TANTALA ASSOCIATES, LLC
CONSULTING ENGINEERS

A STUDY OF THE RELATIONSHIP BETWEEN DIGITAL BILLBOARDS AND TRAFFIC SAFETY IN THE GREATER READING AREA, BERKS COUNTY, PENNSLYVANIA

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A STUDY OF THE RELATIONSHIP BETWEEN DIGITAL BILLBOARDS AND TRAFFIC SAFETY IN THE GREATER READING AREA, BERKS COUNTY, PENNSLYVANIA

KEY POINTS

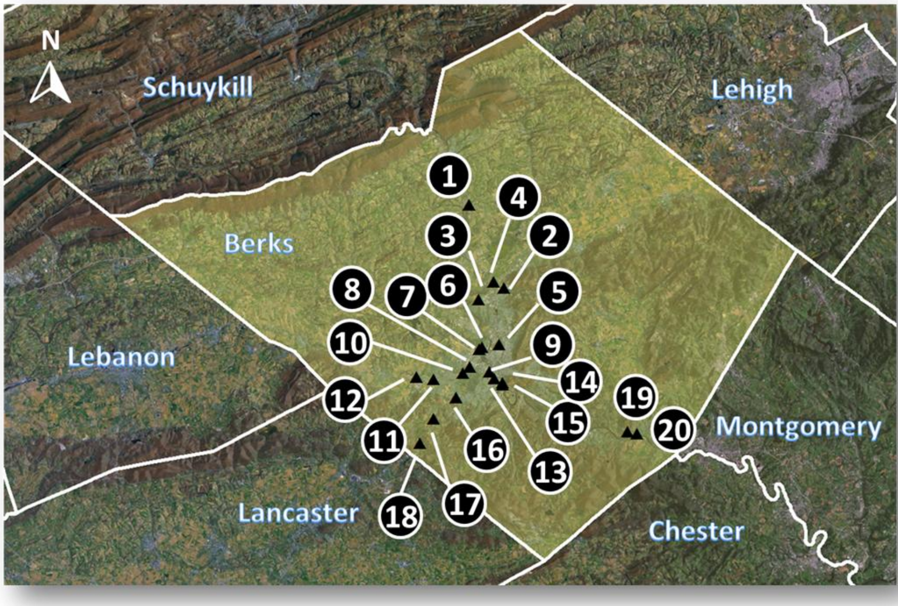
• 8 years of accident data comparison

• 20 locations with 26 digital billboards

• Data shows no statistically significant increase in accident rates using before and after comparisons and an Empirical Bayes Method Analysis

• Comparisons of driver age (young/elderly) and time of day (daytime/nighttime) are neutral factors

• Consistent results for various dwell times (6/8/10 seconds)



KEY

Digital Locations in the Greater Reading Area, Berks County, Pennsylvania

1	Rte 61/ Rte 662	11	Rte 724 / Rte 422
2	Rte 222 N / Leesport	12	422 West / Green Valley
3	Rte 222 N Bypass	13	Lancaster at Rte 10
4	Rte 222 N Bypass	14	West Shore Drive / Lanc Exit
5	5th and Amity	15	West Shore Drive / 176 Exit
6	Waren Bypass at Rte 183	16	Rte 222 / Rte 724
7	Waren Bypass / Allegheny	17	Rte 222 / Gouglersville
8	422 Bypass / Bern	18	Rte 222 / RT 272
9	West Shore Drive / Penn	19	Rte 422 / RT662
10	422 Bypass / State Hill	20	Rte 422 / Old Airport

Figure 1.
Digital Billboard Locations in the Greater Reading Area, Berks County, Pennsylvania

TOC

Eight years of data …

… no statistically significant relationship with the occurrence of accidents …

… consistent results for 6, 8, and 10 second dwell times …

OVERVIEW

The purpose of this study is to **examine the statistical relationship between digital billboards and traffic safety in the Greater Reading Area, Berks County, Pennsylvania**. This study analyzes traffic and accident data along roads near **20 locations with 26 existing, digital billboard faces** (see Figure 1) with traffic volumes on roads collectively representing approximately 233 million vehicles per year. The study uses official data as collected, complied and recorded independently by municipal police departments and the Pennsylvania Department of Transportation.

The study includes **eight years of accident data** representing approximately 35 thousand accidents near twenty locations in Berks County. The billboards were converted to digital format between 2005 and 2009 and afford periods of comparison as long as 8 years (95 months).

Temporal (*when and how frequently*) and spatial (*where and how far*) statistics are summarized near billboards within multiple vicinity ranges as large as one-half mile for areas that are upstream and downstream of the billboards. Subsets of daytime and nighttime accidents and driver age are analyzed for before and after comparisons.

Additionally, an Empirical Bayes Method (EBM) analysis is performed to estimate the number of accidents that could statistically be expected without the introduction of digital signs. This widely accepted analysis establishes benchmarks on the basis of accident records at pre-digital locations and also uses other comparison sites in Reading.

The overall conclusion of the study is that **the digital billboards in the Greater Reading Area have no statistically significant relationship with the occurrence of accidents**. This study also finds that the age of drivers (younger/elderly) and the time of day (daytime/nighttime) are neutral factors which show no significant increase in accident rates near the digital billboards. The results are consistent for 6, 8, and 10 second dwell times (see Figure 2). These conclusions are based on Police Department data and an objective statistical analysis; **the data shows no significant increase in accident rates**.

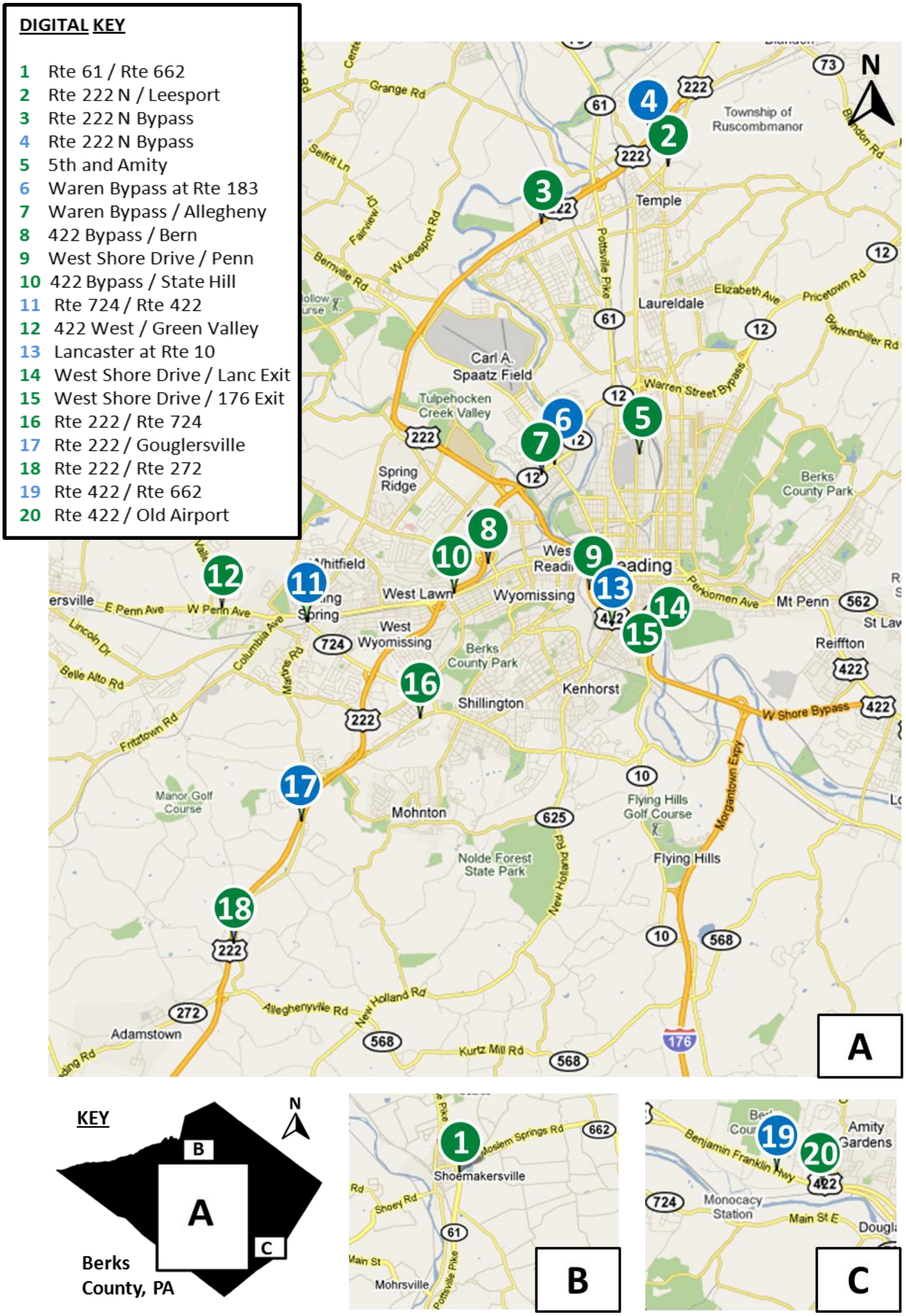


Figure 2.
Digital Billboard Locations in the Greater Reading Area. Locations in “green” have digital bulletins with 10 second dwells times; Locations in “blue” are posters with 8 second dwell times.

The static display on each of these digital billboards have "dwell times" of 6, 8 or 10 seconds.

STUDY REGION

The Greater Reading Area was chosen as a study region, because it has multiple digital billboards in close proximity that were in service for extended periods of time. The roads adjacent to these billboards are heavily traveled (approximately 638 thousand vehicles traveled per day collectively on the sections of road near the digital billboards).

The Greater Reading Area in Berks County, Pennsylvania, is situated in the southeastern part of the State, has an area of approximately 860 square miles, and a population of 373 thousand people and 141 thousand households (2000 census). In 2008, some 162 thousand licensed drivers drove to work in the Greater Reading Area with an average commute time of 22 minutes.

Several federal and state highways allow entry to and egress from Reading. US Route 222 Business is designated as Lancaster Avenue, Bingaman Street, South 4th Street, and 5th Street. US Route 422 Business is designated as Penn Street, Cherry Street, Franklin Street, and Perkiomen Avenue. US Route 422, the major east-west artery, circles the western edge of the city and is known locally as The West Shore Bypass. PA Route 12 is known as the Warren Street Bypass, and bypasses the city to the north. PA Route 10 is known as Morgantown Road.

BILLBOARD CHARACTERISTICS

Digital billboards display static messages which, when viewed, resemble conventional painted or printed billboards. With digital technology, a static copy "dwells" and includes no animation, flashing lights, scrolling, or full-motion video. The static display on each of these digital billboards has "dwell times" of 6, 8, or 10 seconds. The digital billboards use red, green, and blue light-emitting-diode (LED) technology to present text and graphics. The digital billboards compensate for varying light levels, including day and night viewing, by automatically monitoring and adjusting overall display brightness and gamma levels. A photocell is mounted on each digital billboard to measure ambient light. Nineteen of the digital billboards that were studied are owned and operated by *Lamar;* seven, by *Land Displays*.

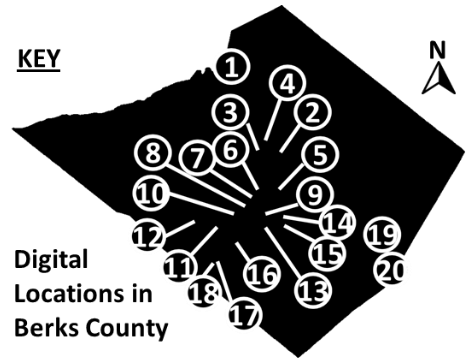
The digital billboards operated by Lamar have dwell times of eight seconds for the smaller poster-sized boards and ten seconds for the larger, bulletin-sized boards. Digital billboards operated by *Land Displays* have dwell times of 8 seconds. Digital billboards which were installed in late 2005 and early 2006 had a dwell time of 6 seconds for a six-month period; these locations were subsequently reset to 8 or 10 seconds (see Figures 2 and 3).

Billboard Location	Location	Operator	Configuration	Road Side	Digital Facing	Reader Side	Face Size (ft)	Dwell Time (seconds)
1	**Rte 61 / Rte 662** on Rte 61, 0.2 miles south of Rte 662	Lamar	Free standing, Center-mount, Vee	E	**N** **S**	cross right	10.5x36 10.5x36	10 10
2	**Rte 222 N / Leesport** on Rte 222 N, 0.1 miles north of Leesport Avenue	Lamar	Free standing, Center-mount, Back-to-Back	E	**S**	right	14x48	10
3	**222 N Bypass** on Rte 222 N Bypass, 1.0 mile south / Rte 61 Exit	Lamar	Free standing, Center-mount, Back-to-Back	E	**N**	cross	14x48	10
4	**222 N Bypass** on Rte 222 N Bypass, 1.0 mile north / Rte 61 Exit	Land Displays	Free standing, Center-mount, Vee	W	**N**	right	20x20	8
5	**5th and Amity** at 5th Street & Amity Street	Lamar	Free standing, Center-mount, Back-to-Back	E	**N**	left	10.5x22.75	8
6	**Waren Bypass at Rte 183** on Rte 12 (Warren Street Bypass) at Rte 183	Land Displays	Roof-top, Frame, Back-to-Back	S	**W**	right	14x48	8
7	**Waren Bypass / Allegheny** on Warren Street west of Allegheny Avenue	Lamar	Free standing, Flag, Vee	S S	**E** **W**	cross right	10.5x36 10.5x36	10 10
8	**422 Bypass / Bern** on Rte 422 Bypass, 0.2 miles west of Bern Road Exit	Lamar	Free standing, Flag, Vee	S S	**E** **W**	cross right	14x48 14x48	10 10
9	**West Shore Drive / Penn** on West Shore Drive, 0.3 miles east of Penn Street	Lamar	Free standing, Center-mount, Vee	S	**E** **W**	left right	10.5x36 10.5x36	10 10
10	**422 Bypass / State Hill** on Rte 422 Bypass, 0.6 miles west / State Hill Rd	Lamar	Free standing, Center-mount, Vee	S	**S**	right	10.5x36	8
11	**Rte 724 / Rte 422** on Rte 724, 1000 feet south of Rte 422	Land Displays	Free standing, Center-mount, Vee	W	**S**	right	10.5x36	8
12	**422 West / Green Valley** on Rte 422 west, 0.1 miles east / Green Valley Rd	Lamar	Free standing, Center-mount, Back-to-Back	N	**E** **W**	right cross	10.5x22.75 10.5x22.75	8 8
13	**Lancaster at Rte 10** on Lancaster Avenue (Rte 422) at Rte 10	Land Displays	Free standing, Center-mount, Back-to-Back	W	**S**	cross	10.5x36	8
14	**West Shore Drive / Lancasater Exit** on West Shore Drive, 0.4 miles east of Lancaster Exit	Lamar	Free standing, Center-mount, Vee	N	**E**	right	10.5x22.75	8
15	**West Shore Drive / 176 Exit** on West Shore Drive, 0.5 miles of Exit 176	Lamar	Free standing, Center-mount, Single-face	N	**W**	cross	10.5x22.75	8
16	**Rte 222 / Rte 724** on Rte 222 S, 0.3 miles south of Rte 724	Lamar	Free standing, Center-mount, Vee	W	**N** **S**	right cross	11x23 11x23	8 8
17	**Rte 222 / Gouglersville** on Rte 222, 0.13 miles north / Gouglersville Exit	Land Displays	Free standing, Center-mount, Single-face	E	**N**	cross	12x25	8
18	**Rte 222 / Rte 272** on Rte 222 S, 1.0 miles north of Rte 272 / 568	Lamar	Free standing, Center-mount, Vee	E	**S**	right	14x48	10
19	**Rte 422 / Rte 662** on Rte 422, 3.0 miles west of Rte 662	Land Displays	Free standing, Center-mount, Double-face	S	**W**	right	10x20	8
20	**Rte 422 / Old Airport** on Rte 422 east, 0.1 mi west of Old Airport Road	Lamar	Free standing, Center-mount, Vee	S	**W**	right	10.5x22.75	8

Figure 3.
Digital Billboard Direction, Sizes and Other Sign Characteristics

The digital, billboard locations are numbered 1 to 20 with 26 billboards. The twenty locations in Reading are shown in Figures 1, 2, and 3 which summarize direction, configuration and other sign characteristics. The digital boards and their surroundings were observed during day and night conditions. A majority of the digital billboards are freestanding, single-pole, structures with one digital face; six locations have two digital boards on the same upright.

Figure 4 summarizes the conversion dates. Nine of the twenty-six billboards were converted to digital format circa December 2005 and the remaining seven were converted on various dates in 2007, 2008 and 2009. These dates allow for before/after comparisons as long as 8.1 years (or 98 months). Additional billboard-location photos, aerials, and map references for each digital location are included within this report as Figures 5 to 25.



Billboard Location	Digital Facing	Install Date	more than 8 years of comparison (2001–2009)
1	N	29Nov08	prior to / as digital
	S	22Sep06	prior to / as digital
2	S	27Jan06	prior to / as digital
3	N	27Jan06	prior to / as digital
4	N	15Jun07	prior to / as digital
5	N	1/13/2006	prior to / as digital
6	W	29Nov05	prior to / as digital
7	E	27Jan06	prior to / as digital
	W	1Aug07	prior to / as digital
8	E	8Jan09	prior to / as digital
	W	8Jan09	prior to / as digital
9	E	29Nov05	prior to / as digital
	W	29Nov05	prior to / as digital
10	S	6Jan09	prior to / as digital
11	S	15Aug08	prior to / as digital
12	E	14May08	prior to / as digital
	W	22Feb08	prior to / as digital
13	S	15Aug08	prior to / as digital
14	E	13Jan06	prior to / as digital
15	W	13Jan06	prior to / as digital
16	N	20Mar08	prior to / as digital
	S	14Mar08	prior to / as digital
17	N	15Aug08	prior to / as digital
18	S	14Apr07	prior to / as digital
19	W	15Jun07	prior to / as digital
20	W	14Apr07	prior to / as digital

Figure 4.
Digital billboard Conversion Dates and Comparison Timelines for Digital Locations in the Greater Reading Area

Location No. 1 is on the east side of Route 61, approximately 0.2 miles south of Route 662. The billboard is a double-face, free standing, center-mount, vee configuration. The north face is a digital bulletin and a cross reader. The north face was converted from a conventional format on 29Nov08 using the existing structure. The south face is a digital bulletin and a right-hand reader. The face was converted from a conventional format on 22Sep06 using the existing structure. Each face is operated by Lamar and has a 10.5x36 size with a dwell time of 10 seconds. Figure 5a is a photo of the south digital face. Figure 5b shows the location in an oblique aerial.

Figure 5. Location No. 1 (5a, left) View on Route 61; inset shows opposite-face digital, (5b, right) Oblique Aerial of location

Location No. 2 is on the east side of Route 222 North, approximately 0.1 miles north of Leesport Avenue. The billboard is a double-face, free standing, center-mount, back-to-back configuration. The south face is a digital bulletin and a right-hand reader. The face was converted from a conventional format on 27Jan06 using the existing structure. The face is operated by Lamar and has a 14x48 size with a dwell time of 10 seconds. Figure 6a is a photo of the digital face. Figure 6b shows the location in an oblique aerial.

Figure 6. Location No. 2 (6a, left) View on Route 222 North, (6b, right) Oblique Aerial of location

Location No. 3 is on the east side of Route 222 North Bypass, approximately 1.0 miles south of the Route 61 Exit. The billboard is a double-face, free standing, center-mount, back-to-back configuration. The north face is a digital bulletin and a cross reader. The north face was converted from a trivision format on 27Jan06 using the existing structure. The face is operated by Lamar and has a 14x48 size with a dwell time of 10 seconds. Figure 7a is a photo of the digital face. Figure 7b shows the location in an oblique aerial.

Figure 7. Location No. 3 (7a, left) View on Route 222 North Bypass, (7b, right) Oblique Aerial of location

Location No. 4 is on the west side of Route 222 North Bypass, approximately 1.0 miles north of Route 61 Exit. The billboard is a double-face, free standing, center-mount, vee configuration. The north face is a digital poster and a right-hand reader. The face was converted from a stacked poster format on 15Jun07 using the existing structure. The face is operated by Land Displays and has a 20x20 size with a dwell time of 8 seconds. Figure 8a is a photo of the digital face. Figure 8b shows the location in an oblique aerial.

Figure 8. Location No. 4 (8a, left) View on Route 222 North Bypass, (8b, right) Oblique Aerial of location

Location No. 5 is on the east side of 5th Street at Amity Street. The billboard is a double-face, free standing, center-mount, back-to-back configuration. The north face is a digital poster and a left-hand reader. The north face was converted from a conventional format on 13Jan06 using the existing structure. The face is operated by Lamar and has a 10.5x22.75 size with a dwell time of 8 seconds. Figure 9a is a photo of the digital face. Figure 9b shows the location in an oblique aerial.

Figure 9. Location No. 5 (9a, left) View at 5th Street and Amity Street, (9b, right) Oblique Aerial of location

5a

5b

6a

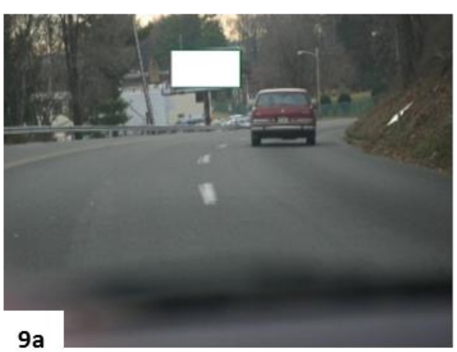
6b

7a

7b

8a

8b



9a

9b

Location No. 6 is on the south side of Route 12 (Warren Street Bypass) at Route 183. The billboard is a double-face, roof-top, frame, back-to-back configuration. The west face is a digital bulletin and a right-hand reader. The face was converted from a conventional format on 29Nov05 using the existing structure. The face is operated by Land Displays and has a 14x48 size with a dwell time of 8 seconds. Figure 10a is a photo of the digital face. Figure 10b shows the location in an oblique aerial.

Figure 10. Location No. 6 (10a, left) View at Route 12 (Warren Street Bypass) at Route 183, (10b, right) Oblique Aerial of location

Location No. 7 is on the south side of the Warren Street Bypass, west of Allegheny Avenue. The billboard is a double-face, free standing, flag, vee configuration. The east face is a digital bulletin and a cross reader. The east face was converted from a conventional format on 27Jan06 using the existing structure. The west face is a digital bulletin and a right-hand reader. The west face was converted from a conventional format on 01Aug07 using the existing structure. Each face is operated by Lamar and has a 10.5x36 size with a dwell time of 10 seconds. Figure 11a is a photo of the digital face. Figure 11b shows the location in an oblique aerial.

Figure 11. Location No. 7 (11a, left) View at Warren Street Bypass, inset shows opposite-face digital, (11b, right) Oblique Aerial of location

Location No. 8 is on the south side of the Route 422 Bypass, approximately 0.2 miles west of the Bern Road Exit. The billboard is a double-face, free standing, flag, vee configuration. The east face is a digital bulletin and a cross reader. The east face was converted from a conventional format on 08Jan09 using the existing structure. The west face is a digital bulletin and a right-hand reader. The west face was converted from a conventional format on 08Jan09 using the existing structure. Each face is operated by Lamar and has a 14x48 size with a dwell time of 10 seconds. Figure 12a is a photo of the digital face. Figure 12b shows the location in an oblique aerial.

Figure 12. Location No. 8 (12a, left) View at Route 422 Bypass, inset shows opposite-face digital, (12b, right) Oblique Aerial of location

Location No. 9 is on the south side of West Shore Drive, approximately 0.3 miles east of Penn Street. The billboard is a double-face, free standing, center-mount, vee configuration. The east face is a digital bulletin and a left-hand reader. The east face was converted from a trivision format on 29Nov05 using the existing structure. The west face is a digital bulletin and a right-hand reader. The west face was converted from a trivision format on 29Nov05 using the existing structure. Each face is operated by Lamar and has a 10.5x36 size with a dwell time of 10 seconds. Figure 13a is a photo of the digital face. Figure 13b shows the location in an oblique aerial.

Figure 13. Location No. 9 (13a, left) View at West Shore Drive, inset shows opposite-face digital, (13b, right) Oblique Aerial of location

Location No. 10 is on the south side of the Route 422 Bypass, approximately 0.6 miles west of State Hill Road. The billboard is a double-face, free standing, center-mount, vee configuration. The south face is a digital poster and a right-hand reader. The face was converted from a conventional format on 06Jan09 using the existing structure. The face is operated by Lamar and has a 10.5x36 size with a dwell time of 8 seconds. Figure 14a is a photo of the digital face. Figure 14b shows the location in an oblique aerial.

Figure 14. Location No. 10 (14a, left) View at Route 422 Bypass, (14b, right) Oblique Aerial of location

10a

10b

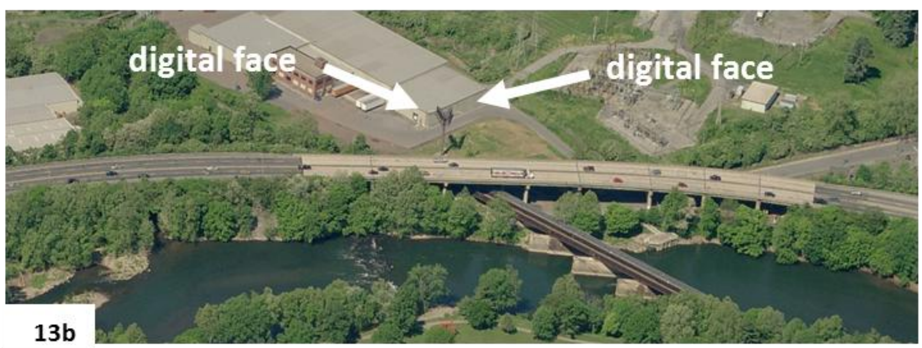

11a

11b


12a

12b


13a



13b


14a

14b

Location No. 11 is on the west side of Route 724, approximately 1000 feet south of Route 422. The billboard is a double-face, free standing, center-mount, vee configuration. The south face is a digital bulletin and a right-hand reader. The face was converted from a conventional format on 15Aug08 using the existing structure. The face is operated by Land Displays and has a 10.5x36 size with a dwell time of 8 seconds. Figure 15a is a photo of the digital face. Figure 15b shows the location in an oblique aerial.

Figure 15. Location No. 11 (15a, left) View at Route 724, (15b, right) Oblique Aerial of location

Location No. 12 is on the north side of Route 422 West, approximately 0.1 miles east of Green Valley Road. The billboard is a double-face, free standing, center-mount, back-to-back configuration. The east face is a digital poster and a right-hand reader. The east face was converted from a conventional format on 14May08 using the existing structure. The west face is a digital poster and a cross reader. The west face was converted from a conventional format on 22Feb08 using the existing structure. Each face is operated by Lamar and has a 10.5x22.75 size with a dwell time of 8 seconds. Figure 16a is a photo of the digital face. Figure 16b shows the location in an oblique aerial.

Figure 16. Location No. 12 (16a, left) View at Route 422 West, inset shows opposite-face digital, (16b, right) Oblique Aerial of location

Location No. 13 is on the west side of Lancaster Avenue (Route 422) at Route 10. The billboard is a double-face, free standing, center-mount, back-to-back configuration. The south face is a digital bulletin and a cross reader. The south face was converted from a poster format on 15Aug08 using the existing structure. The face is operated by Land Displays and has a 10.5x36 size with a dwell time of 8 seconds. Figure 17a is a photo of the digital face. Figure 17b shows the location in an oblique aerial.

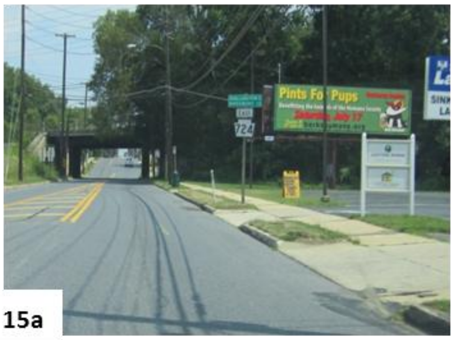
Figure 17. Location No. 13 (17a, left) View at Lancaster Avenue (Route 422) at Route 10, (17b, right) Oblique Aerial of location

Location No. 14 is on the north side of West Shore Drive, approximately 0.4 miles east of the Lancaster Exit. The billboard is a single-face, free standing, center-mount, vee configuration. The east face is a digital poster and a right-hand reader. The face was converted from a conventional format on 13Jan06 using the existing structure. The face is operated by Lamar and has a 10.5x22.75 size with a dwell time of 8 seconds. Figure 18a is a photo of the digital face. Figure 18b shows the location in an oblique aerial.

Figure 18. Location No. 14 (18a, left) View at West Shore Drive, (18b, right) Oblique Aerial of location

Location No. 15 is on the north side of West Shore Drive, approximately 0.5 miles west of Exit 176. The billboard is a single-face, free standing, center-mount configuration. The west face is a digital poster and a cross reader. The face was converted from a conventional format on 13Jan06 using the existing structure. The face is operated by Lamar and has a 10.5x22.75 size with a dwell time of 8 seconds. Figure 19a is a photo of the digital face. Figure 19b shows the location in an oblique aerial.

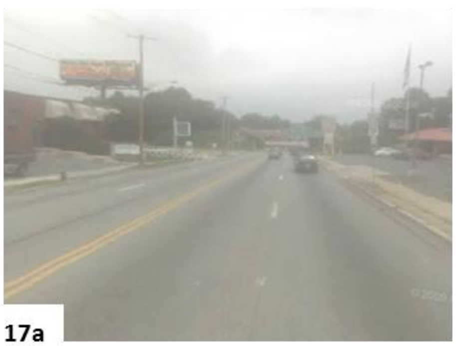
Figure 19. Location No. 15 (19a, left) View at West Shore Drive, (19b, right) Oblique Aerial of location


15a

15b


16a

16b


17a

17b


18a

18b


19a

19b

Location No. 16 is on the west side of Route 222 South, approximately 0.3 miles south of Route 724. The billboard is a double-face, free standing, center-mount, vee configuration. The north face is a digital poster and a right-hand reader. The north face was converted from a conventional format on 20Mar08 using the existing structure. The south face is a digital poster and a cross reader. The south face was converted from a conventional format on 14Mar08 using the existing structure. Each face is operated by Lamar and has a 11x23 size with a dwell time of 8 seconds. Figure 20a is a photo of the digital face. Figure 20b shows the location in an oblique aerial.

Figure 20. Location No. 16 (20a, left) View at Route 222 South, inset shows opposite-face digital, (20b, right) Oblique Aerial of location

Location No. 17 is on the east side of Route 222, approximately 0.13 miles north of the Gouglersville Exit. The billboard is a single-face, free standing, center-mount configuration. The north face is a digital poster and a cross reader. The face was a new location that was installed and activated on 15Aug08. The face is operated by Land Displays and has a 12x25 size with a dwell time of 8 seconds. Figure 21a is a photo of the digital face. Figure 21b shows the location in an oblique aerial.

Figure 21. Location No. 17 (21a, left) View at Route 222, (21b, right) Oblique Aerial of location

Location No. 18 is on the east side of Route 222 South, approximately 1.0 mile north of the intersection of Routes 272 and 568. The billboard is a single-face, free standing, center-mount, vee configuration. The south face is a digital bulletin and a right-hand reader. The face was converted from a conventional format on 14Apr07 using the existing structure. The face is operated by Lamar and has a 14x48 size with a dwell time of 10 seconds. Figure 22a is a photo of the digital face. Figure 22b shows the location in an oblique aerial.

Figure 22. Location No. 18 (22a, left) View at Route 222 South, (22b, right) Oblique Aerial of location

Location No. 19 is on the south side of Route 422, approximately 3.0 miles west of Route 662. The billboard is a single-face, free standing, cemter-mount configuration. The west face is a digital poster and a right-hand reader. The face was converted from a conventional format on 15Jun07 using the existing structure. The face is operated by Land Displays and has a 10x20 size with a dwell time of 8 seconds. Figure 23a is a photo of the digital face. Figure 23b shows the location in an oblique aerial.

Figure 23. Location No. 19 (23a, left) View at Route 422, (23b, right) Oblique Aerial of location

Location No. 20 is on the south side of Route 422 East, approximately 0.1 miles west of Old Airport Road. The billboard is a single-face, free standing, center-mount, vee configuration. The west face is a digital poster and a right-hand reader. The face was converted from a conventional format on 14Apr07 using the existing structure. The face is operated by Lamar and has a 10.5x22.75 size with a dwell time of 8 seconds. Figure 24a is a photo of the digital face. Figure 24b shows the location in an oblique aerial.

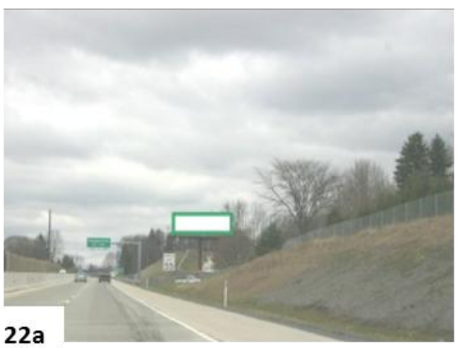
Figure 24. Location No. 20 (24a, left) View at Route 422 East, (24b, right) Oblique Aerial of location


20a

20b


21a

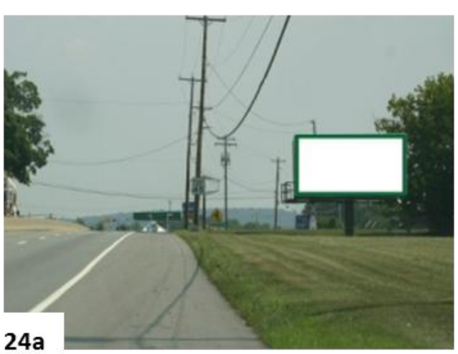
21b

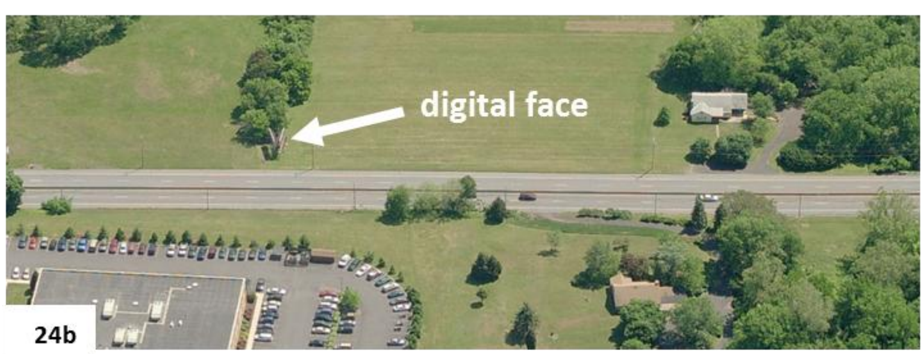

22a

22b


23a

23b


24a



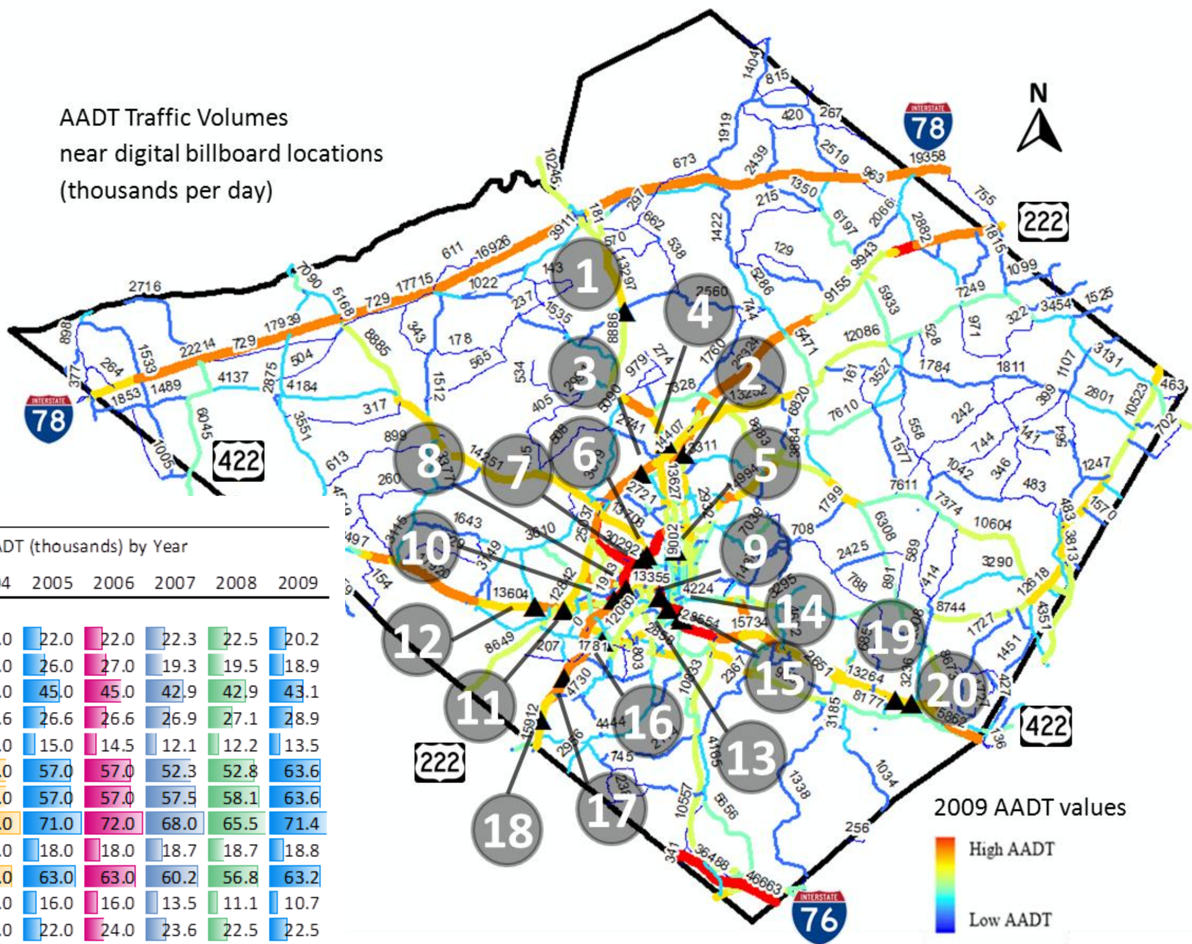
24b

AADT ranges individually near the 20 digital locations from 6 to 72 thousand vehicles per day, or equivalently 2 to 26 million vehicles per year.

TRAFFIC VOLUME DATA

Traffic volume data for the Greater Reading Area was obtained from the Pennsylvania Department of Transportation (PennDOT) and includes the annual average daily traffic (AADT), which is the average of 24-hour counts collected throughout the year. The AADT volumes were recorded in the Greater Reading area between 2002 and 2009.

The AADT values are summarized in Figure 25. AADT ranges individually near the 20 digital locations from 6 to 72 thousand vehicles per day, or equivalently 2 to 26 million vehicles per year. For each of the location, this collectively represents approximately 665 thousand vehicles per day or 240 million vehicles per year.



Location	AADT (thousands) by Year							
	2002	2003	2004	2005	2006	2007	2008	2009
1	18.0	18.0	19.0	22.0	22.0	22.3	22.5	20.2
2	24.0	24.0	25.0	26.0	27.0	19.3	19.5	18.9
3	40.0	40.0	44.0	45.0	45.0	42.9	42.9	43.1
4	22.7	23.9	26.6	26.6	26.6	26.9	27.1	28.9
5	14.5	15.0	15.0	15.0	14.5	12.1	12.2	13.5
6	62.0	54.0	55.0	57.0	57.0	52.3	52.8	63.6
7	62.0	54.0	55.0	57.0	57.0	57.5	58.1	63.6
8	71.0	68.0	72.0	71.0	72.0	68.0	65.5	71.4
9	17.0	17.0	18.0	18.0	18.0	18.7	18.7	18.8
10	60.0	60.0	62.0	63.0	63.0	60.2	56.8	63.2
11	14.0	14.0	14.0	16.0	16.0	13.5	11.1	10.7
12	20.0	20.0	22.0	22.0	24.0	23.6	22.5	22.5
13	5.8	5.8	6.0	9.8	9.8	15.7	15.9	16.9
14	52.0	59.0	58.0	57.0	55.0	58.4	53.8	57.9
15	52.0	59.0	58.0	57.0	55.0	58.4	53.8	57.9
16	9.3	9.4	9.5	9.5	9.4	9.3	9.1	9.1
17	29.0	29.0	30.0	33.0	35.5	37.9	37.9	38.2
18	29.0	29.0	30.0	33.0	35.5	31.9	30.6	30.6
19	24.0	24.0	24.0	27.0	27.0	27.5	27.8	27.3
20	24.0	24.0	24.0	27.0	27.0	26.6	27.8	27.3

Figure 25. AADT Volume Data near Digital Billboard Locations in the Greater Reading Area; the Data is summarized in a table from 2002 to 2009 (left) and thematically mapped for 2009 (above)

ACCIDENT DATA

In the Greater Reading Area, the majority of accident reports are investigated and recorded by each Township's Police Department. Data was maintained by those Police Departments and compiled by the Pennsylvania Department of Transportation. Law-enforcement officials are required to submit reports on crashes they investigate which meet reporting thresholds provided by statue, or in which someone was injured or killed in the crash. Data generally conform to the American National Standards Institute (ANSI) Standard D16.1 – 1996, Manual on Classification of Motor Vehicle Traffic Accidents.

The accident data set provided by PennDOT includes 35,000 accidents during the eight years between 2001 and 2009 and near digital billboard locations. Most of the data is specified by latitude and longitude or addresses and intersections with offset distances. Figure 26 shows the geocoded accident locations generally within Berks County.

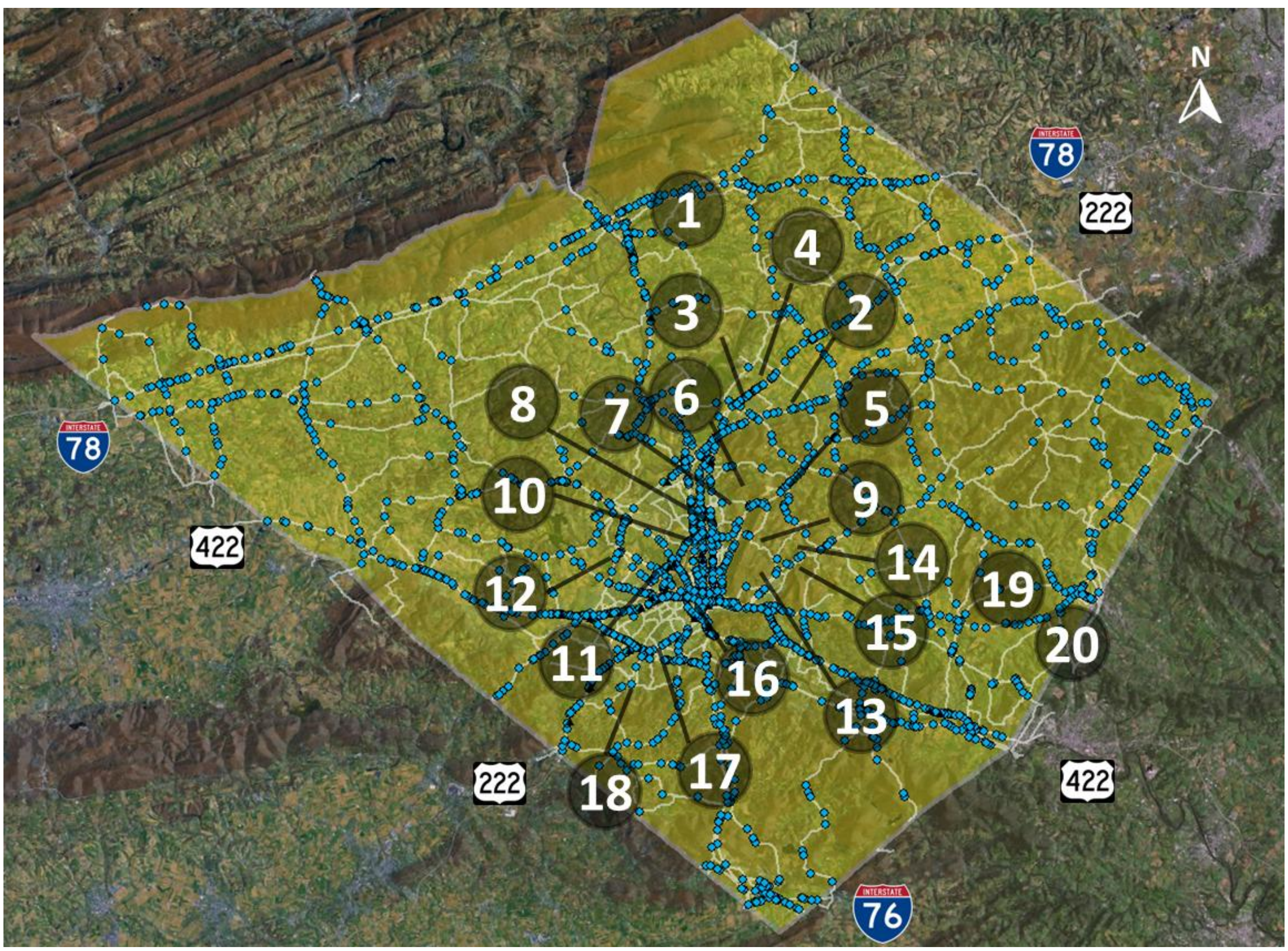


Figure 26. Traffic Accidents (blue dots) near Digital Billboard Locations in the Greater Reading Area from 2001 to 2009

F igure 27 summarizes the traffic accident data for the past seven years generally within the Greater Reading Area and shows the distribution of accidents by year, month, day of week and time of day. This represents a consistent pattern of data and illustrates that more accidents occur on weekdays and at rush hour (before and after work).

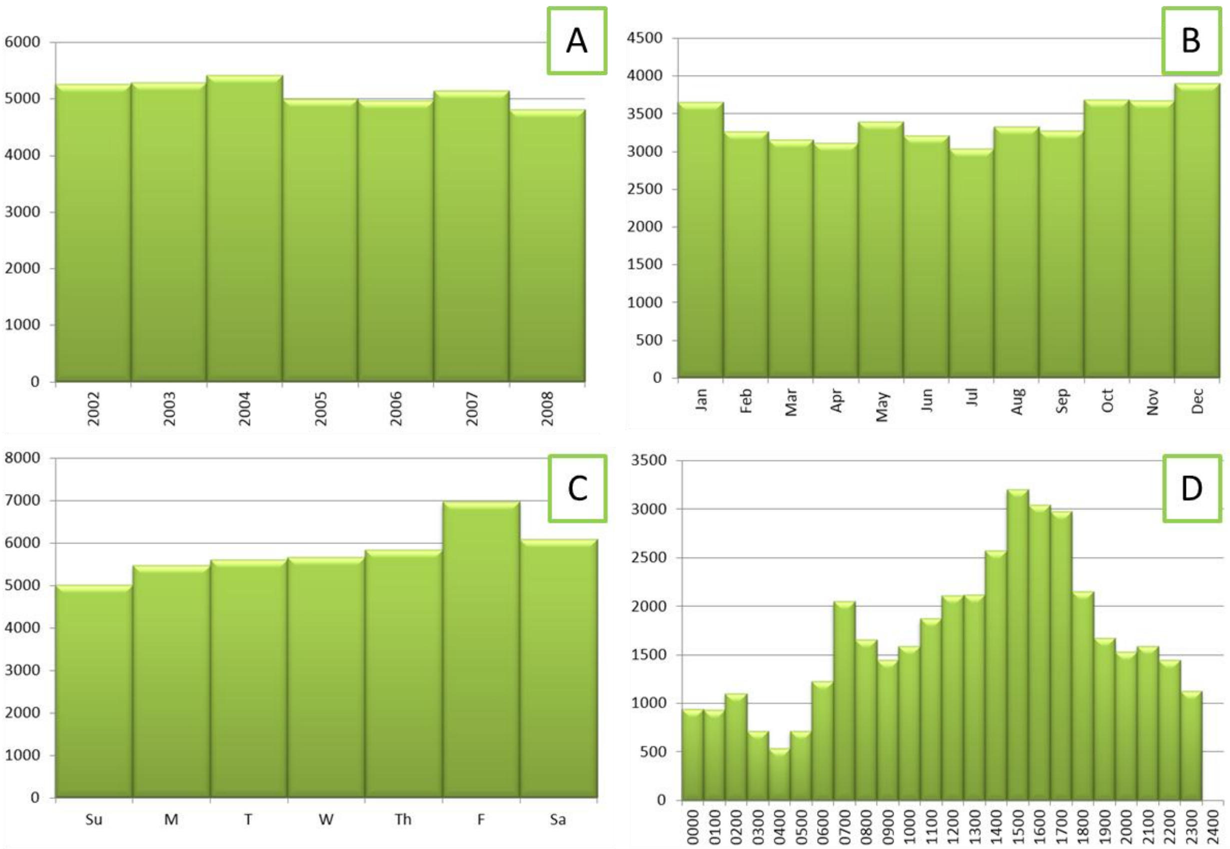


Figure 27. Histogram of Traffic Accident Data of the Past Seven Years in the Greater Reading Area and by (A) Year, (B) Month, (C) Day of Week and (D) Time of Day

The analysis of this robust data involves an engineering-statistics based approach and uses widely accepted methods to show what happened when these 26 digital billboards were installed in Reading.

ANALYSIS

The a nalysis of this robust data involves an engineering-statistics based approach and uses widely accepted methods to show what happened when these 26 digital billboards were installed in the Greater Reading Area.

The analysis has three parts.

Part 1 is a temporal analysis which compares *before* and *after* changes in crash rates and other metrics.

Part 2 is a spatial analysis which compares *where* and *how far* data to establish statistical correlation coefficients for various scenarios accounting for accident density and billboard proximity.

Part 3 uses the Empirical Bayes (EB) uses the 'before' accident statistics to predict the number of accidents "expected" at the locations assuming that no digital billboard technology was introduced. We then quantify what the actual 'after' accident statistics are and compare them with what the predicted values are from the EB analysis. This method analyzes data from the twenty billboard location and incorporates data using non-digital "comparison" sites.

Analysis: Part 1 – Temporal Comparisons

The first part is a temporal analysis. The incidence of traffic accidents near the digital billboards is examined for an equal length of time before and after the digital billboards were installed and activated. This part is for the purpose of establishing if traffic accidents occurred more or less frequently in the presence of these digital billboards. With information collected from police accident reports, the temporal analysis also uses metrics such as traffic volumes, the accident-rate values, the maximum number of accidents during any given month, etc.

For comparison, accident statistics were summarized near the digital billboards within multiple vicinity ranges of 0.1, 0.2, 0.3, 0.4, and 0.5 miles both upstream and downstream of each billboard. For locations on local roads, these vicinity ranges also sampled data to include: (1) accidents along the principal roads to which the digitals directly advertise, (2) accidents recorded as occurring within the intersection of the primary road and any cross roads, and (3) for crossroad accidents within a reasonable distance from the primary road to include drivers turning onto or leaving the primary road. Accident data for roads to which the digitals do not advertise or are not connected were excluded, even if they were within the specified vicinity range.

Analysis: Part 2 – Spatial Comparisons

The second part is a spatial analysis. This establishes statistical correlation coefficients between the digital billboards and accidents. Correlation coefficients are statistical measures of the "association" between two sets of data. The results are analyzed for various scenarios accounting for accident density and billboard proximity.

Additionally, subsets of accident data for age of driver and for daytime and nighttime accidents are analyzed for before and after comparisons. For a more lengthy discussion of analysis methods, please refer to previous studies (see References 6 and 7).

Analysis: Part 3 – The Empirical Bayes (EB) Method

The third part of the analysis uses the Empirical Bays (EB) method.

Research literature suggests that the EB method is appropriate for this type of analysis and is a widely accepted method in the field of traffic safety. The correction for regression to the mean and the use of a negative binomial distribution are strengths of the EB method.

The negative binomial distribution is established by researchers as an accurate description of yearly crash variation between sites and was previously used to model and evaluate various transportation safety projects (see References 14 through 30).

The empirical bayes method is used to estimate the number of crashes before the site change (ie, before the introduction of digital technology). These "before" estimates are then used to predict the number of crashes that could be expected to occur at a certain location, during a specified year, without the introduction of digital technology.

The change in safety at a location is given as:

$$\Delta\, safety \;=\; B - A$$

where $\Delta\, safety$ is the change in the number of crashes, B is the expected number of crashes in the after period without the introduction of digital technology, and A is the actual number of crashes reported in the after improvement period.

After identifying digital locations, a statistical crash estimate model (CEM) is developed. The CEM model is a multivariate, regression model used to estimate the mean and variance of the annual number of crashes that could be expected at each location. Various multivariate models were tested through an iterative process by fitting the available traits. The analysis uses a negative binomial distribution by fitting a generalized, linear model to the data by maximum likelihood estimation of the parameter vector, B.

The p-value is used as an indicator of the significance of the individual traits. The traits that produced a statistically sound model include the average daily traffic (ADT) for the location. The resulting CEM is then:

$$P = \alpha_{\lambda}(AADT)^{\beta_1}\,(LANE)^{\beta_2}(Speed)^{\beta_3}$$

The model paramters and the over-dispersion parameter (theta) is then calculated. The over-dispersion paramter is a measure of the extra variation in the negative binomial distributions compared to a traditional Poisson distribution; this parameter is commonly used in the calculation of the variance, or

$$variance = mean * \left(1 + \frac{mean}{\phi}\right)$$

Using the model, analyzed parameters and data, the expected number of crashes is estimated for each location, had there been no digital technology introduced.

For each location, the first year for available data was used as a base year and a normalized mean number of crashes for each year, y is calculated as

$$C_y = \frac{P_y}{P_b}$$

Where, P_y and P_b are the predicted total number of crashes from the CEM for the year y and the base year, respectively for each location. The projection of the number of crashes is independent of the choice of the base year.

The variance of the expected number of crashes, $Var(P)$ is calculated using the overdispersion parameter, as

$$Var(P) = (1 + \phi * P) * P$$

The relative weight, α, is calculated as

$$\alpha = \frac{P}{Var(P)}$$

Actual location crash counts, K, are then used to determine the EB estimate of mean and variance of the number of crashes for a site; EB and $Var(EB)$, respectively are:

$$EB = \alpha * P + (1 - \alpha) * K$$

$$Var(EB) = (1 - \alpha) * EB$$

The projection of the expected "after" treatment number of crashes is based on the weighted average of the EB estimates of number of crashes of all "before" treatment years for conversion to digital technology.

The estimate of the baseline mean and the variance number of crashes, PC_b and $Var(PC_b)$ is determined as:

$$PC_b = \frac{\sum_{before} EB}{\sum_{before} C_y}$$

$$Var(PC_b) = \frac{\sum_{before} Var(EB)}{\left(\sum_{before} C_y\right)^2}$$

The projected number of crashes for the conversion locations in the "after" conversion period is calculated by multiplying the normalized number of crashes/year, C_y, by the baseline projected number of crashes, PC_b. The mean and variance of the projected crash count in the "after" conversion period for year, y, B and $Var(B)$, are calculated as

$$B = C_y * PC_b$$

$$Var(B) = C_y^2 * Var(PC_b)$$

The overall index of effectiveness, theta, is then calculated by comparing the total projected number of crashes (B) in the after period to the total actual number of crashes (A) in the after period as

$$\theta = \frac{\sum A}{\sum B}$$

The unbiased estimate, θ_u, is then

$$\theta_u = \frac{\theta}{1 + \frac{\sum Var(B)}{(\sum B)^2}}$$

The percent change in total crashes due to the introduction of digital technology is

$$\Delta\, crashes\ (\%) = (1 - \theta_u) * 100$$

If the change of introducing digital technology causes crashes to be increased, then θ_u will be significantly larger than one and $\Delta\, crashes$ will be a negative value significantly lower than zero.

This analysis is applied to the data at 77 locations representing the twenty digital locations and 57 comparison sites.

The number of accidents and rates of accidents near the twenty digital billboards remained consistent within all vicinity ranges.

RESULTS

Figure 28 shows a comparison of the accident metrics for before and after conversions near all twenty digital billboards in the Greater Reading Area. The statistics are summarized for vicinity ranges of 0.1, 0.2, 0.3, 0.4, and 0.5 miles of the digital locations with 8 and 10 second dwell times. Figures 29 and 30 separately summarize comparison statistics for the 8 and 10 second dwell times, respectively. The metrics in Figures 28, 29, and 30 include the total number of accidents, the average number of accidents in any given month, the peak number of accidents in any given month, etc. Other metrics, including rates and vehicle-miles traveled were also analyzed.

For 8 and 10 second-dwell locations (Figure 28), the number of accidents and rates of accidents near the twenty, digital billboards decreased in all vicinity ranges. The benchmark, 0.5-mile vicinity experienced an 11.1% decrease in the number of accidents over the eight year span for all location; this includes 13.0% decrease in accident rates per million AADT vehicles.

For 8-second-dwell locations (Figure 29), the number of accidents and rates of accidents near these seven digital locations decreased in all vicinity ranges. The benchmark 0.5 mile vicinity experienced a 11.9% decrease in the number of accidents over the eight year span; this includes 12.2% decrease in accident rates per million AADT vehicles. Within the 0.5 mile vicinity, the peak number of accidents at any one location and in any given month decreased from 10 to 9. Similar decreases and trends in both averages and peaks were observed for both smaller and larger vicinity ranges.

For 10-second-dwell locations (Figure 30), the number of accidents and rates of accidents near these 13 digital locations decreased in all vicinity ranges. The benchmark 0.5 mile vicinity experienced a 10.4% decrease in the number of accidents over the eight year span; this includes 13.4% decrease in accident rates per million AADT vehicles.

Figure 31 shows the distributions of the number of accidents per month near digital billboards for 8 and 10 second-dwell locations within the benchmark 0.5 mile vicinity between 2001 and 2009. Figure 32 compares this distribution with 8 second-dwell and 10 second-dwell locations separately.

A statistical t-test is used to determine whether the average difference between the two, time periods is really significant or if it is due to random difference. Using a 95% confidence interval, indicates no statistically significant difference in the accident statistics evaluated between conventional and digital billboards at these digital locations.

Consistent results were obtained for before and after comparisons of the six month period in 2006 when the dwell time was 6 seconds. Additionally, consistent results were obtained for driver-age comparisons. Low correlation coefficients were calculated for the spatial analysis. Correlation coefficients were calculated and indicated a very strong correlation of accident patterns near the digital billboards when compared with the accident patterns prior to conversion.

The statistical evaluation of the Empirical Bayes method and results show that the total number of accidents are approximately equivalent to what would be statistically expected with or without the introduction of digital technology and that the safety near this locations are consistent with the model benchmarked by 77 locations within Berks County.

Betwen 2001 and 2009 for equal periods before and after at each location
At all 20 locations with **8 and 10 second dwells**

		Vicinity Range from Digital Location (miles)				
		0.1	0.2	0.3	0.4	0.5
Prior to Installation	Total Number of Accidents for Equal Periods Before Conversion	203	501	693	872	1063
Prior to Installation	Average Number of Accidents per Month at Each Location	0.31	0.76	1.06	1.33	1.62
Prior to Installation	Rate of Accidents per Million Vehicles (by million AADT)	0.29	0.72	0.99	1.25	1.52
Prior to Installation	Standard Deviation of Number of Accidents in any given month at locations	0.64	1.09	1.35	1.52	1.68
Prior to Installation	Peak Number of Accidents in any given Month per Location	5	8	8	9	10
Prior to Installation	Minimun Number of Accidents per Month per Location	0	0	0	0	0
Prior to Installation	Average Number of Accident-Free Months at Locations	80%	58%	48%	40%	34%
As Digital Location	Total Number of Accidents for Equal Periods After Conversion	167	412	540	707	925
As Digital Location	Average Number of Accidents per Month at Each Location	0.25	0.63	0.82	1.08	1.41
As Digital Location	Rate of Accidents per Million Vehicles (by million AADT)	0.24	0.60	0.79	1.03	1.35
As Digital Location	Standard Deviation of Number of Accidents in any given month at locations	0.59	1.05	1.21	1.43	1.69
As Digital Location	Peak Number of Accidents in any given Month per Location	4	6	7	8	9
As Digital Location	Minimun Number of Accidents per Month per Location	0	0	0	0	0
As Digital Location	Average Number of Accident-Free Months at Locations	84%	67%	59%	51%	43%
Comparison	Change in Number of Accidents	-36	-89	-153	-165	-138
Comparison	Change in Average per Month	-0.05	-0.14	-0.23	-0.25	-0.21
Comparison	Change in Rate per million vehicles (by million AADT)	-0.05	-0.11	-0.20	-0.21	-0.17
Comparison	Percent Change in Number of Accidents	-17.7%	-17.8%	-22.1%	-18.9%	-13.0%
Comparison	Percent Change in Rate of Accidents	-15.9%	-16.0%	-20.4%	-17.1%	-11.1%

Figure 28. Summary Accident Statistics within Vicinity Ranges near Twenty Digital-Billboards Locations with 8 and 10 second Dwell Times in the Greater Reading Area

Betwen 2001 and 2009 for equal periods before and after at each location
At 7 locations with **8 second dwells**

		Vicinity Range from Digital Location (miles)				
		0.1	0.2	0.3	0.4	0.5
Prior to Installation	Total Number of Accidents for Equal Periods Before Conversion	79	193	262	315	368
	Average Number of Accidents per Month at Each Location	0.29	0.71	0.96	1.16	1.35
	Rate of Accidents per Million Vehicles (by million AADT)	0.28	0.68	0.92	1.10	1.29
	Standard Deviation of Number of Accidents in any given month at locations	0.56	0.99	1.21	1.37	1.56
	Peak Number of Accidents in any given Month per Location	3	5	5	6	8
	Minimun Number of Accidents per Month per Location	0	0	0	0	0
	Average Number of Accident-Free Months at Locations	79%	58%	50%	46%	42%
As Digital Location	Total Number of Accidents for Equal Periods After Conversion	65	161	225	266	323
	Average Number of Accidents per Month at Each Location	0.24	0.59	0.83	0.98	1.19
	Rate of Accidents per Million Vehicles (by million AADT)	0.23	0.57	0.79	0.94	1.14
	Standard Deviation of Number of Accidents in any given month at locations	0.60	1.05	1.22	1.38	1.59
	Peak Number of Accidents in any given Month per Location	4	6	6	7	8
	Minimun Number of Accidents per Month per Location	0	0	0	0	0
	Average Number of Accident-Free Months at Locations	86%	69%	59%	55%	49%
Comparison	Change in Number of Accidents	-14	-32	-37	-49	-45
	Change in Average per Month	-0.05	-0.12	-0.14	-0.18	-0.17
	Change in Rate per million vehicles (by million AADT)	-0.05	-0.11	-0.13	-0.17	-0.15
	Percent Change in Number of Accidents	-17.7%	-16.6%	-14.1%	-15.6%	-12.2%
	Percent Change in Rate of Accidents	-17.4%	-16.2%	-13.8%	-15.2%	-11.9%

Figure 29. Summary Accident Statistics within Vicinity Ranges near Seven Digital Billboards Locations with 8-second Dwell Times in the Greater Reading Area

Betwen 2001 and 2009 for equal periods before and after at each location
At 13 locations with **10 second dwells**

		Vicinity Range from Digital Location (miles)				
		0.1	0.2	0.3	0.4	0.5
Prior to Installation	Total Number of Accidents for Equal Periods Before Conversion	124	308	431	557	695
	Average Number of Accidents per Month at Each Location	0.30	0.75	1.06	1.37	1.71
	Rate of Accidents per Million Vehicles (by million AADT)	0.30	0.74	1.04	1.34	1.68
	Standard Deviation of Number of Accidents in any given month at locations	0.67	1.12	1.40	1.57	1.71
	Peak Number of Accidents in any given Month per Location	5	8	8	9	10
	Minimun Number of Accidents per Month per Location	0	0	0	0	0
	Average Number of Accident-Free Months at Locations	89%	65%	54%	42%	34%
As Digital Location	Total Number of Accidents for Equal Periods After Conversion	102	251	315	441	602
	Average Number of Accidents per Month at Each Location	0.25	0.61	0.76	1.06	1.47
	Rate of Accidents per Million Vehicles (by million AADT)	0.25	0.63	0.79	1.10	1.50
	Standard Deviation of Number of Accidents in any given month at locations	0.57	1.03	1.17	1.44	1.72
	Peak Number of Accidents in any given Month per Location	3	6	7	8	9
	Minimun Number of Accidents per Month per Location	0	0	0	0	0
	Average Number of Accident-Free Months at Locations	92%	73%	66%	57%	46%
Comparison	Change in Number of Accidents	-22	-57	-116	-116	-93
	Change in Average per Month	-0.06	-0.15	-0.30	-0.31	-0.25
	Change in Rate per million vehicles (by million AADT)	-0.04	-0.12	-0.25	-0.24	-0.17
	Percent Change in Number of Accidents	-17.7%	-18.5%	-26.9%	-20.8%	-13.4%
	Percent Change in Rate of Accidents	-14.9%	-15.7%	-24.4%	-18.1%	-10.4%

Figure 30. Summary Accident Statistics within Vicinity Ranges near 13 Digital Billboards Locations with 10-second Dwell Times in the Greater Reading Area

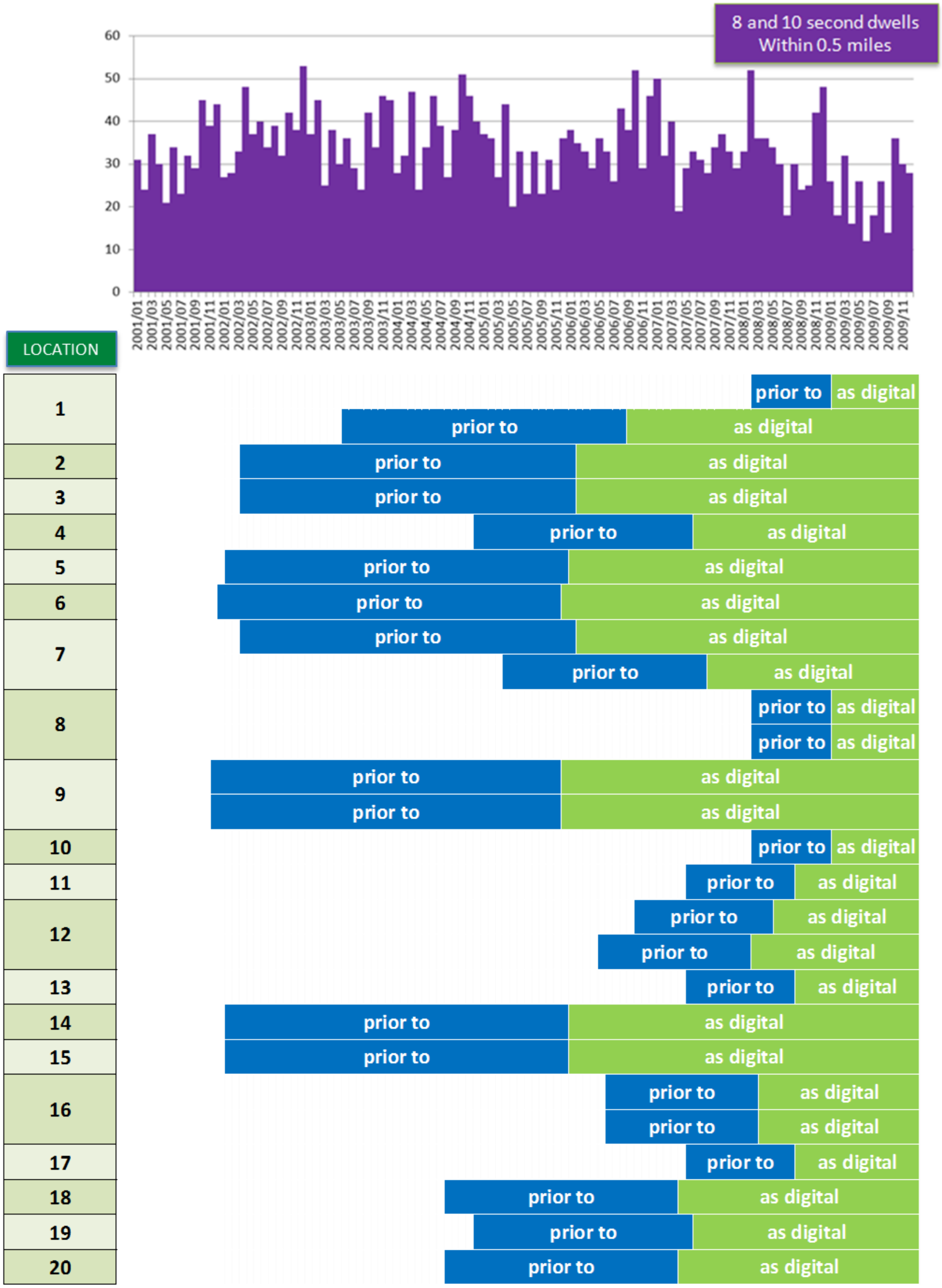


Figure 31. Distributions of the Number of Accidents per Month near Digital Billboards between 2001 and 2009 within a 0.5-mile Vicinity Range near all Digital Locations for 8 and 10 Second-dwell Times (top, purple) compared with Conversion Dates and Before/After Comparison Periods

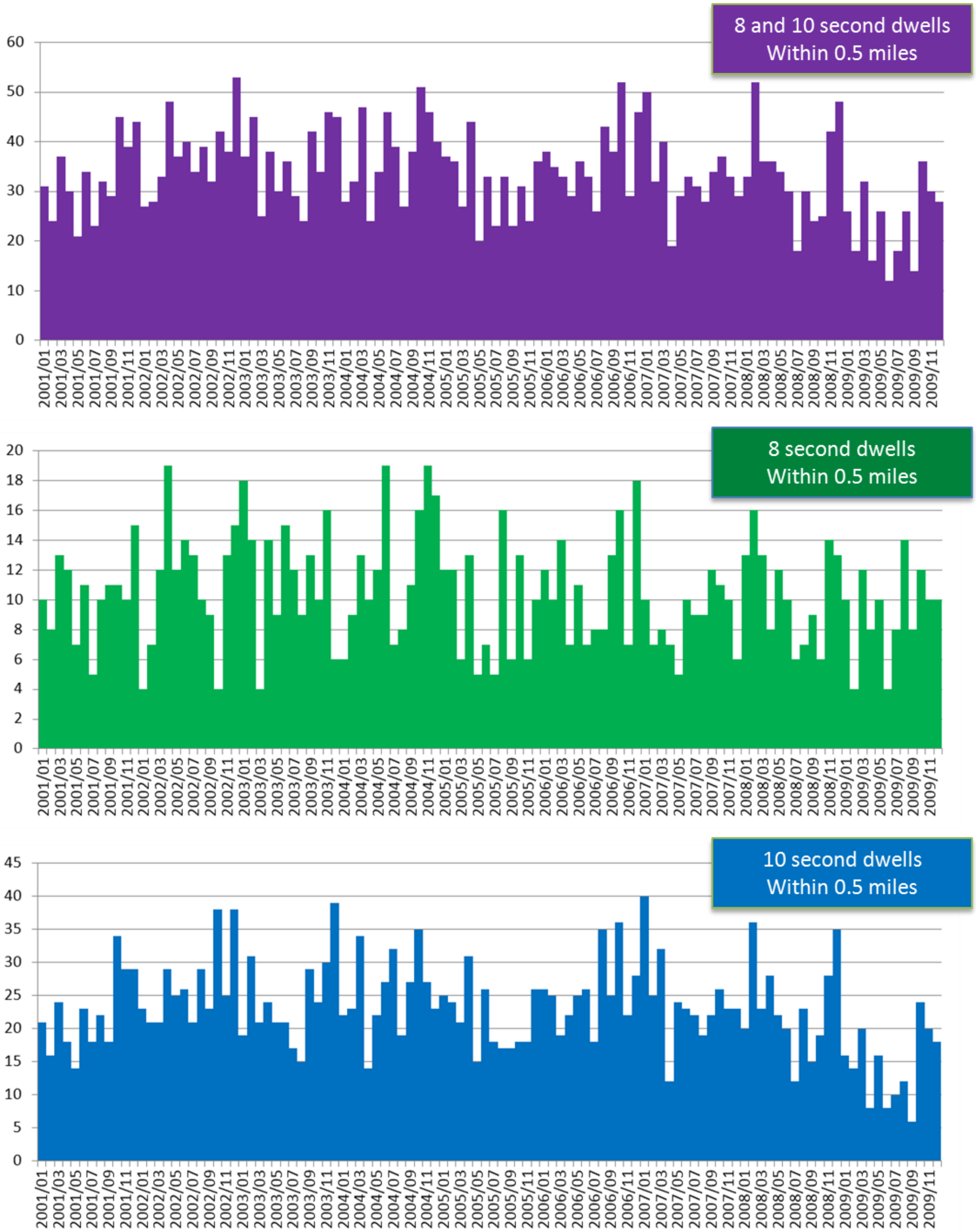


Figure 32. Distributions of the Number of Accidents per Month near Digital Billboards between 2001 and 2009 within a 0.5-mile Vicinity Range near all Digital Locations for 8 and 10 Second-dwell Times (top, purple), 8 Second-dwell Times (middle, green) and 10 Second-dwell Times (bottom, blue)

Figure 33 summarizes the accident rates that account for variations in traffic volumes for all digital locations within vicinity ranges of 0.1, 0.2, 0.3, 0.4, and 0.5 miles of the digital location with 8 and 10 second dwell times. The 0.5 mile benchmark vicinity experienced a decrease in accident rates over the eight-year span. The change in accident rates decreased by 0.17 accidents per million vehicles per year; an 11.1% decrease. Similar decreases and trends were observed for both smaller vicinity ranges.

Betwen 2001 and 2009 for equal periods before and after at each location
At all 20 locations with **8 and 10 second dwells**

		Vicinity Range from Digital Location (Miles)				
		0.1	**0.2**	**0.3**	**0.4**	**0.5**
Prior to Installation	Number of Accidents per million vehicles (by million AADT)	0.29	0.72	0.99	1.25	1.52
As Digital Location	Number of Accidents per million vehicles (by million AADT)	0.24	0.60	0.79	1.03	1.35
Comparison	Change in Rate per million vehicles (by million AADT)	-0.05	-0.11	-0.20	-0.21	-0.17
	Percent Change in Rate of Accidents	-15.9%	-16.0%	-20.4%	-17.1%	-11.1%

Figure 33. Summary Accident Rates within Vicinity Ranges near Twenty Digital Billboards Locations with 8 and 10 Second-dwell Times in the Greater Reading Area

COMPARISON OF ACCIDENTS BY AGE OF DRIVER

The accident statistics were also analyzed to determine if the age of the drivers involved in the accidents near digital billboards was a factor. The data was specially studied to determine if there are increases in the accident rates of young drivers (under 17 and under 21) or elderly drivers (65 and older). Figure 34 summarizes the accidents and accident-rates by age of driver for all accidents.

Figure 35 shows the distributions of ages of driver for all accidents within Berks County (A, purple) and for all accident within 0.5 miles of all digital locations (B, orange).

Figure 36 shows the distributions of driver ages within 0.5 miles of all digital locations for before (green) and after (blue) periods of comparison. Figure 38 (left) also shows the correlation between before and after conversions for the number of accidents for each age. Individual accidents may have multiple cars and drivers involved, which is reflected in the analysis. In comparing the histograms in Figure 36, note the typical distribution type (shape) and typical average values. The average driver age for accidents prior to digital conversion is 38.4 years; the average drive age after conversions is 38.6 years.

Correlation coefficients were calculated and indicated a very strong correlation of accident patterns for age-of-driver factors. Figure 33 shows a 0.980 (98.0%) correlation coefficient when comparing accidents before conversion with those after conversion.

Betwen 2001 and 2009 for equal periods before and after at each location
At all 20 locations with **8 and 10 second dwells**

		Crashes By Driver Age Group			
		under 17	under 21	21-65	over 65
Prior to Installation	Number of Accidents for equal periods prior to conversion	155	676	2412	533
As Digital Location	Number of Accidents for equal periods after conversion	103	440	2065	316
Comparison	Change in Number of Accidents	-52	-236	-347	-217
	Percent Change in Number of Accidents	-33.5%	-34.9%	-14.4%	-40.7%

Figure 34. Summary Accidents by Age Group within Vicinity Ranges near Twenty Digital Billboard Locations in the Greater Reading Area

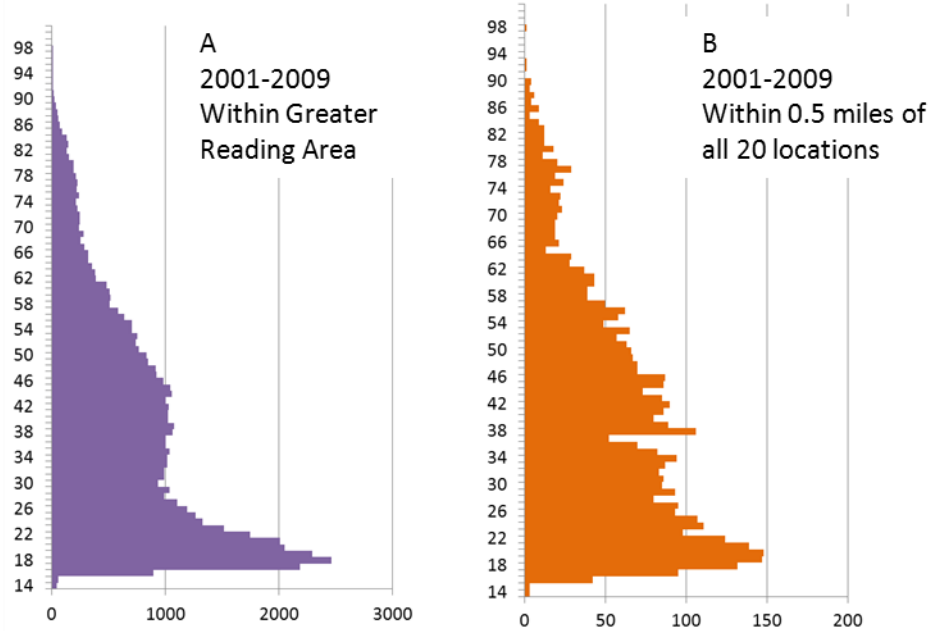


Figure 35. Distributions of Age of Drivers for all Accidents in the Greater Reading Area (left, purple), and within 0.5 miles of all Digital Locations (right, orange)

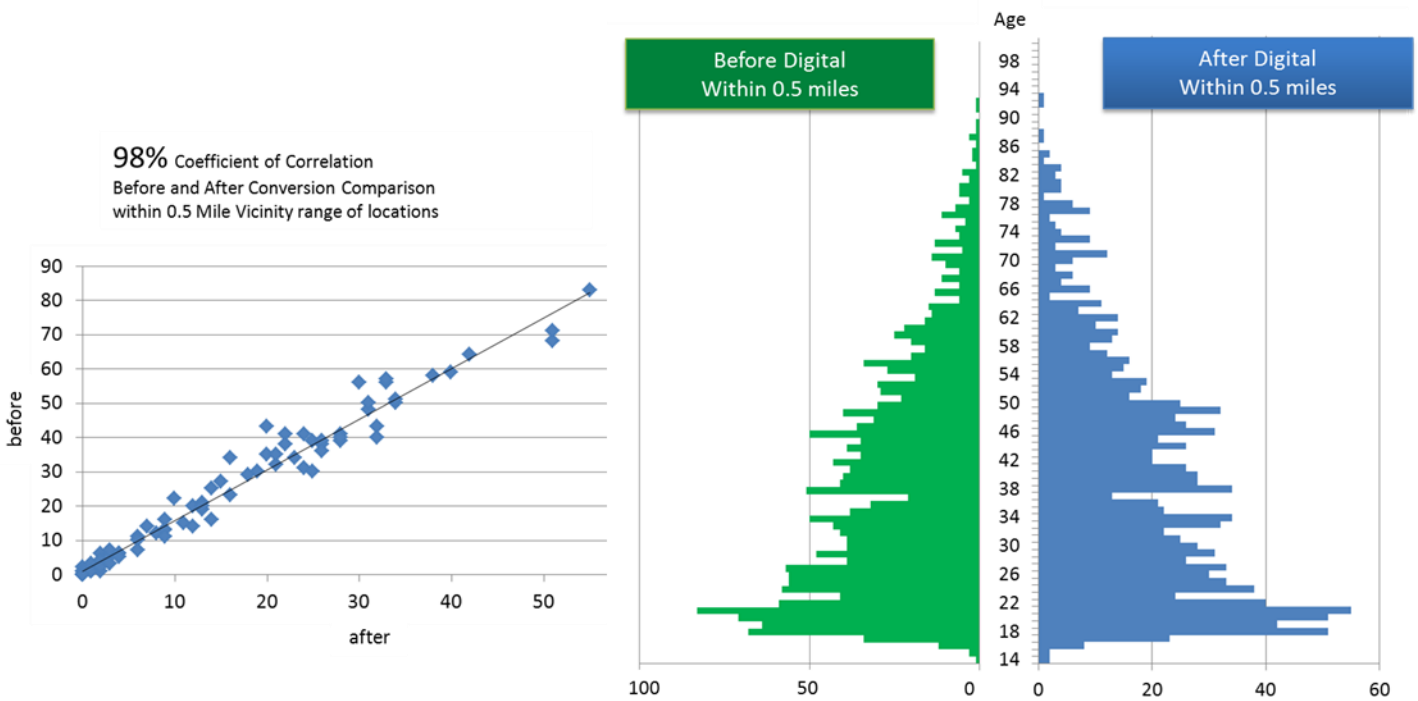


Figure 36. Distributions of Age of Drivers for all Accidents before Digital Conversion (left green histogram), after Digital Conversion (right, blue histogram) and the Correlation between Before and After Accident Counts for each Age (left).

COMPARISON OF ACCIDENTS BY TIME OF DAY

The accident statistics are also analyzed to determine if the time of day of the accidents near digital billboards is a factor.

The data was studied to determine if any increases in the accident rates during dawn, daylight, dusk and dark/nighttime conditions occurred. Figure 37 summarizes the accidents and accident-rates by time of day for all accidents within 0.5 miles of the digital locations. The daylight accident rate experienced an 8.9 percent decrease after conversion; the nighttime accident rate experienced an 11.7% decrease.

Figure 38 shows the distributions of times of accidents within 0.5 miles for before conversion (top, blue) and for after conversion (middle, green) data periods of comparison. Figure 38 (bottom) also shows the correlation between before and after conversions for the number of accidents. In comparing the histograms in Figure 38, note the typical distribution type (shape) and typical average values. Correlation coefficients were calculated and indicated a very strong correlation of accident patterns for time-of-day factors. Figure 40 shows a 0.90 (90.0%) correlation coefficient when comparing accidents before conversion with those after conversion.

Betwen 2001 and 2009 for equal periods before and after at each location
At all 20 locations with **8 and 10 second dwells**

		During Time of Day and Lighting			
		Dawn	Daylight	Dusk	Dark
Prior to Installation	Number of Accidents for equal periods prior to conversion	15	762	73	206
	Number of Accidents per million vehicles (by million AADT)	0.02	1.09	0.10	0.29
As Digital Location	Number of Accidents for equal periods after conversion	15	679	67	178
	Number of Accidents per million vehicles (by million AADT)	0.02	0.99	0.10	0.26
Comparison	Change in Number of Accidents	0	-83	-6	-28
	Change in Rate per million vehicles (by million AADT)	0.00	-0.10	-0.01	-0.03
	Percent Change in Number of Accidents	0.0%	-10.9%	-8.2%	-13.6%
	Percent Change in Rate of Accidents	2.2%	-8.9%	-6.2%	-11.7%

Figure 37. Summary Accident Rates during Dawn, Daylight, Dusk and Dark/Nighttime Conditions within a 0.5 mile vicinity range near twenty Digital Billboards Locations with 8 and 10 Second-dwell times in the Greater Reading Area

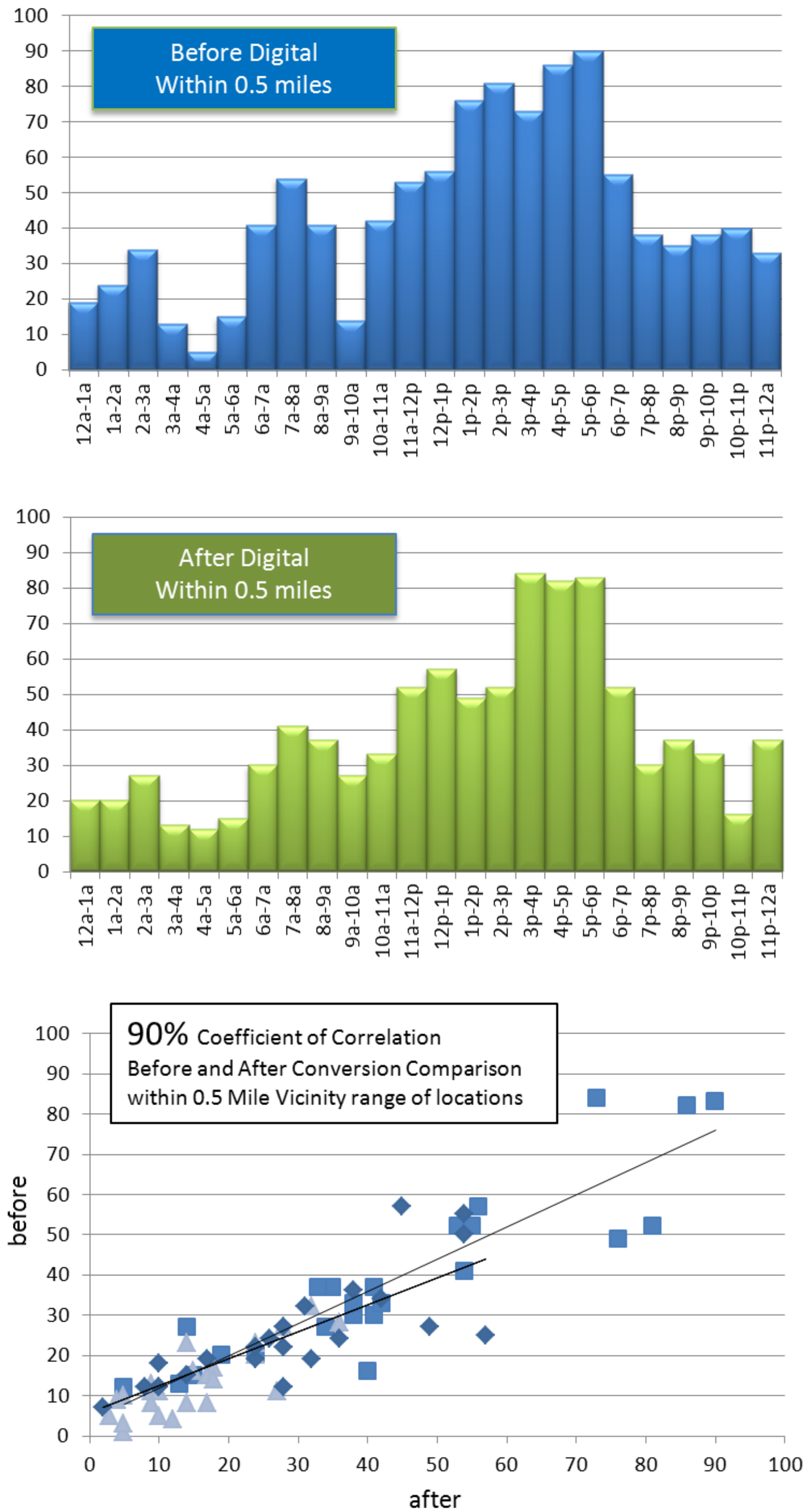


Figure 38. Distributions of Number of Accidents Accident by Time of Day within a 0.5 mile Vicinity Range prior to Digital Conversion (top, blue) and after digital conversion (middle, green) near twenty digital billboards locations with 8 and 10 second-dwell times in the Greater Reading Area

STATISTICAL MODEL AND RESULTS FOR THE EMPIRICAL BAYES METHOD

The Empirical Bayes (EB) method is used to analyze the available crash data for Berks County. The EB method is a rigorous method capable of estimating the safety impact of changes at a location. The EB method is well documented and used in numerous traffic-safety studies (see References 14 through 30). Simply stated, the method estimates the number of crashes at a location that would have occurred without the introduction of digital billboards. The estimates may then be compared with the actual crashes that have occurred.

The expected number of crashes as estimated by the Crash Estimation Model (CEM) and using the SAS statistical package and the parameters discussed in our methodology were computed. A multivariate, regression model was developed to estimate the mean of the expected number of crashes at a location. Our general CEM is shown in Figure 39 and models Average Annual Daily Traffic (AADT), Number of Lanes (Lane), and the posted Speed Limit (Speed) as independent variables; $\beta_0, \beta_1, \beta_2$ and β_3 are model parameters of the independent variables. The model is fit using the maximum likelihood method and includes 77 sites representing 20 digital billboard locations and 57 comparison sites. Figure 40 shows these locations. Figure 39 summarizes the CEM parameters using a maximum likelihood estimates for a multivariate regression model with negative binomial distribution. The CEM parameters are significant at $\alpha = 0.05$. The resulting CEM equation is also presented in Figure 39.

The projected, total crash counts were estimated for the “after” periods to represent what the number of crashes would have been in future period without the introduction of digital billboards. These were compared with the crash data that actually occurred after the introduction of digital billboards at each location to determine the unbiased overall index of effectiveness.

General CEM: $$P = (AADT)^{\beta_1} (LANE)^{\beta_2} (Speed)^{\beta_3} e^{\beta_0}$$

Explicit CEM: $$P = (AADT)^{0.1291} (LANE)^{0.2584} (Speed)^{-0.0231} e^{2.8671}$$

CEM Model Parameters:

Variable		Coefficient	Standard Error	Chi-square statistic	Pr > Chi-square	Wald 90% confidence limits	
						Lower	Upper
Intercept		2.8671	0.2490	132.63	<.0001	2.3792	3.3551
AADT	β_1	0.1291	0.0157	67.27	<.0001	0.0982	0.1599
Lanes	β_2	0.2584	0.0757	11.66	0.0006	0.1101	0.4067
Speed	β_3	-0.0231	0.0040	33.76	<.0001	-0.0309	-0.0153
Dispersion	ϕ	0.5207	0.0329			0.4562	0.5852

SAS Goodness of fit measures: deviance (value/d.f.) = 669.0944 (1.0933); Pearson chi-square (value/d.f.) = 712.7582 (1.1646); Number of observations = 616

Figure 39. General and Explicit Crash Estimation Model (CEM) and CEM Model Parameters from SAS Output

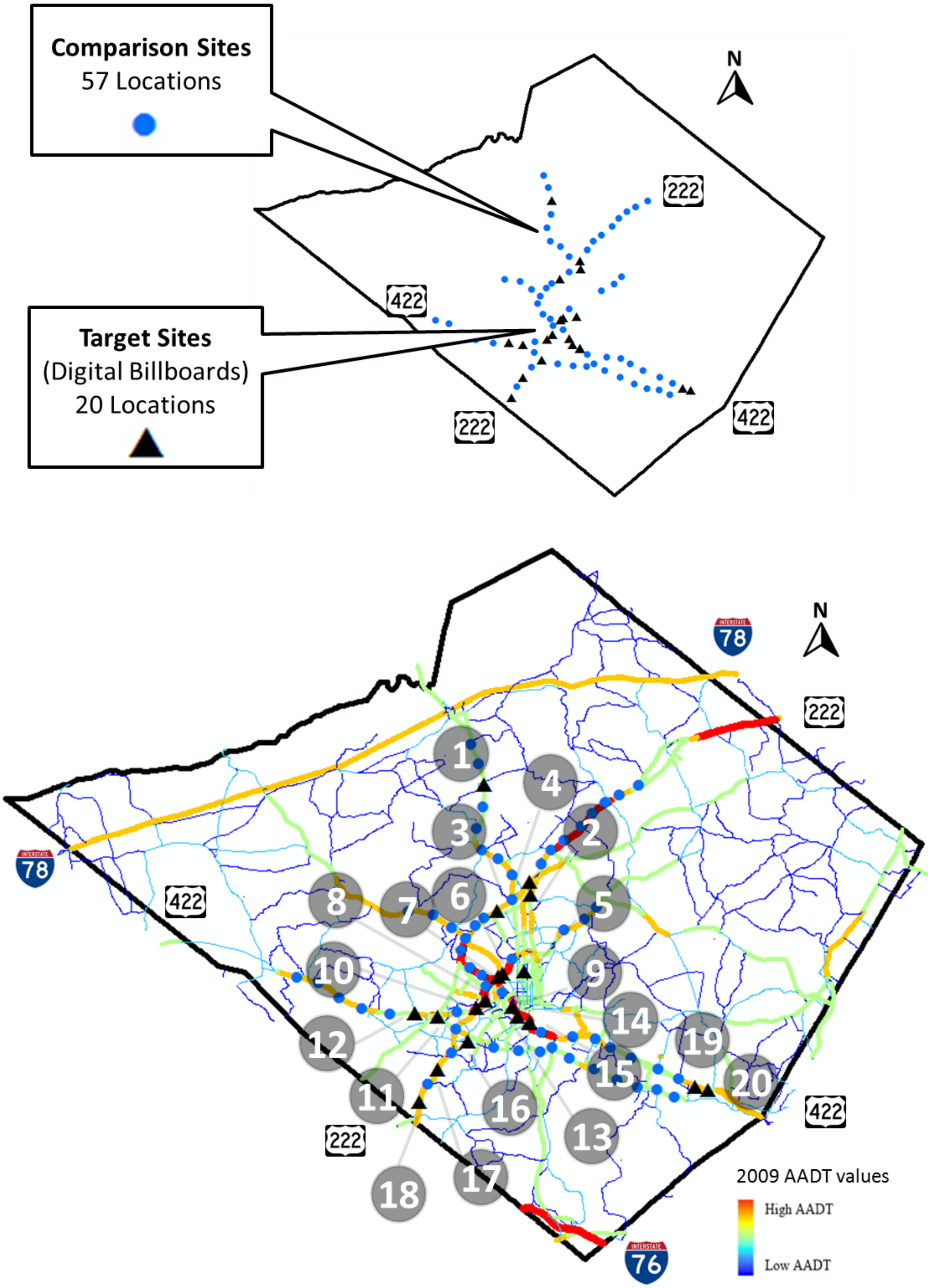


Figure 40. Crash and AADT Data for 20 Target (Digital) Locations and 57 Comparison (non-Digital) Locations

The Empirical Bayes results indicate a 0.87% (0.0087) difference between the “after” conversion crashes that occurred near the 20 digital locations and the statistically predicted Empirical Bayes estimate of those same locations had no digital billboards been installed. This comparison has a p-value < 0.0001. The analysis of this data indicated that the actual and predicted means are almost statistically identical. A large sample size was used with 20 digital locations, 57 treatment or comparison sites with eight years of accident data. The statistical evaluation of the Empirical Bayes results shows that the total number of accidents are approximately equivalent to what would be statistically expected with or without the introduction of digital technology and that the safety near these locations are consistent with the model benchmarked by 77 locations within Berks County. Additional studies should be considered with other independent variables, consider for lower volume roads, other robust crash estimation models, and cross-comparison of results between digital.

Parameter	Value
Total Crashes for the "After" Period with Digital Conversion (Actual Values)	925
Total Crashes for the "After" Period assuming no Digital Conversion ever occurred (Estimate by Empirical Bayes Method)	917
Overall Index of Effectiveness	1.009
Percent Change in Crashes between actual and estimate	-0.87%

Figure 41. Results of the Empirical Bayes Estimation in Berks County with 20 digital locations, 57 treatment or comparison sites and with eight years of accident data

Simply stated, the data show no statistically significant increase of accident rates near these billboards.

FINDINGS

The Greater Reading Area of Berks County, Pennsylvania, is a unique opportunity for this study about the statistical associations between digital billboards and traffic safety using robust data-sets and analyzing multiple locations for periods of as long as eight years. The overall conclusion is that these digital billboards in Reading have no statistically significant relationship with the occurrence of accidents. This conclusion is based on local Police and PennDOT data and an objective statistical analysis; the data show no statistically significant increase in accident rates. This study also finds that **the dwell time of 6, 8, or 10 seconds,** the **age of the driver (younger, older) and the time of day (nighttime, daytime) are neutral factors** which show no increase or decrease in accident rates the near digital billboards along the local roads in the Greater Reading Area.

The specific conclusions of this study indicate the following.

- **The rates of accidents near the twenty digital billboards show a 11.1% decrease** within 0.5 miles of all digital billboards over eight years near twenty locations. Similar decreases and trends in both averages and peaks are observed for both smaller and larger vicinity ranges, and for specific loops and groups of locations by dwell time.

- **The accident statistics and metrics remain consistent**, exhibiting statistically insignificant variations at each of the digital billboards. The metrics include the total number of accidents in any given month, the average number of accidents, the peak number of accidents in any given month, and the number of accident-free months. These conclusions account for variations in traffic-volume and other metrics.

- The statistical evaluation of the Empirical Bayes method and results show that the **total number of accidents are approximately equivalent to what would be statistically expected with or without the introduction of digital technology** and that the safety near this locations are consistent with the model benchmarked by 77 locations within Berks County.

- The overall conclusion of the study is that **these digital billboards in the Greater Reading Area have no statistically significant relationship with the occurrence of accidents**.

This study also finds that the age of drivers (younger/elderly) and the time of day (daytime/nighttime) are neutral factors which show no significant increase or decrease in accident rates near the digital billboards. The results are consistent for the 6, 8, and 10 second dwell times. These conclusions are based on the collected Police Department data and an objective statistical analysis.

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