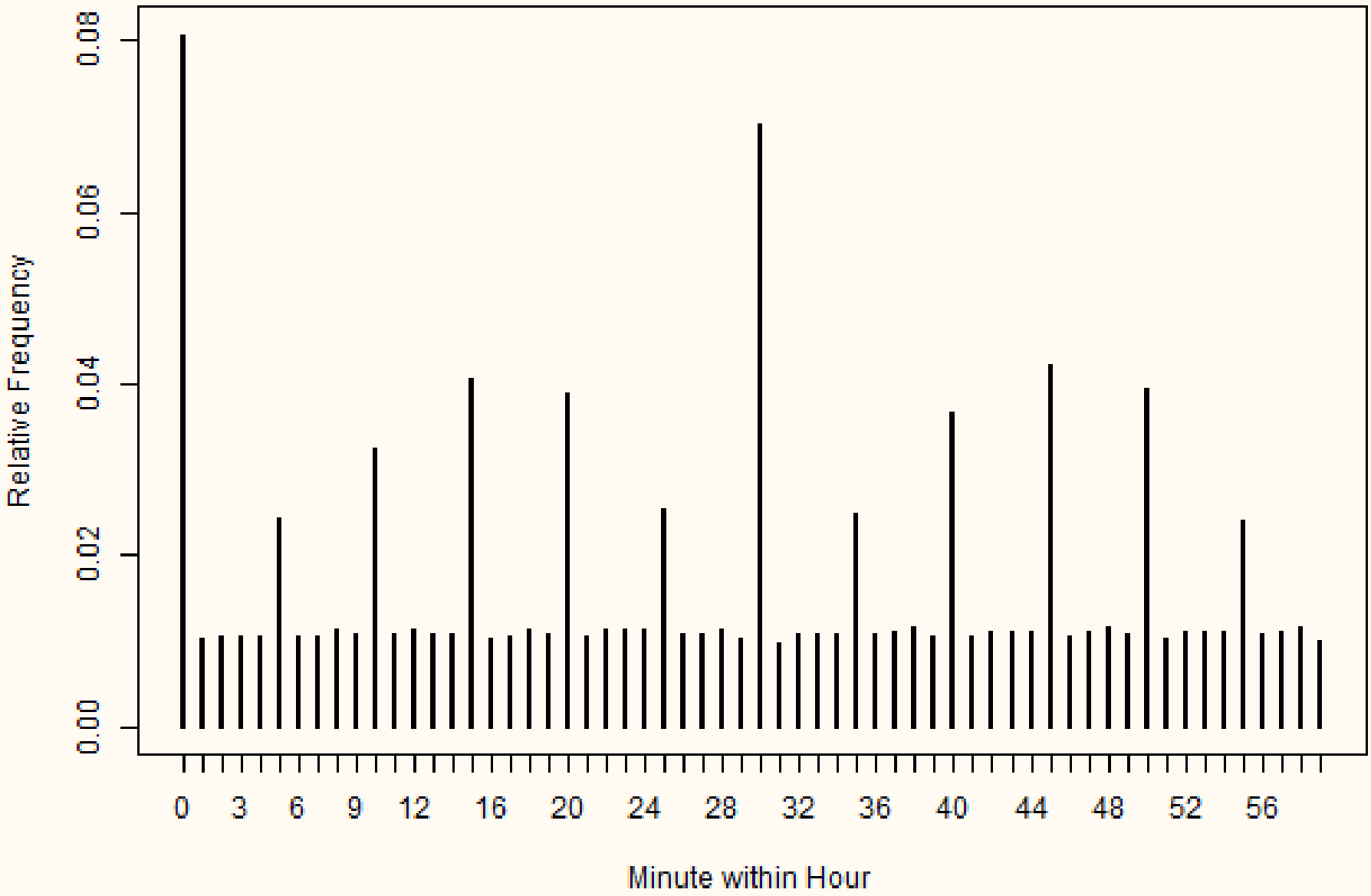
Data from INRIX:

- Hourly speed estimates by segment

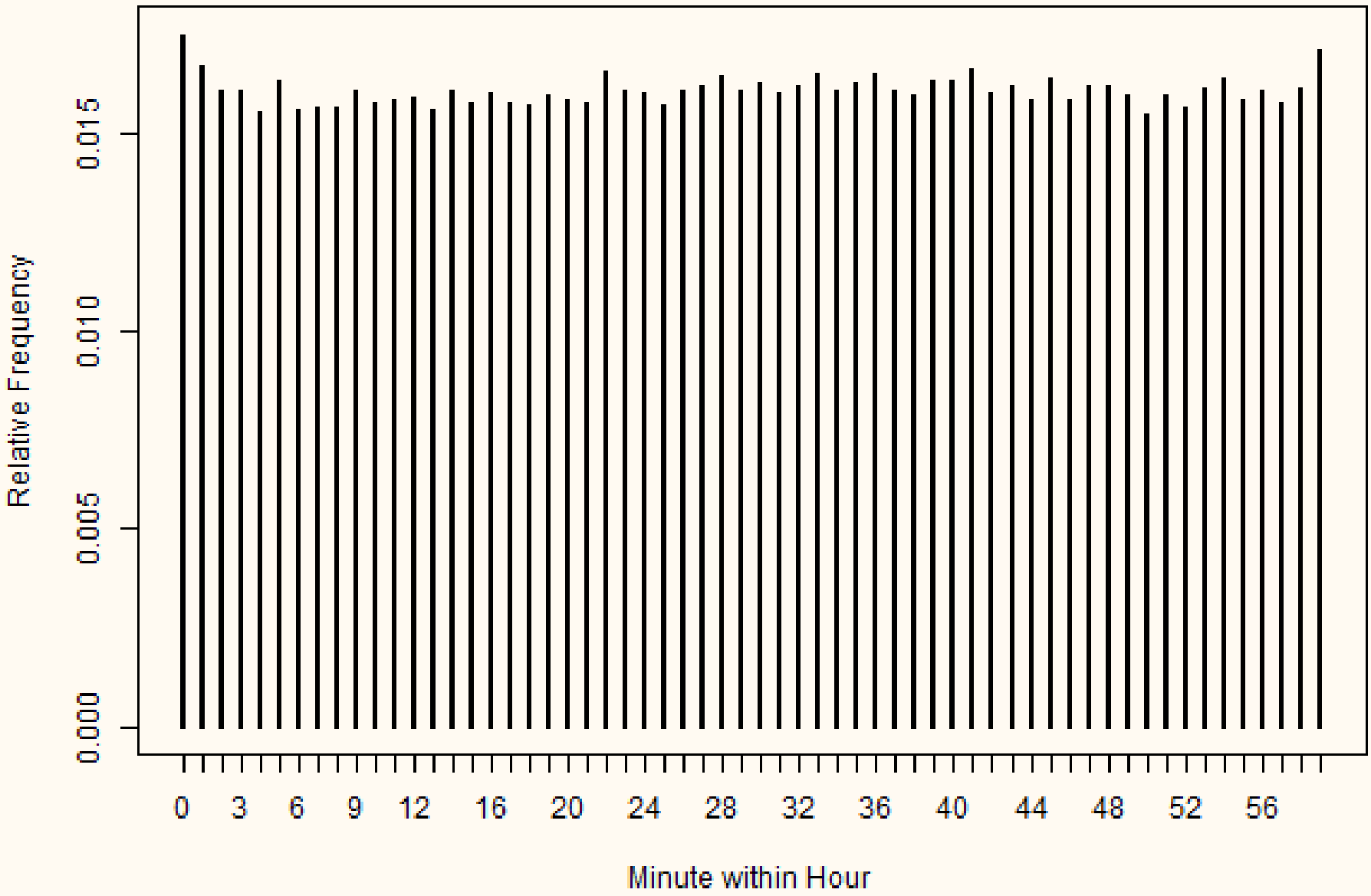
Unit of Analysis: hourly speed and crashes for 391 DMS locations

- 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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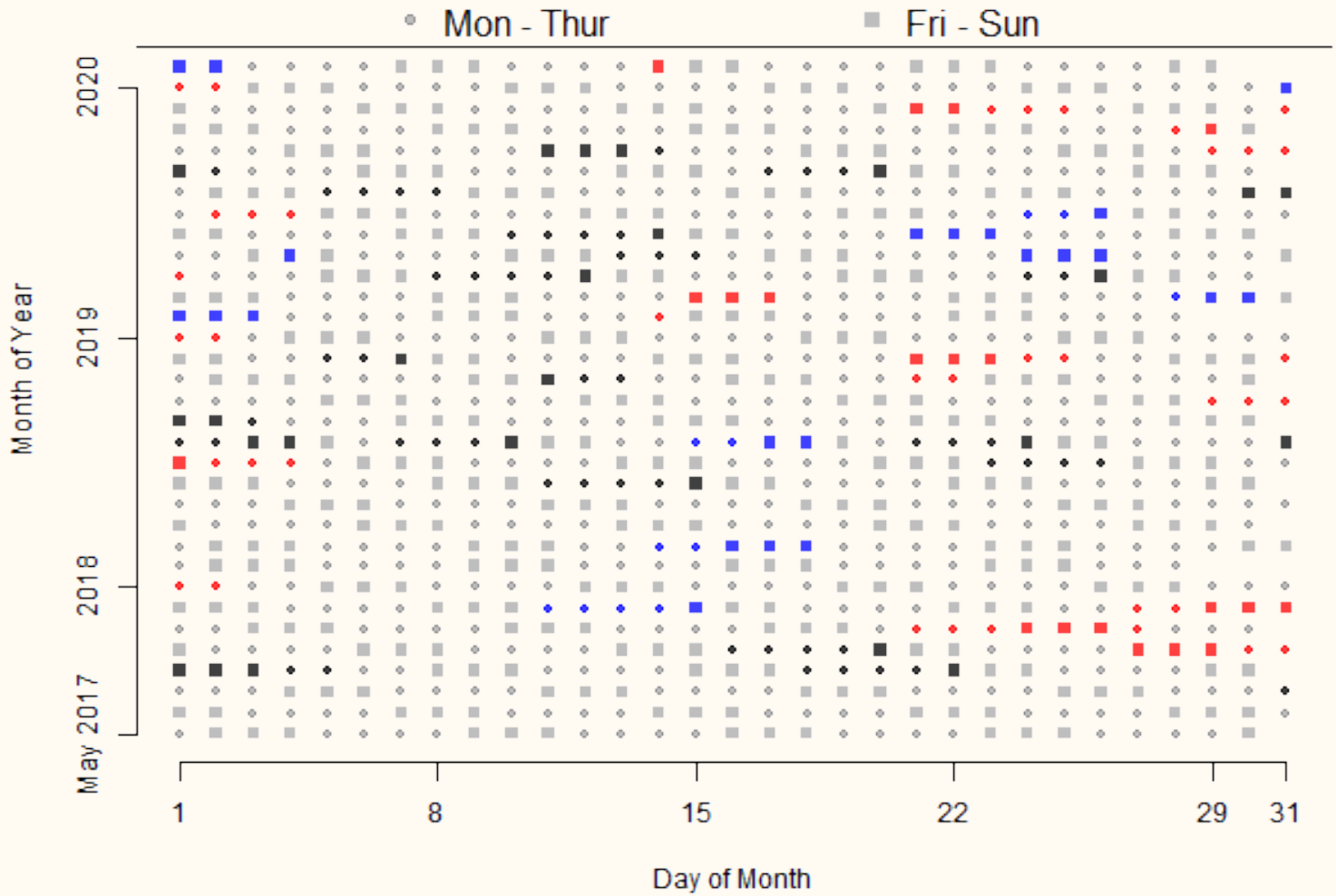
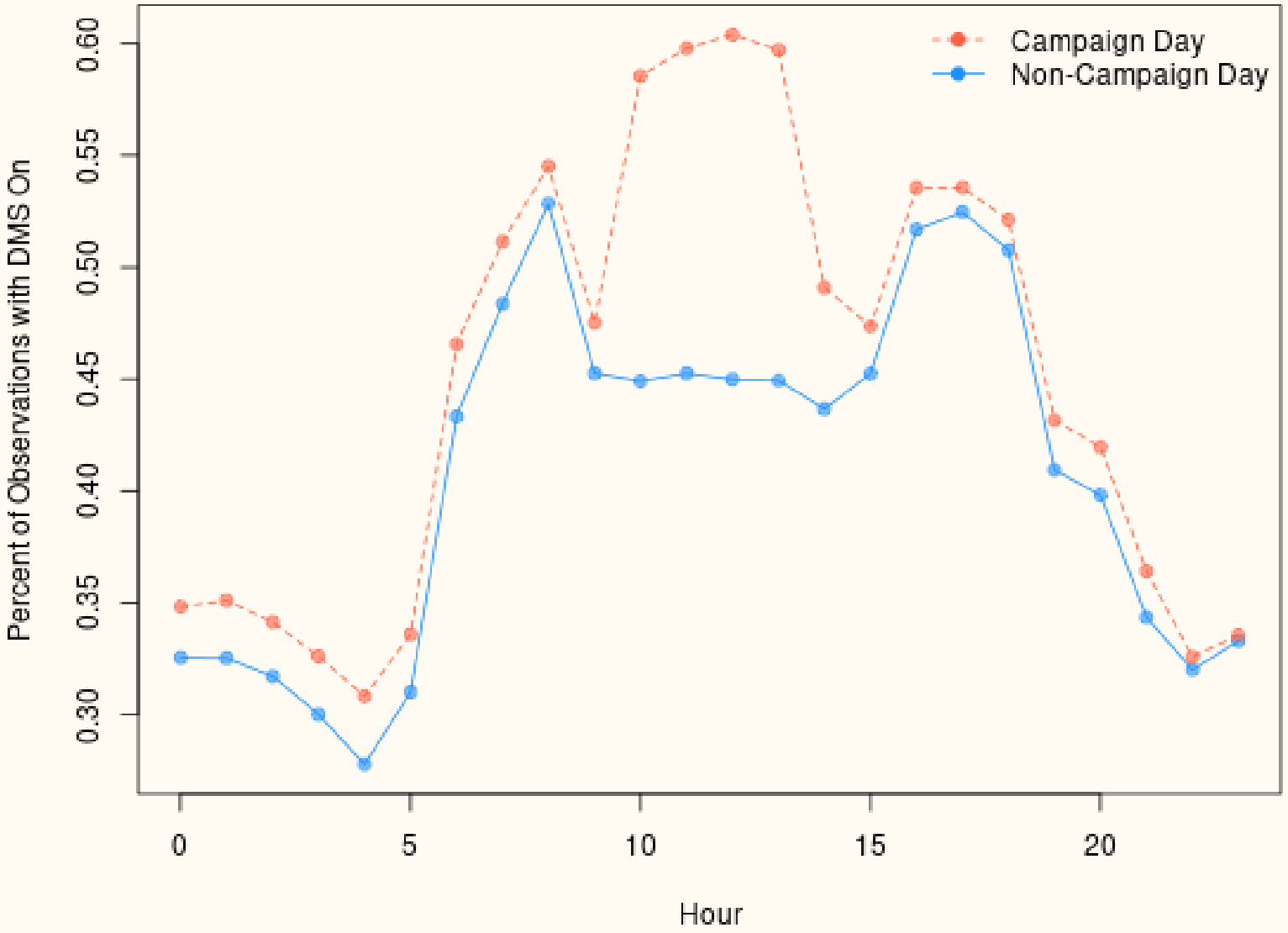
Empirical Strategy - Safety Campaign Timing



Black: generic; **Red**: holiday; **Blue**: popular culture

Empirical Strategy - Safety Campaign Timing



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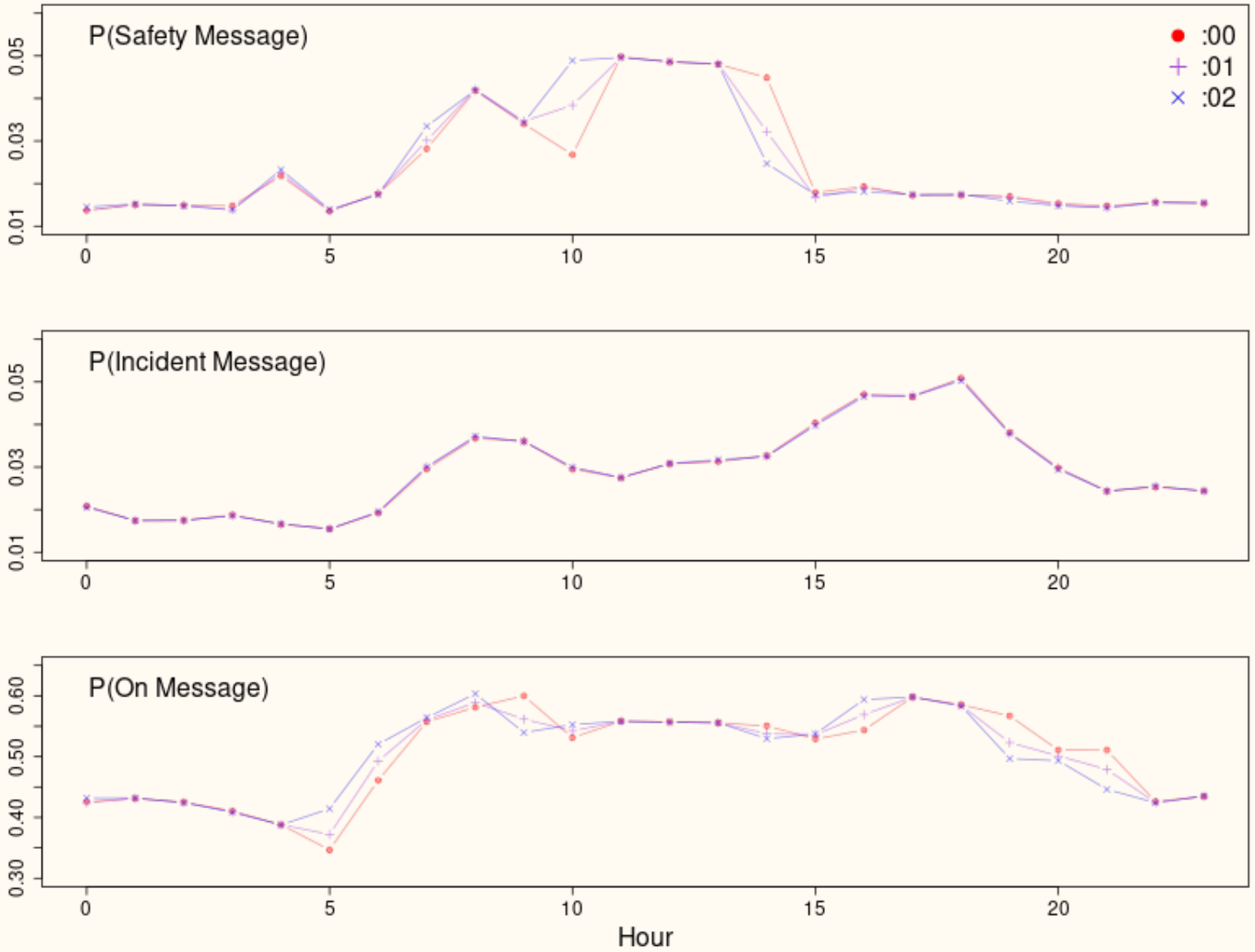
Solution 1: Use pre-planned safety campaigns as exogenous variation.

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

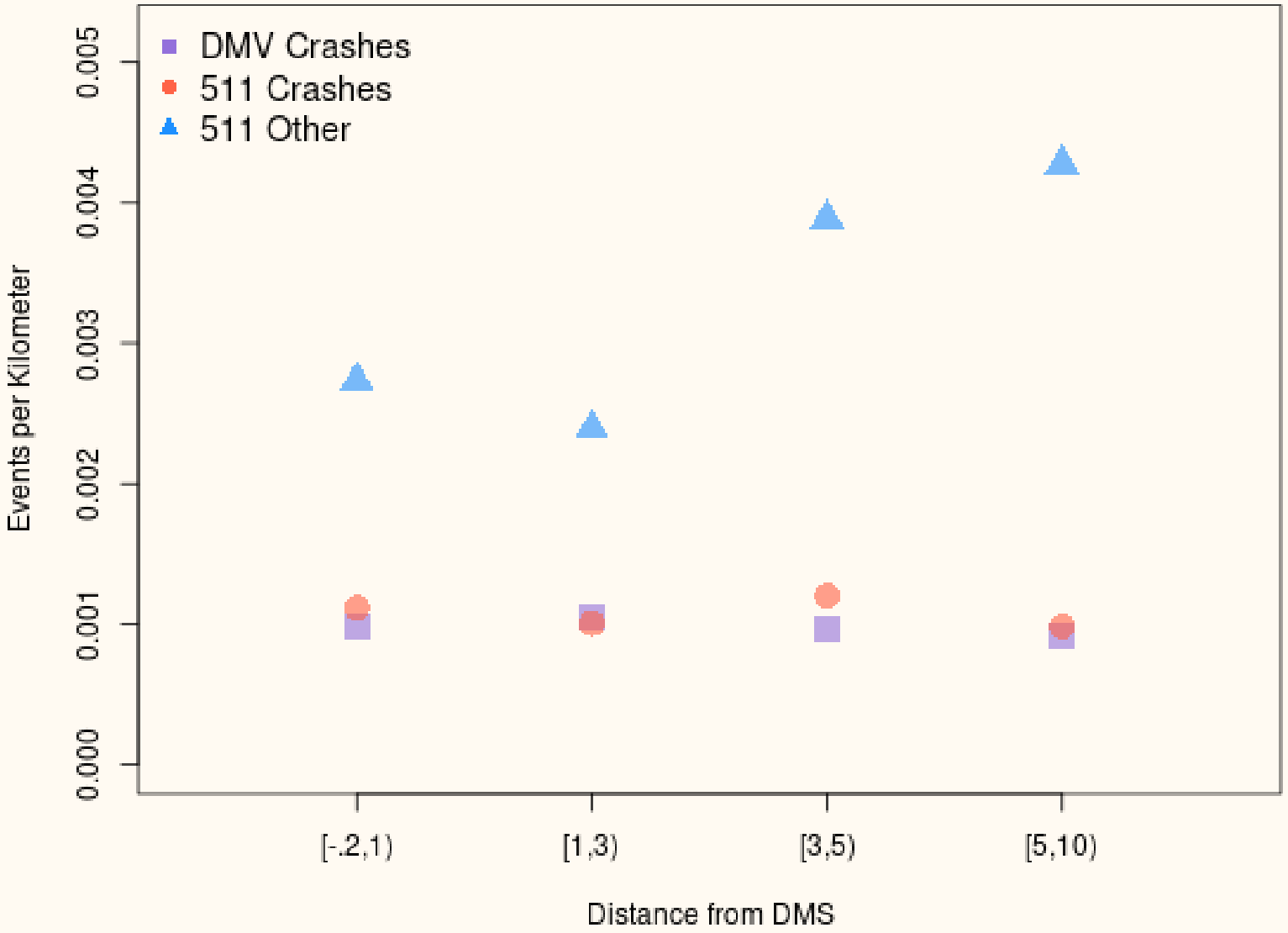

P(Safety Message)
:00
:01
:02
0.01
0.03
0.05
P(Incident Message)
0.01
0.03
0.05
P(On Message)
0.30
0.40
0.50
0.60
0
5
10
15
20
Hour

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

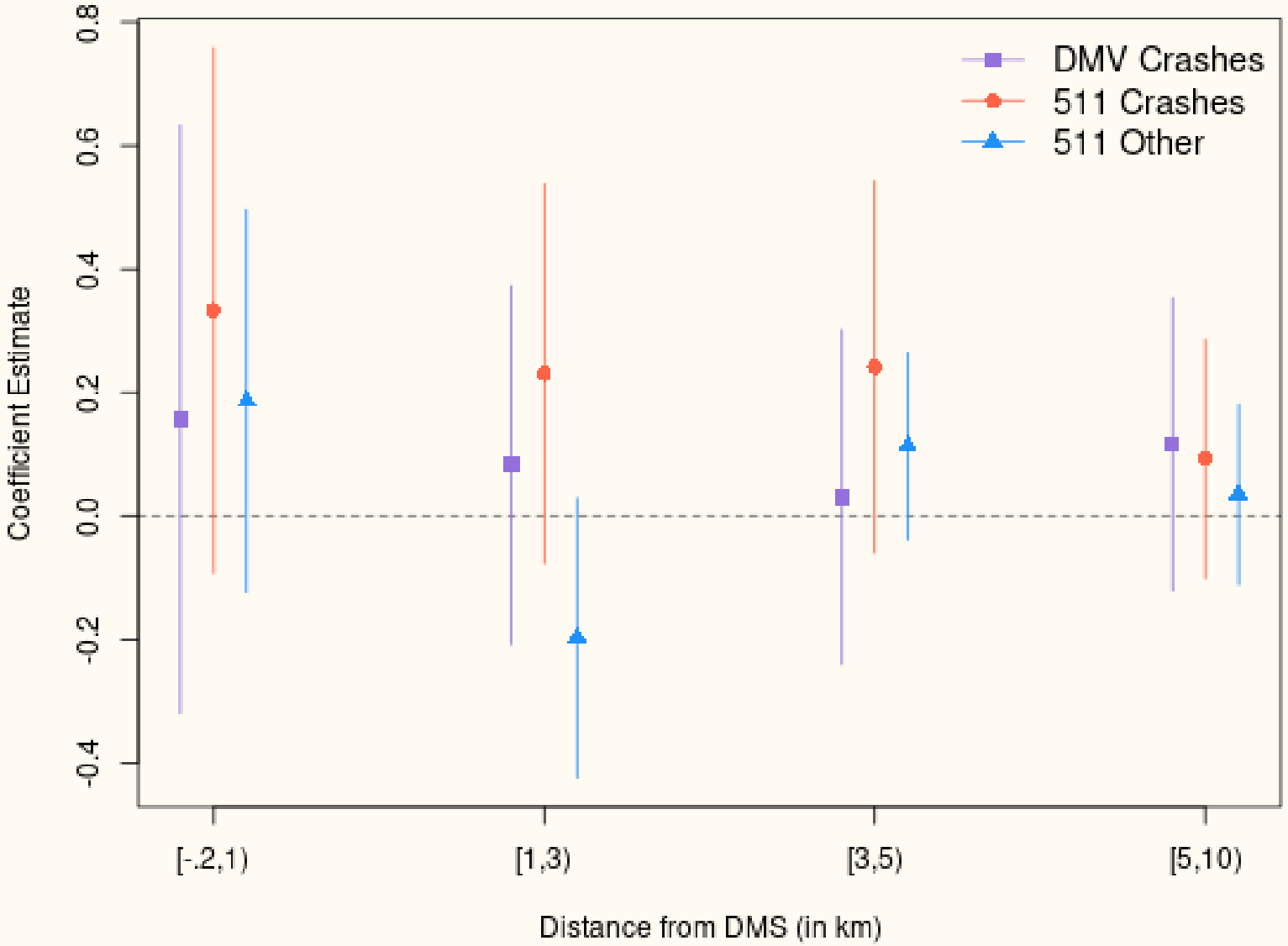
Data Summary



Model 1 - Safety Campaigns

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

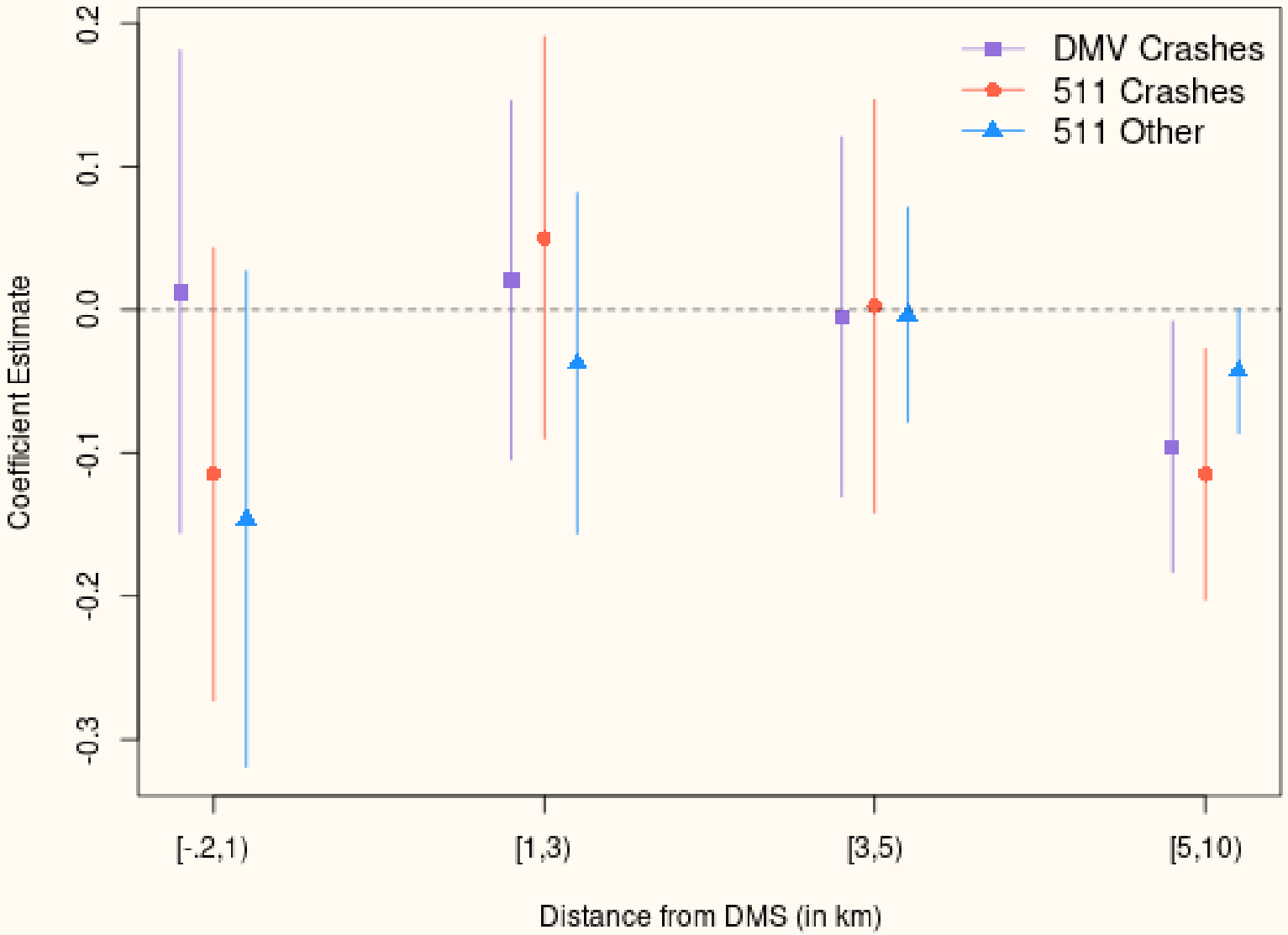
Effect of Safety Campaigns on Incidents Over Space



Model 2 - Safety Messages

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

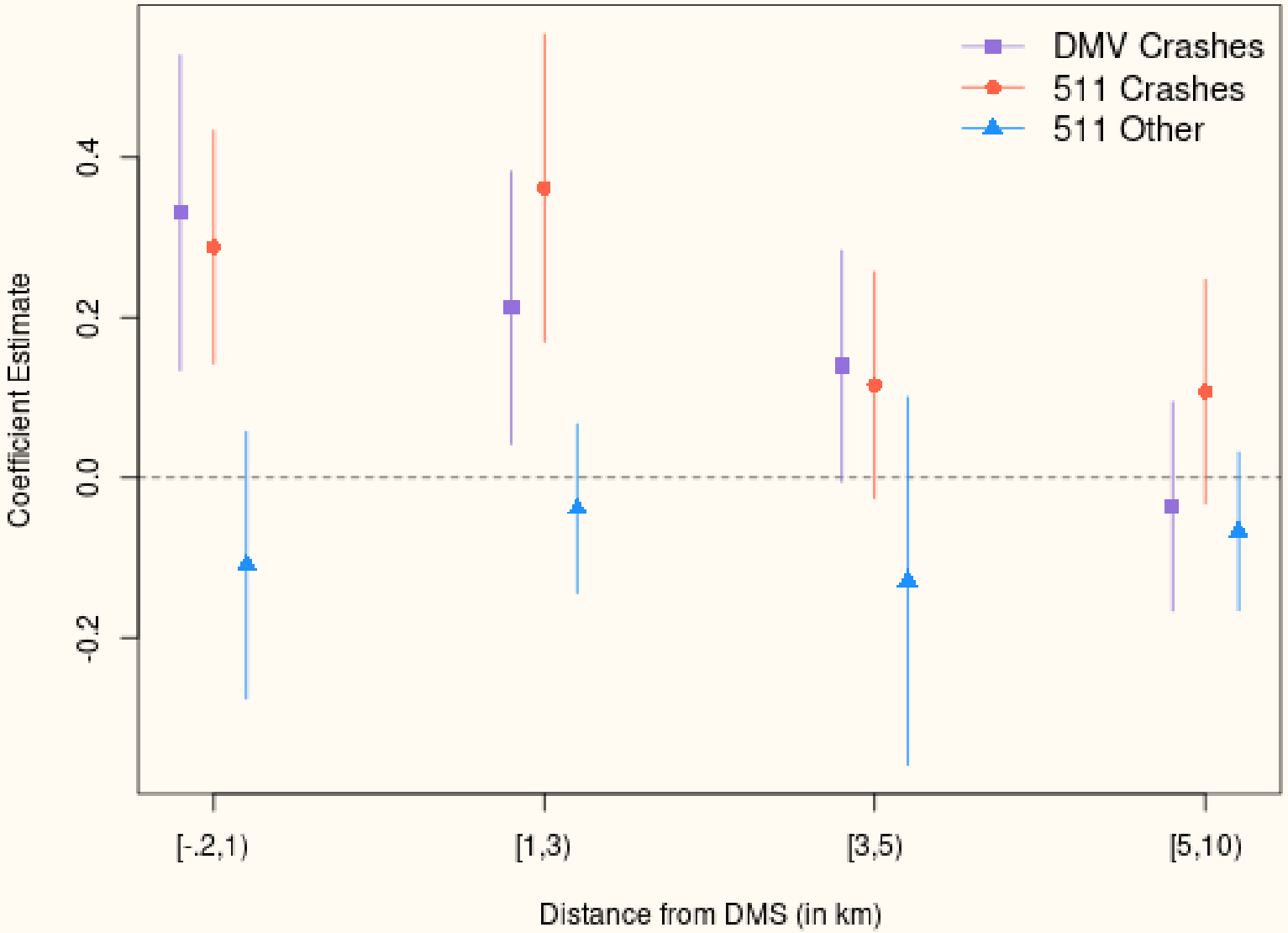
Effect of Safety Messaging on Incidents Over Space



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)
Campaign_t x Off-Peak_t x 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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  $\implies$ 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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