Transportation Research Record

The Influence of Creative Advertisements in Bus Rear-End Safety Campaign

--Manuscript Draft--

Full Title:	The Influence of Creative Advertisements in Bus Rear-End Safety Campaign
Abstract:	Rear-ended collisions in which a vehicle rear ends a bus account for a relatively large proportion of total bus collisions. While the literature does identify transit organizations that have engaged in using rear-end safety advertisements as a collision countermeasure, quantitive studies on the effectiveness of such a countermeasure is lacking. Furthermore, some research suggests that the use of rear-end safety advertisements may stimulate distracted driving, potentially resulting in an increase of collisions. This study involves a before-after analysis with a comparison group to evaluate the influence of creative advertisements used in the Capital Metropolitan Transportation Authority's (Capital Metro) rear-end safety advertisement campaigns. There were two campaign periods, which were studied separately and together (combined). The analysis reveals that there have been reductions in rear-ended crashes following the campaigns. This reduction in crashes was seen across different comparison groups. Due to the limited sample size and small window of time during the after-period, however, only one comparison was statistically significant. The before-after comparison between crashes (rear-ended and non-rear-ended) involving campaign buses showed a 69 percent decrease in rear-ended crashes (statistically significant at the 95 percent confidence interval). This study is an initial exploration for quantifying the effectiveness of creative safety advertisements in reducing rear-ended crashes. This finding is important for Capital Metro and others in the transportation industry when considering countermeasures to address rear-end safety.
Manuscript Classifications:	Data and Information Technology; Safety Data, Analysis, and Evaluation ANB20; Before and After Safety Studies; Crash Data; Transit Safety and Security AP018; Public Transportation
Manuscript Number:	20-00938
Article Type:	Presentation and Publication
Order of Authors:	Boya Dai
	Joan Hudson
	Eun Sug Park
	Chris Simek

The Influence of Creative Advertisements in Bus Rear-End Safety Campaign

Boya Dai, AICP
Associate Transportation Researcher
Texas A&M Transportation Institute
505 E. Huntland Dr, Suite 455, Austin, TX 78752
Email: b-dai@tti.tamu.edu
ORCiD: 0000-0002-3144-8815

Joan G. Hudson, P.E.
Research Engineer
Texas A&M Transportation Institute
505 E. Huntland Dr, Suite 455, Austin, TX 78752
Email: j-hudson@tti.tamu.edu

Eun Sug Park, Ph.D.
Senior Research Scientist
Texas A&M Transportation Institute
1111 RELLIS Parkway, Bryan, TX 77807
Email: e-park@tti.tamu.edu
ORCiD: 0000-0001-6224-7007

Chris Simek, PMP
Associate Research Scientist
Texas A&M Transportation Institute
505 E. Huntland Dr, Suite 455, Austin, TX 78752
Email: c-simek@tti.tamu.edu

Word Count: 5,266 words + 4 tables * 250 = 6,266 words

Submission Date: July 22, 2019

ABSTRACT

Rear-ended collisions in which a vehicle rear ends a bus account for a relatively large proportion of total bus collisions. While the literature does identify transit organizations that have engaged in using rear-end safety advertisements as a collision countermeasure, quantitive studies on the effectiveness of such a countermeasure is lacking. Furthermore, some research suggests that the use of rear-end safety advertisements may stimulate distracted driving, potentially resulting in an increase of collisions. This study involves a before-after analysis with a comparison group to evaluate the influence of creative advertisements used in the Capital Metropolitan Transportation Authority's (Capital Metro) rear-end safety advertisement campaigns. There were two campaign periods, which were studied separately and together (combined). The analysis reveals that there have been reductions in rear-ended crashes following the campaigns. This reduction in crashes was seen across different comparison groups. Due to the limited sample size and small window of time during the after-period, however, only one comparison was statistically significant. The before-after comparison between crashes (rear-ended and non-rear-ended) involving campaign buses showed a 69 percent decrease in rear-ended crashes (statistically significant at the 95 percent confidence interval). This study is an initial exploration for quantifying the effectiveness of creative safety advertisements in reducing rear-ended crashes. This finding is important for Capital Metro and others in the transportation industry when considering countermeasures to address rear-end safety.

Keywords: transit crashes, transit safety, crash analysis, countermeasure evaluation

INTRODUCTION

Public transit safety is a priority and a major focus for both operators and passengers. The Safety and Security Time Series data from the Federal Transit Administration show that while bus revenue miles only increased by 2 percent during the last decade between 2009 and 2018, the number of bus collisions increased by a quarter. Bus collisions not only increase the operation costs and squeeze the limited profit margin of transit agencies, but also lead to traffic congestion, personal injuries, and distrust in public transit as a safe travel mode.

The National Transit Database (NTD) Safety and Security Reporting Manual separates the definition for “rear-ended” and “rear-ending” collisions. The “rear-ended” collision occurs when an agency’s transit vehicle is impacted on its rear end by the front of another vehicle. The “rear-ending” collision represents the opposite scenario. The rear-ended collision is one of the most common types of bus collisions. A National Center for Transit Research report concluded that rear-ended collisions overall accounted for 20 percent of total collisions in the NTD Major Incident Database between 2008 and 2012 (*1*). The percentage of rear-ended collisions was as high as 38.3 percent of all collisions for transit agencies in Florida.

In examining the existing literature related to transit bus rear-ended collisions, three countermeasures were identified that are commonly implemented by public transit organizations to help minimize the occurrence of the rear-ended bus collisions: bus advertisements, safety campaigns, and technology. Among them, technology countermeasures, such as light enhanced or supplemented braking systems and deceleration alert systems, have been most frequently discussed and evaluated in the literature. In multiple studies, these systems have been found to reduce the occurrence of rear-ended collisions. While the literature identifies transit organizations that have engaged in both public education campaigns and bus advertisements as collision countermeasures, rigorous evaluations of their efficacy are lacking. Furthermore, some research suggests that the use of traditional advertisements on the rear of buses may stimulate distracted driving, potentially resulting in increases in collisions.

This study contributes to the existing body of research by performing a quantitive evaluation of the effectiveness of the creative advertisement used in the rear-end safety advertisement campaigns of Capital Metro to address fixed route buses being rear ended by other vehicles. Capital Metro is the regional public transportation provider in Austin, Texas. There were essentially two campaign periods over Capital Metro’s Fiscal Years (FY) 2016 and 2017, during which the rear-end advertisements were installed on about 60 buses. These buses were chosen because they have enough space and a flat surface for a full-back ad, as well as either lights, windows, digital signs, louvers, or other elements that would not interfere with a full back-of-the-bus ad. Various creative rear bus wraps were installed for this campaign, four of which are shown in Figure 1.

This paper includes a literature review about the influence of creative advertisements and other countermeasures to address rear-end crashes; introduction to the rear-end safety advertisement campaign data, bus mileage data, and bus crash data obtained from Capital Metro; explanation of the methodology used to evaluate the target rear-end safety advertisement campaigns and analyses of the results; conclusions of the findings; and potential future research.

Figure 1. Capital Metro Creative Bus Rear-End Bus Advertisements Examples

LITERATURE REVIEW

Details of the literature review are presented in the following three sections:

- Use of Bus Advertisement as a Countermeasure. This section focuses on the use of traditional rear-end bus advertisement as a collision countermeasure.
- Use of Safety Campaigns as a Countermeasure. This section focuses on the use of public education safety campaigns as a collision countermeasure.
- Use of Technology as a Countermeasure. This section focuses on the use of technology as a collision countermeasure.

Use of Bus Advertisement as a Countermeasure

Traditional advertisement on the rear of buses has been used by public transit organizations as a rear-end crash countermeasure. Most of these advertisement campaigns attempt to attract the attention of passenger vehicle drivers following the transit vehicles. The campaigns help to remind the passenger vehicle driver about often ignored local yield-to-bus policies, ongoing safety campaigns, and/or the negative outcome of rear-end collisions (*2*). Because of research conducted by the Center for Urban Transportation Research (CUTR), Palm Tran redesigned its yield-to-buses sign to make them more prominent on older fleet vehicles (*2*).

Rigorous evaluations on the efficacy of bus advertisement countermeasures are rare. To that end, the literature review only yielded one somewhat quantitative assessment. A Florida statewide bus operators' survey conducted by Zhou et al. suggests that the commonly used decal on the rear of the bus, which is meant to remind following drivers of the yield-to-bus laws, had "no significant safety or operational effects" (*2*).

In some instances, in lieu of rear-end safety advertisements, a transit organization may choose to alter the rear of the bus in some other dramatic way. For example, in 1995, Utica Transit Authority (UTA) changed the color of the rear of its buses from white to blue at the suggestion of its maintenance department. Anecdotal reports by UTA staff indicate that, for a significant period of time after this practice began, UTA had no rear-end collisions (*3*).

Some research supports the notion that advertisements and the mental tasks associated with processing the advertisements may actually burden passenger vehicle drivers to some extent, hence increasing the likelihood of collisions. This is because drivers tend to have a longer fixation period when performing mental tasks, such as identifying and understanding the advertisement. It may be at least partially due to this eye freezing effect (*4*) that some public transit agencies do not allow rear advertisement. Research conducted by Wiley et al. provides some support for this policy action by estimating that some agencies that do not allow rear advertisement have a lower collision rate than the national average. Conversely, the research points out that most agencies with higher collision rates allow for rear advertisement. This research should be interpreted with caution, however, as the sample number associated with this study is quite small (*5*).

Use of Safety Campaigns as a Countermeasure

Even though some previous research provides reason to be optimistic about the effectiveness of public education campaigns to increase safe driving behavior (*6*, *7*), the literature review did not yield any research to assess the effectiveness of safety campaigns as a bus rear-end crash countermeasure.

Research conducted by CUTR for the Florida Department of Transportation involved interviewing staff from two transit agencies (VTA in San Jose, CA, and TriMet in Portland, OR) to obtain details about their yield-to-bus programs and educational campaigns. The most significant findings from this effort were the following:

- Periodic reminders to the public and bus operators are needed to carry out a successful yield-to-bus programs.
- Placing educational advertisements on the back of buses is one of the most effective ways to keep the public informed about traffic safety practices related to transit buses.
- Traffic safety and engineering studies are important to justify the benefits of a yield-to-bus program.
- Promotion of effective communications between yield-to-bus program leaders and enforcement officials is necessary (*8*).

A recognized shortcoming of these studies is the inherent difficulty in assessing the efficacy of the campaign in such a way as to remove the impact of other events that occur during the campaign. For example, many public safety campaigns are supplemented with law enforcement. In these instances, it is difficult to separate the effect of the actual campaign message from the effect of law enforcement when assessing changes in behavior. Wundersitz also pointed out that safety campaigns are more effective at “conveying the messages” and “changing attitudes” rather than “changing behaviors” (*9*).

Use of Technology as a Countermeasure

Of the three basic types of countermeasures (advertisements, public education campaigns, and technology), the literature provides more examples of how technology was used to combat rear-end crashes, than either of the other two types of countermeasures.

Research funded by the National Highway Transportation Safety Administration investigating 100 rear-end crashes or near-rear-end crashes suggested that rear-signaling devices can direct distracted drivers back to the forward roadway. An enhanced rear-signaling system should focus on directing drivers who glance away from the forward roadway more than 2 seconds (*10*).

Both PTS (Phoenix) and Tulsa Metropolitan Transit Authority have implemented deceleration alert systems (DASs), and anecdotally claimed that the number of rear-end collisions decreased (*3*). Minneapolis Metro Transit equipped a portion of its fleet with DASs in 1989. For calendar year 1990, it compared the number and rate of rear-end collisions for DAS-equipped buses with those of a conventionally equipped bus fleet. The rear-end collision crash rate was reduced by nearly 50 percent (*3*).

Transit Cooperative Research Program Report 66: *Effective Practices to Reduce Bus Accidents* presents some insights into the efficacy of using different brake lights and warning sign technology as rear-end crash countermeasures. Results at Pierce Transit suggest that buses equipped with a red cyclops light at the rear center of the bus with amber flashing lights on either side had a vehicle-into-bus crash rate that was approximately 25 percent lower than those same buses without warning lights (*3*). Metro Transit buses equipped with the high-luminosity light emitting diode (LED) brake lights have a Metro-vehicle-rear-ended incident rate that is approximately 40 percent lower than the rate for buses with conventional brake lights (*3*). DTA (Duluth, MN) found that a set of four high-mounted, flashing amber lights automatically activated when the rear door of the bus is opened had no discernible effect on the rate of rear-ended-in-bus-stop crashes (*3*). MARTA has 15–20 buses equipped with large center brake lights that flash when the bus is braking. Even though no formal evaluation has been conducted, MARTA reports that very few of these specially equipped buses have been involved in rear-end crashes (*3*).

In one of the more rigorous evaluations found in the literature review, Rey et al. found that the installation of rear-end high-density lights on Lynx vehicles resulted in an 8 percent decline in per vehicle rear-end crash rates (pre-implementation to post-implementation). Even more significant was the finding that vehicles without the upgraded lights experienced a 22 percent increase in per vehicle rear-end crash rates during the same period. These numbers suggest a 30 percent decline from the level of rear-end crash occurrence that would have been expected had the high-density lights not been introduced by Lynx (*11*).

Finally, Lin et al. found statistical evidence that use of yield-to-bus LED signs placed on the back of the bus had a positive effect on the yield-to-bus behavior of motorists behind the bus, relative to the effects of a yield-to-bus decal only treatment group (*8*).

METHODS

Data Preparation

Three data sets were used in evaluating the effectiveness of the creative advertisements during the Capital Metro rear-end safety campaigns. They include campaign information, bus collision data, and bus mileage data. As mentioned before, Capital Metro conducted two rear-end safety campaigns with creative advertisements between 2016 and 2018. Bus number, installation date, and removal date of these campaigns were obtained. Not all installation and removal dates were properly recorded. For those buses that were missing these dates, researchers assumed that the installation and removal took place between the corresponding dates associated with other campaign buses.

During the first rear-end safety campaign, the advertisements were installed on the back of 59 buses. The installation process began in August 2016 and was completed in December 2016. This first campaign lasted for about six months. All the advertisements were removed in June 2017. The installation process for the second campaign began in October 2017 and was completed in December 2017. It involved 62 buses and included all the buses from the first campaign. Records showed that advertisements on 10 out of the 62 campaign buses were removed soon after the installation in January and February 2018. Those 10 buses were excluded from this study.

Researchers also requested and obtained the collision data for all Capital Metro buses between October 1, 2008, and May 31, 2018. This data set included 9,576 crashes. Rear ended crashes, in which a vehicle ran into the back of a Capital Metro bus, accounted for 8.5 percent (832) of total bus crashes. Figure 2 displays the target rear-ended crash frequency trends during this period by Capital Metro's fiscal year. Though crash data were available back to October 2008, not all the campaign buses were put into operation until November 2010. Thus, only crashes that occurred from November 2010 were used in the safety evaluation.

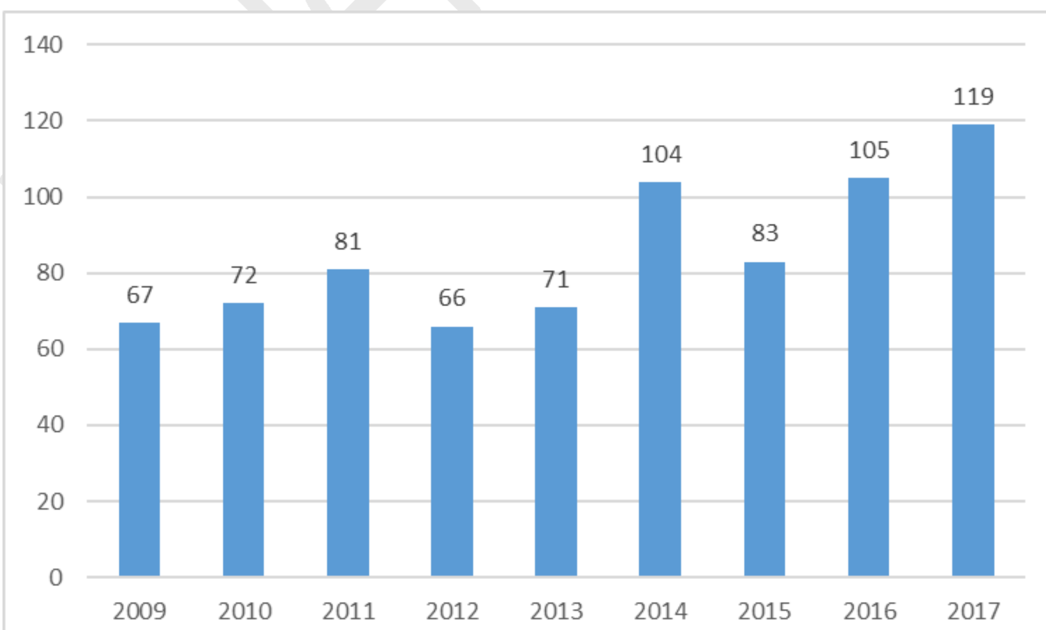

Figure 2. Target Rear-Ended Crash Frequency by Fiscal Year

Besides the safety campaign and bus collision data, monthly mileage for all Capital Metro buses were also gathered. These data could only be traced back to April 2015. During the data quality control process, Capital Metro staff confirmed that some of the records with abnormally low mileage were due to that bus being in the maintenance shop that month. By matching the campaign data, bus crash data, and bus mileage data based on the bus number, researchers were able to calculate important crash statistics like crash rate based on the bus mileage to better understand the impact of the safety campaigns. Since each bus could rotate to a different route every day, it was not feasible to calculate the rear crashes as a percentage of the total on routes where the campaign buses operated.

Before-After Safety Analysis

The method used to assess the effect of creative advertisements on rear-ended collisions is a before-after analysis with a comparison group that is based on the bus crashes that occurred before and after the installation of advertisements. The comparison group methodology is effective in controlling for the effects of any extraneous factors that change over time (such as weather, driving behavior, reporting practice). It assumes that the change in crashes between the before and after periods for a comparison group is representative of the change in crashes that would have occurred for the corresponding treatment group had the countermeasure not been implemented for the treatment group (i.e., had the advertisements not been installed on the campaign buses). The comparison group methodology is explained, for example, in Hauer (*10*) and Harwood et al. (*12*). The steps used in this study to obtain the safety effectiveness index estimate and the corresponding 95 percent confidence interval are detailed in the next section.

Researchers performed analyses utilizing two different comparison groups: the analysis with non-rear-ended crashes from the same campaign buses as a comparison group, and a sensitivity analysis with rear-ended crashes involving non-campaign buses as a comparison group. Correspondingly, crash data were divided into four subsets. Each represents a unique combination of rear-ended crashes or non-rear-ended crashes involving campaign buses or non-campaign buses. The rear-ended campaign bus crashes constitute a treatment group. Non-rear-ended crashes from the same campaign buses constitute Comparison Group 1. The use of the same campaign buses as a comparison group in this case automatically controls for the difference in bus mileage between before and after periods. Comparison Group 2 consists of rear-ended crashes involving non-campaign buses.

Table 1 shows the number of campaign buses and the number of months in the before and after periods for the target safety campaigns. The first campaign and the second campaign were evaluated separately aside from a third evaluation that combines data from the two campaigns. The before period of the first campaign consisted of 60 months and started November 2010. After the installation being completed in December 2016, the creative advertisements were kept on the buses for 5 months (after period), then all removed in June 2017. The new installation began in October 2017 and was completed by 2018. Because the gap between the end of the first campaign and the beginning of the second campaign was so short (only 3 months), it was difficult to perform an independent evaluation of the second campaign without including crash data from the first campaign. Thus, the before period of the first campaign (November 2010 to

July 2016) and additional three months (July 2018 to September 2018) were used as the before period for the analysis of the second rear-end safety campaign. Five months following the completion of the advertisement installation for the second campaign (from January 2018 to May 2018) were used as the after period for both campaigns. The third evaluation scheme was developed based on the crash data from the 49 buses that were involved in both campaigns and the advertisements of which remained intact as of May 2018. It used the 60-month before period (November 2010 to July 2016) and the 10-month after period (January 2017 to May 2017 and January 2018 to May 2018).

Table 1. Number of campaign buses and number of months in the before and after periods for rear-end safety campaigns

Campaign	# of campaign buses included in the analysis	# of months in the before period	# of months in the after period
1	59	60 months (11/2010–07/2016)	5 months (01/2017–05/2017)
2	52	63 months (11/2010–07/2016, 07/2018–09/2018)	5 months (01/2018–05/2018)
1 & 2 combined	49	60 months (11/2010–07/2016)	10 months (01/2017–05/2017, 01/2018–05/2018)

Table 2 contains the number of non-campaign buses included in the Comparison Group 2 along with the number of months in the study period. When using rear-ended crashes from non-campaign buses as a comparison group, the change in bus mileage from the before to the after periods might be different for campaign buses and for non-campaign buses. This difference in bus mileage needs to be explicitly incorporated into the analysis. Unfortunately, bus mileage data were available only for April 2015 to May 2018. Because of that, though crash data for campaign buses were available from November 2010, crash data for non-campaign buses before April 2015 could not be included in the analysis with Comparison Group 2. Besides, not all non-campaign buses have monthly mileage data. So only a subset of non-campaign buses that have the corresponding mileage information could be included in the analysis.

Table 2. Number of non-campaign buses used for Comparison Group 2

Campaign	# of non-campaign buses included in the analysis	# of months in the before period	# of months in the after period
1	276	16 months (04/2015–07/2016)	5 months (01/2017–05/2017)
2	236	19 months (04/2015–07/2016, 07/2018–09/2018)	5 months (01/2018–05/2018)
1 & 2 combined	234	16 months (04/2015–07/2016)	10 months (01/2017–05/2017, 01/2018–05/2018)

Table 3 summarizes bus crash data used in the safety analyses with the two comparison groups mentioned above. As noted earlier, rear-ended campaign buses constitute the treatment group. For a comparison group, non-rear-ended crashes for the same campaign buses in the treatment group are used as Comparison Group 1 and rear-ended crashes for non-campaign buses are used as Comparison Group 2.

Table 3. Summary of bus crash data used in the before-after analysis with a comparison group

Campaign	Analysis	Crash (# of buses)	Total before crashes (# of months)	Total after crashes (# of months)	Total before mileage	Total after mileage
1	Analysis with Comparison Group 1	Campaign bus rear-ended crashes (59)	49 (60)	4 (5)	NA	NA
		Campaign bus non-rear-ended crashes (59)	603 (60)	104 (5)	NA	NA
	Sensitivity Analysis with Comparison Group 2	Campaign bus rear-ended crashes (59)	14 (16)	4 (5)	6,209,357	1,240,076
		Non-campaign bus rear-ended crashes (276)	45 (16)	21 (5)	20,754,946	4,495,177
2	Analysis with Comparison Group 1	Campaign bus rear-ended crashes (52)	39 (63)	2 (5)	NA	NA
		Campaign bus non-rear-ended crashes (52)	580 (63)	83 (5)	NA	NA
	Sensitivity Analysis with Comparison Group 2	Campaign bus rear-ended crashes (51)	15 (19)	1 (5)	6,164,380	1,047,436
		Non-campaign bus rear-ended crashes (236)	43 (19)	9 (5)	20,230,394	4,048,350
1 & 2 combined	Analysis with Comparison Group 1	Campaign bus rear-ended crashes (49)	37 (60)	4 (10)	NA	NA
		Campaign bus non-rear-ended crashes (49)	495 (60)	170 (10)	NA	NA
	Sensitivity Analysis with Comparison Group 2	Campaign bus rear-ended crashes (48)	14 (16)	3 (10)	5,036,948	1,967,927
		Non-campaign bus rear-ended crashes (234)	38 (16)	29 (10)	17,592,641	8,137,733

Estimation of Safety Effectiveness

As mentioned, the objective of this study is to assess the effects of creative advertisements installed on campaign buses on rear-ended crashes. The safety effectiveness of the advertisements is quantified by the safety effectiveness index (θ), which is defined as the ratio of the expected number of crashes after the treatment (here, installation of the advertisements on campaign buses) to what it would have been without the treatment. The steps of the comparison group method used in this study to obtain the safety effectiveness index estimate and the corresponding 95 percent confidence interval are given below for completeness. Additional details on the comparison group method are available in Hauer (*10*) and Harwood et al. (*12*)

Step 1. Obtain an estimate of the index of effectiveness θ by:

$$\hat{\theta} = \frac{Crash_{AT} \times Crash_{BC}}{Crash_{BT} \times Crash_{AC}}$$

where

CrashBT= Sum of crashes during the before period for the treatment group.

CrashAT = Sum of crashes during the after period for the treatment group.

CrashBC = Sum of crashes during the before period for the comparison group.

CrashAC = Sum of crashes during the after period for the comparison group.

Step 2. Compute the log odds ratio, R, as follows:

$$R = \ln\left(\frac{Crash_{AT} \times Crash_{BC}}{Crash_{BT} \times Crash_{AC}}\right) = \ln\hat{\theta}.$$

Step 3. Compute the squared standard error for R by:

$$s.e.(R) = \sqrt{\frac{1}{Crash_{BT}} + \frac{1}{Crash_{AT}} + \frac{1}{Crash_{BC}} + \frac{1}{Crash_{AC}}}.$$

Step 4. Compute the approximate 95 percent confidence interval for R:

$$R_{lower} = R - 1.96 s.e.(R)$$

and

$$R_{upper} = R + 1.96 s.e.(R),$$

where R_{upper} and R_{lower} stand for the upper and lower limit of the approximate 95 percent confidence interval, respectively.

Step 5. The 95 percent confidence interval for the index of effectiveness (θ) can be obtained by exponentiating R_{lower} and R_{upper}, respectively, as:

$$L_{\theta} = e^{R_{lower}}$$

and

$$U_{\theta} = e^{R_{upper}}.$$

Note that if the confidence interval for θ does not contain the value 1, the effect is statistically significant at the 95 percent confidence level.

Step 6. The estimate for the percent crash reduction and the associated 95 percent confidence interval can also be obtained as:

$$\text{Percent crash reduction} = \left(1-\hat{\theta}\right)\times 100$$

and

$$\left[\left(1-L_{\theta}\right)\times 100, \left(1-U_{\theta}\right)\times 100\right].$$

The above procedure is applicable if both the treatment and comparison groups have the same changes in bus mileage from the before period to the after period (as in the case of the analysis with Comparison Group 1). Otherwise, the changes in bus mileage from the before to the after periods should be incorporated into estimation of θ. For the analysis with Comparison Group 2, the before crash count for the treatment group ($Crash_{BT}$) needs to be replaced by $Crash_{BT} \times \frac{Mileage_{AT}}{Mileage_{BT}}$ where $Mileage_{BT}$ and $Mileage_{AT}$ are the total mileage for the buses in the treatment group during the before period and the after period, respectively. Likewise, the before crash count for the comparison group ($Crash_{BC}$) needs to be replaced by $Crash_{BC} \times \frac{Mileage_{AC}}{Mileage_{BC}}$ where $Mileage_{BC}$ and $Mileage_{AC}$ are the total mileage for the buses in the comparison group during the before period and the after period, respectively.

RESULTS

Table 4 shows the estimates of the safety effectiveness index and the percent of crash reduction for the first, second, and the combined rear-end safety campaigns. There were reductions in rear-ended crashes following the campaigns. Even though the crash reduction for each of Campaign 1 and Campaign 2 was not statistically significant due to the limited time during the after period (only 5 months for each), the reduction was statistically significant for the combined rear-end safety campaigns (incorporating the after period data from both Campaign 1 and Campaign 2) with Comparison Group 1 using the 60 months of before data. Crash reduction estimates from the analysis with Comparison Group 2 were not statistically significant probably due to a much shorter before period (only 15 months) compared to the analysis with Comparison Group 1 (60 months).

Table 4. Percent crash reduction for rear-end safety campaigns

Analysis	Campaign	Safety effectiveness index ($\hat{\theta}$)	95% confidence interval		Percent crash reduction
			Lower limit ($L\theta$)	Upper limit ($U\theta$)	
With Comparison Group 1	**1**	0.473	0.167	1.339	53%
	2	0.358	0.085	1.512	64%
	1 & 2 combined	**0.315**	0.111	0.896	**69%**
With Comparison Group 2	**1**	0.664	0.121	3.658	34%
	2	0.375	0.031	4.544	62%
	1 & 2 combined	0.332	0.072	1.532	67%

Note: Statistically significant results at the 95% confidence level are shown in bold.

Recall that the use of the same campaign buses as a comparison group automatically controls for the difference in bus mileage as well as controlling for other differences caused by extraneous factors resulting from bus-to-bus variability. Thus, comparing rear-ended crashes for campaign buses to non-rear-ended crashes for the same campaign buses is deemed to be a better choice than comparing to rear-ended crashes for non-campaign buses. The analysis with Comparison Group 1 may be viewed stronger than the analysis with Comparison Group 2.

CONCLUSIONS

As the result of the before-after safety analyses suggest, Capital Metro seems to have effectively used the creative advertisements in the rear-end safety campaigns that resulted in a reduction of rear-ended crashes. Both campaigns saw fewer rear-ended crashes during the implementation. Due to the small window of time and limited sample size, however, the reductions estimated for each campaign separately were not statistically significant. The crash reduction ranged from a 34 percent decrease to a 69 percent decrease depending on the campaign and the comparison group.

When the data from the two campaigns were combined and the before-after comparison was performed between crashes (rear-ended and non-rear-ended) involving campaign buses, the crash reduction in rear-ended collisions estimated to be associated with Capital Metro's rear-end advertisement campaigns was 69 percent (statistically significant at the 95 percent confidence level) . Note that the magnatude of percent crash reduction based on the combined data was roughly the same regardless which comparison group researchers use. This finding is important for Capital Metro and others who are working on addressing rear-end crashes.

This study is subject to the limited availability of bus mileage data and short length of the after-period. For future research, some questions that may be worth exploring include:

- What is the long-term effect of this or any other advertisement campaign?
- Which ad design had the best results in terms of crash reduction?
- What does the public think about these messages?
- How effective are other safety advertisement campaigns in comparison to this one?
- Would the results be similar if bus mileage data were available for each bus prior to 2015?

When other vehicles rear end a bus, there can be serious consequences for the drivers and passengers of that vehicle. Capital Metro implemented the rear-end safety campaigns to improve safety for the drivers and passengers invehicles on the Austin area roadways. Having implemented a safety campaign that has resulted in a crash reduction for the rear-ended crash in particular, Capital Metro has improved the safety for all the road users in Austin. In addition, with this study providing quantitative results of the advertisement campaign's effectiveness, Capital Metro has added to the body of knowledge such that others in the transportation industry can benefit when considering countermeasures to address safety.

ACKNOWLEDGMENTS

This project was supported by the research agreement between Capital Metro and the Texas A&M Transportation Institute. The contents of this paper reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein.

AUTHOR CONTRIBUTIONS

The authors confirm contribution to the paper as follows: study conception and design: BD, JH, EP; literature review: CS; data collection and preparation: BD; analysis and interpretation of results: EP; draft manuscript preparation: BD, CS, JH, EP. All authors reviewed the results and approved the final version of the manuscript.

REFERENCES

1. Morris, W. P., and C. P. DeAnnuntis. *Evaluation of Rear-end Bus Collisions and Identification of Possible Solutions.* National Center for Transit Research, Tampa, 2014. https://www.nctr.usf.edu/wp-content/uploadvertisements/2014/04/77955.pdf. Accessed July 6, 2019.

2. Zhou, H., S. Bromfield, and P.-S. Lin. "An Overview of Yield-to-Bus Programs in Florida." *Journal of Public Transportation*, 2011. 14: 151-163.

3. Ketola, H.N., D. Chia, A. Boyd, P. Maier, M. Kaddatz, and R. W. King. *TCRP Report 66: Effective Practices to Reduce Bus Accidents*. Transportation Reserach Board, Washington, D.C., 2016.

4. Recarte, M. A., and L. M. Nunes. "Effects of Verbal and Spatial–Imagery Tasks on Eye Fixations While Driving." *Journal of Experimental Psychology Applied*, 2000. 2000: 151-163.

5. Gregg, R. J., B. Pessaro, M. Catala, and J. Tucci. *Strategies to Prevent, Reduce and Mitigate Bus Collisions*. USF Center for Urban Transportation Research, Tampa, 2016. https://ftson.org/wp-content/uploadvertisements/2016/04/Strategies-to-Prevent-Reduce-and-Mitigate-Bus-Collisions-FINAL.pdf. Accessed July 6, 2019.

6. Delhomme, P., T. Vaa, T. Meyer, C. Goldenbeld, S. Jaermark, N. Christie, and V. Rehnova. *Deliverable 4: Evaluated road safety media campaigns: an overview of 265 evaluated campaigns and some meta-analysis on accidents*. Institut National de Recherche sur les Transports et leur Securite (INRETS), Brussels, March 1999.

7. Elliott, B. *CR 118: Road Safety Mass Media Campaigns: A Meta Analysis*. Federal Office of Road Safety, Canberra, 1993. https://www.infrastructure.gov.au/roadvertisements/safety/publications/1993/pdf/Edu_Media_1.pdf. Accessed July 6, 2019.

8. Zhou, H., P.-S. Lin, A. Fabregas, and E. Gonzalez-Velez. *Moving the Bus Back Into Traffic Safely, Phase II.* National Center for Transit Research, Tampa, 2010. https://www.nctr.usf.edu/wp-content/uploadvertisements/2011/04/77910.pdf. Accessed July 6, 2019.

9. Wundersitz, L., T. Hutchinson, and J. Woolley. *Best practice in road safety mass media campaigns: A literature review.* Centre for Automotive Safety Research, Adelaide, 2010. http://casr.adelaide.edu.au/casrpubfile/972/CASR074.pdf. Accessed July 6, 2019.

10. Hauer, E. *Observational Before-After Studies in Road Safety: Estimating the Effect of Highway and Traffic Engineering Measures on Road Safety*. Pergamon Press, Oxford, U.K., United Kingdom.

11. Rey, J. R., D. Hinebaugh, and J. Fernandez. *Analysis of Florida Transit Bus Crashes.* Transportation Research Board, Washington, DC, 2002. http://dx.doi.org/10.3141/1791-05.

12. Harwood, D. W., K. M. Bauer, I. B. Potts, D. J. Torbic, K. R. Richard, E. R. Kohlman Rabbani, E. Hauer, L. Elefteriadou, and M. S. Griffith. *Safety Effectiveness of Intersection Left- and Right-Turn Lanes.* Transportation Research Board, Washington, DC, 2003. http://dx.doi.org/10.3141/1840-15.