TANTALA ASSOCIATES, LLC
CONSULTING ENGINEERS

AN UPDATE OF A STUDY OF THE RELATIONSHIP BETWEEN DIGITAL BILLBOARDS AND TRAFFIC SAFETY IN CUYAHOGA COUNTY, OHIO

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1850 M STREET, NW, SUITE 1040
WASHINGTON, DC 20036-5821

BY

MICHAEL WALTER TANTALA, P.E.
ALBERT MARTIN TANTALA, SR., P.E.

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TANTALA ASSOCIATES, LLC
CONSULTING ENGINEERS
4903 FRANKFORD AVENUE
PHILADELPHIA, PA 19124-2617
www.TANTALA.com

AN UPDATE OF A STUDY OF THE RELATIONSHIP BETWEEN DIGITAL BILLBOARDS AND TRAFFIC SAFETY IN CUYAHOGA COUNTY, OHIO

Key points:

- Eight years of accident data comparison
- Seven digital boards on Interstate Routes with eight second dwell times
- Data shows no statistically significant increase in accident rates
- Driver Age (young/elderly) is a neutral factor
- Time of day (daytime/nighttime) is a neutral factor

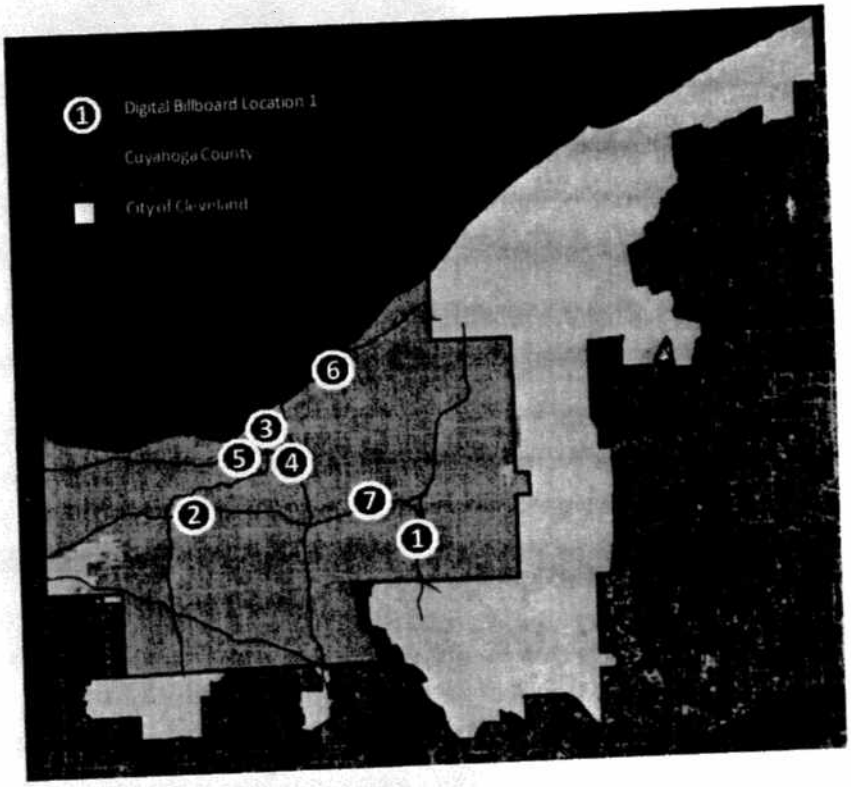

Figure 1.
Digital Billboard locations in Cuyahoga County, Ohio and within the City of Cleveland

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Eight years of data ...

... no statistically significant relationship with the occurrence of accidents ...

... age of drivers and time of day are neutral factors.

OVERVIEW

This **2009 study** is an update of our 2007 study of the statistical relationship between digital billboards and traffic safety in Cuyahoga County, Ohio. This study revisits the same seven digital billboards in Ohio for longer periods of time and looks more closely at comparisons of specific attributes within accident reports, including comparisons of driver age (young/elderly) and time of day (daytime/nighttime).

This 2009 study examines and compares **eight years of traffic accident data** near seven digital billboards in Ohio. This eight-year comparison more than doubles the three-year study period in 2007. This study analyzed traffic and accident data along Interstate Routes I-77, I-90, I-271, and I-480 and near seven existing, digital billboards (see Figure 1). The seven billboards have eight-second dwell times, were converted to digital from conventional format in July 2005 and collectively have traffic volumes as much as 335 million vehicles per year. The study uses official data as collected, compiled and recorded independently by the Ohio Department of Transportation. Over eight years, this accident data represents approximately 46,000 accidents on Interstate Routes within the County and 360,000 accidents on all roads within the County.

Temporal (*when and how frequently*) and spatial (*where and how far*) statistics were summarized near billboards within multiple vicinity ranges within 0.2, 0.4, 0.6, 0.8, and 1.0 miles upstream and downstream of the billboards.

The overall conclusion of this study is that **digital billboards in Cuyahoga County have no statistically significant relationship with the occurrence of accidents**.

This study reinforces the findings of our original study for longer periods of time with a robust eight years of data. This study also finds that the **age of drivers (younger/elderly) and the time of day (daytime/nighttime) are neutral factors** which show no increase in accident rates near the digital billboards in Cuyahoga County.

This conclusion is based on the Ohio Department of Transportation's own data and an objective statistical analysis; **the data shows no increase in accident rates**.

STUDY REGION

Cuyahoga County was revisited as a study region, because the County has multiple digital billboards in close proximity which were in service for extended periods of time (five percent of the Interstate billboards in Cuyahoga County are digital), and the Interstate Routes adjacent to these billboards are heavily traveled with approximately 12.6 million vehicle-miles traveled per day on these Interstate Routes.

Cuyahoga County is the most populous County in Ohio with 1.4 million people, with a population density of 3,040 people per land-square-mile, and with a median age of 37. The County is south of Lake Erie, and is contiguous with six other counties in Ohio.

Cuyahoga County's seat is the City of Cleveland, and is part of the Greater Cleveland metropolitan area. Cuyahoga County has 571,000 households with an average household size of 2.39 people. In Cuyahoga County, approximately 623,000 workers commute, with a mean travel time of 24.4 minutes.

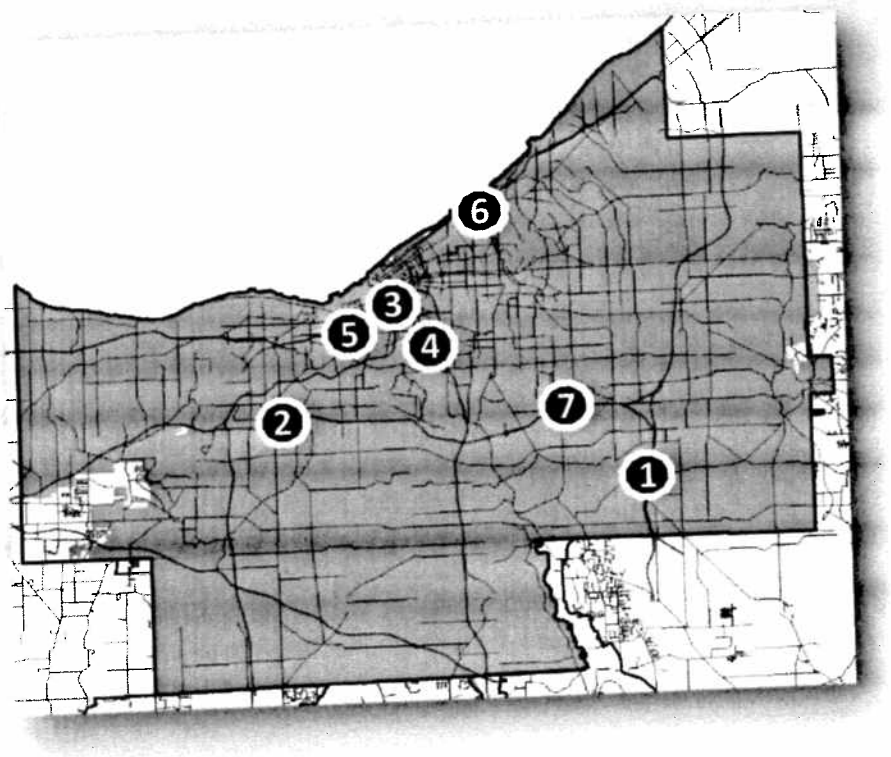

Figure 2.
Digital Billboard locations in Cuyahoga County, Ohio

Cuyahoga County is served by three primary (two-digit) Interstate Routes (I-71, I-77, and I-90) and three (three-digit) auxiliary Interstate Routes (I-271, I-480, and I-490). Cuyahoga County's transportation infrastructure serves 1.2-million registered, motor vehicles of which 82% are passenger vehicles. The County has 132.07 Interstate-highway miles, 18.90 turnpike miles, 107.21 U.S.-highway miles and 232.56 State-highway miles. In 2005, the estimated daily vehicle miles traveled (DVMT) was 28.3 million, of which 12.6 million (44.5%) was on Interstate Routes. In 2005, the number of reported traffic accidents was 37,039, of which 5,400 (14.6%) were on Interstate Routes.

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 a "dwell time" of eight seconds.

The digital billboards were designed and manufactured by *Daktronics*, and 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 levels. A photocell is mounted on each digital billboard to measure ambient light. All seven digital billboards are owned and operated by *Clear Channel Outdoor*.

BILLBOARD No.	ROUTE	LOCATION	SIGN CONFIG	DIGITAL FACE ADVERTISES TO DIRECTION	FACE SIZE (FEET)	READ
1	271	West side of I-271 (125 feet South of Solon Road)	Free Standing, Vee Flag Double Faced	Southbound	14x48	Right Hand Reader
2	480	South side of I-480 (2 miles East of I-71)	Free Standing, Parallel Faced Double Faced	Westbound	14x48	Cross Reader
3	90	South side of Innerbelt Freeway (100 feet East of West 3rd Street)	Free Standing, Parallel Faced Double Faced	Eastbound	14x48	Right Hand Reader
4	77	West side of I-77 (0.3 miles South of Pershing Avenue)	Free Standing, Parallel Faced Double Faced	Southbound	14x48	Right Hand Reader
5	90	South side of I-90 (70 feet East of West 55th Street)	Free Standing, Vee Flag Double Faced	Eastbound	14x48	Right Hand Reader
6	90	South side of I-90 (0.5 miles West of Eddy Street)	Free Standing, Vee Flag Double Faced	Westbound	14x48	Cross Reader
7	480	North side of I-480 (0.5 miles East of Broadway Avenue)	Free Standing, Vee Flag Double Faced	Westbound	14x48	Right Hand Reader

Figure 3.
Digital Billboard locations, configuration, sizes and other characteristics

The static display on each of these digital billboards has a "dwell time" of eight seconds.

Each of the seven digital billboards is a freestanding, single-pole, double-faced structure with one digital face that measures 14-feet high and 48-feet wide (a face area of 672 square feet). The digital billboards are numbered 1 to 7 and are located along major Interstate Routes (I-77, I-90, I-271, and I-480). The locations of the seven billboards in Cuyahoga County are shown in Figures 2 and 3 which summarize location, configurations, sizes and other characteristics. These are the only digital billboards in Cuyahoga County. The digital billboards and their surroundings were observed during day and night conditions.

Figure 4 summarizes conversion dates and compares the timelines of comparison of the 2007 study (three-year period) with this study (eight-year period). The billboards were converted from conventional to digital format in July 2005. This allows for before/after comparisons in excess of eight years individually with a cumulative of 56 years. Additional billboard-location photos, aerials, and map references for each billboard number are included within this report.

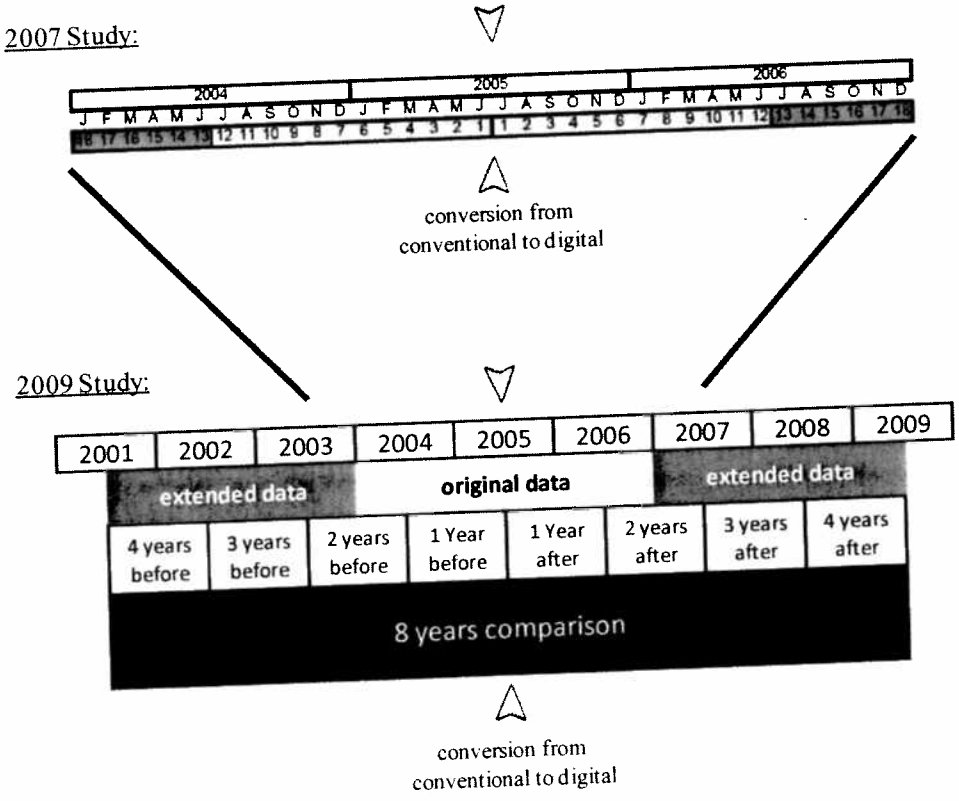

Figure 4.
Digital Billboard Conversion Dates and period of study in 2007 study compared with this 2009 study

Figure 5 summarizes characteristics of the digital billboards and the Interstate Routes to which they advertise. This includes the Route's lanes and geometry and the billboard's overall height, hagl, distance to nearest advertising and opposite lanes.

Billboard No.	Interstate Route No.	Number of Lanes	Interstate Breakdown Widths (Feet)	Overall Height	HAGL Height Above Grade Line	Distance from Upright to Nearest Lane	Distance from Upright to Nearest Lane in Opposite Direction
				(All dimensions in feet ±)			
1	271	6 total 3 NB 3 SB	10-36-4 181 4-36-10	97	83	88.0	304.4
2	480	8 total 4 WB 4 EB	10-48-11 4 11-48-10	50	36	106.1	178.7
3	90	8 total 4 NB 4 SB	0-52-6 4 6-52-0	180	166	55.4	111.5
4	77	6 total 3 NB 3 SB	10-36-4 2 4-36-10	83	69	80.4	126.0
5	90	10 total 5 WB 5 EB	10-60-3 70 3-60-10	115	101	144.4	315.0
6	90	8 total 4 WB 4 EB	10-48-3 3 3-48-10	65	51	136.1	195.6
7	480	8 total 4 WB 4 EB	10-48-6 26 6-48-10	87	73	174.6	246.0

Figure 5.
Interstate Route Characteristics near digital billboards including number of lanes, widths, sign height, height above grade line, and distances to lanes

Billboard No. 1 advertises to traffic on the southbound lanes of Interstate Route 271 south of the Solon Road overpass. The digital face is a right-hand reader and a vee, flag configuration with an overall height of 66 feet and an offset distance of 85 feet to the nearest lane to which it advertises. Figure 6 is a photo of the digital face. Figure 9 shows the location in an oblique aerial. The digital face was converted from a conventional face on the existing structure in July 2005.

Figure 6. Digital Billboard 1 on I-271

Billboard No. 2 advertises to traffic on the westbound lanes of Interstate Route 480 about two miles east of I-271. The digital face is a left-hand cross-reader and has a parallel-faced configuration with an overall height of 50± feet and an offset distance of 178.7 feet to the nearest lane to which it advertises. Figure 7 is a photo of the digital face. Figure 10 shows the location in an oblique aerial. The digital face was converted from a conventional face on the existing structure in July 2005.

Figure 7. Digital Billboard 2 on I-480

Billboard No. 3 advertises to traffic on the eastbound lanes of Interstate Route 90, east of West 3rd Street. The digital face is a right-hand reader and has a parallel-faced configuration with an overall height of 180± feet and an offset distance of 55.4 feet to the nearest lane to which it advertises. Figure 8 is a photo of the digital face. Figure 11 shows the location in an oblique aerial. The digital face was converted from a conventional face on the existing structure in July 2005.

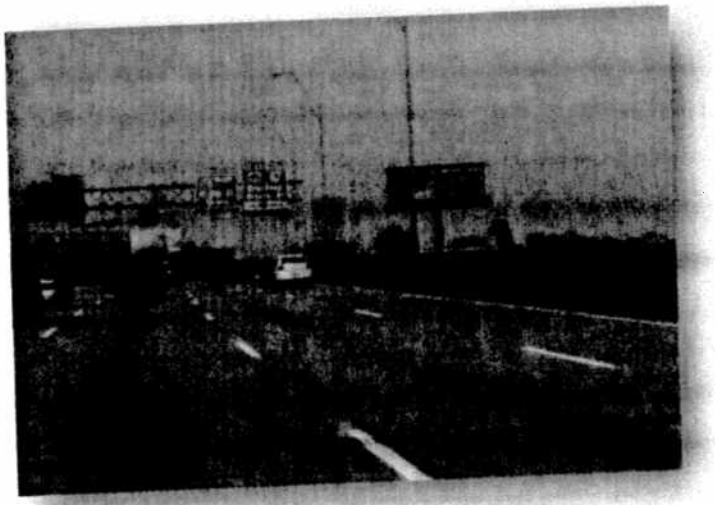

Figure 8. Digital Billboard 3 on I-90

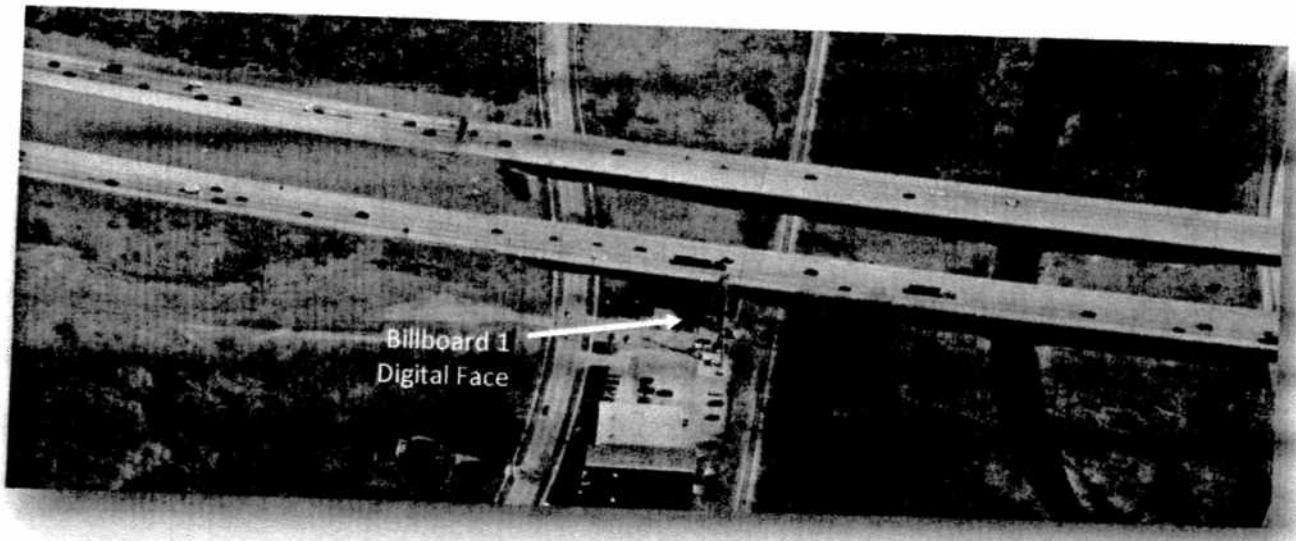

Figure 9. Oblique Aerial of Digital Billboard 1 on I-271

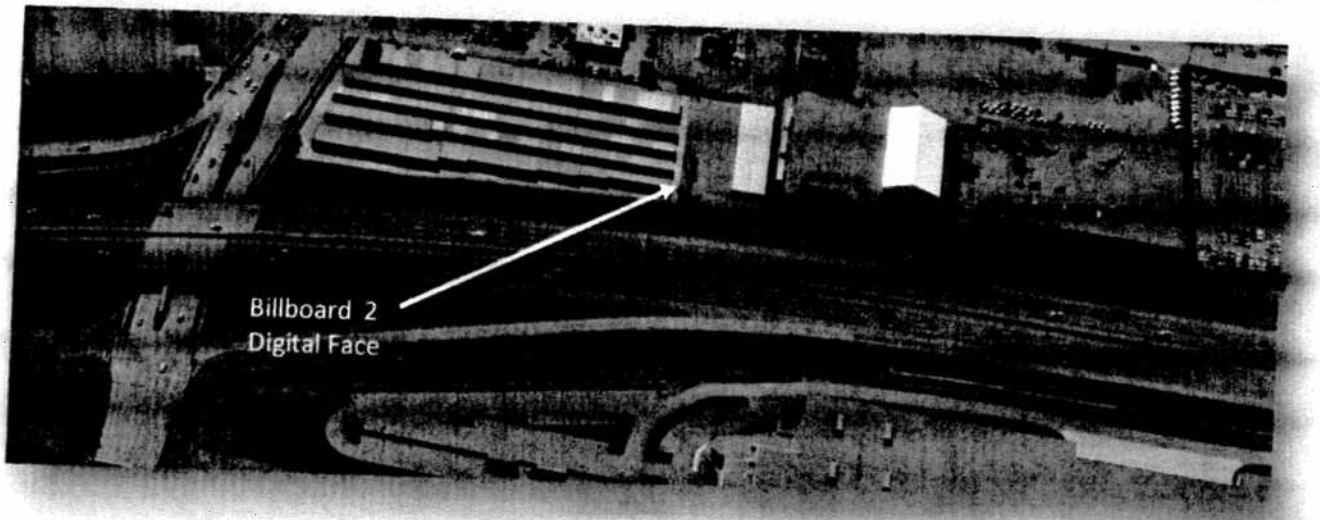

Figure 10. Oblique Aerial of Digital Billboard 2 on I-480

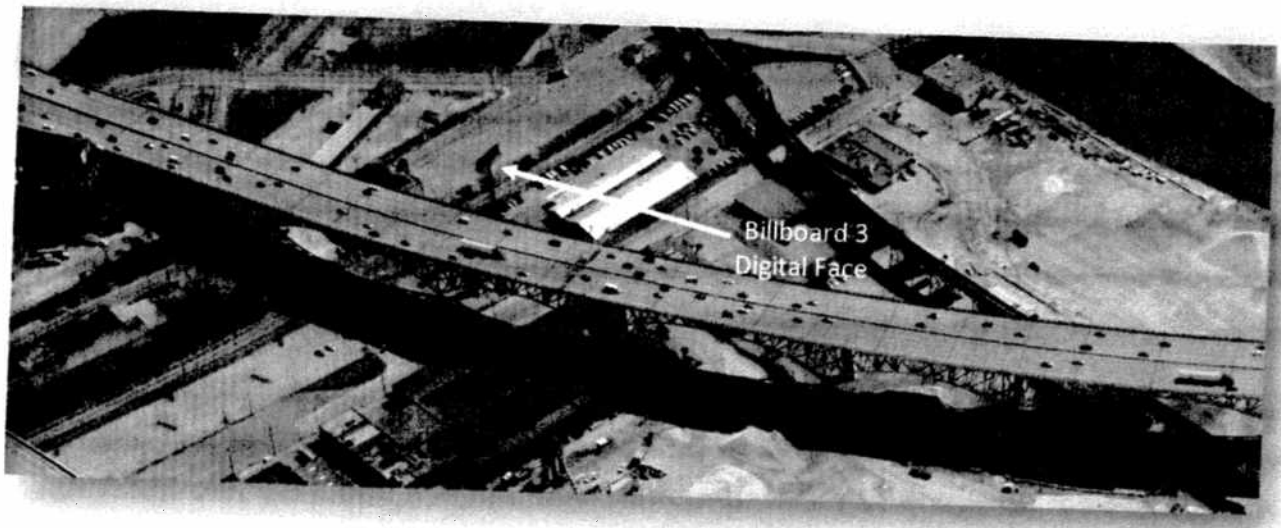

Figure 11. Oblique Aerial of Digital Billboard 3 on I-90

Billboard No. 4 advertises to the traffic on southbound lanes of Interstate Route 77, south of Pershing Avenue. The digital face is a right-hand reader and has a parallel-faced configuration with an overall height of 83± feet and an offset distance of 80.4 feet to the nearest lane to which it advertises. Figure 12 is a photo of the digital face. Figure 14 shows the location in an oblique aerial. The digital face was converted from a conventional face on the existing structure in July 2005.

Figure 12. Digital Billboard 4 on I-77

Billboard No. 5 advertises to traffic on the eastbound lanes of Interstate Route 90, east of West 55th Street. The digital face is a right-hand reader and has a vee, flag configuration with an overall height of 115± feet and an offset distance of 144.4 feet to the nearest lane to which it advertises. Figure 13 is a photo of the digital face. Figure 15 shows the location in an oblique aerial. The digital face was converted from a conventional face on the existing structure in July 2005.

Figure 13. Digital Billboard 5 on I-90

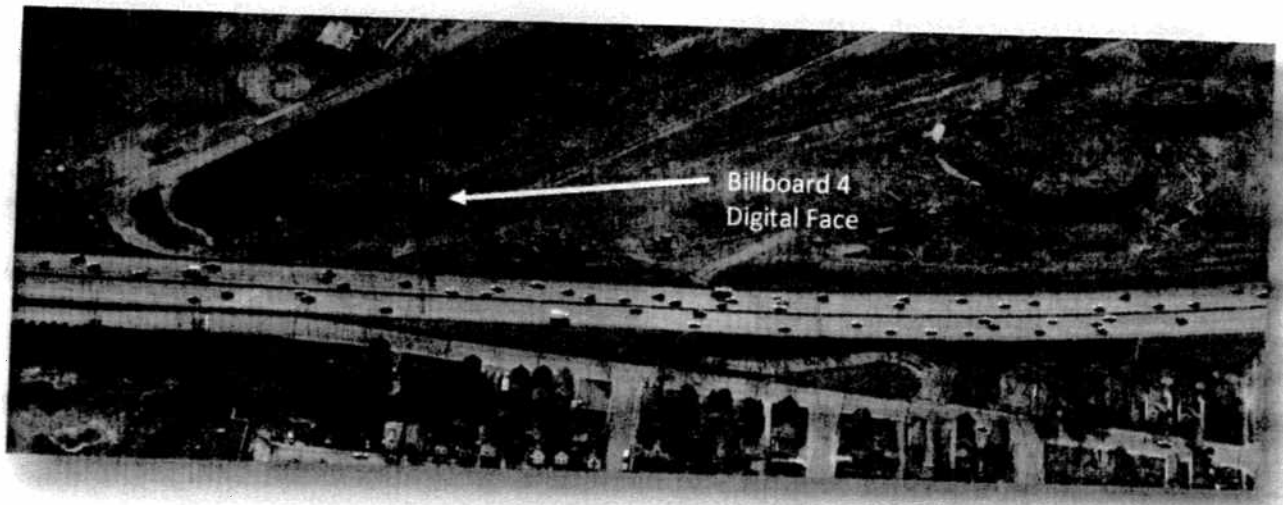

Figure 14. Oblique Aerial of Digital Billboard 4 on I-77

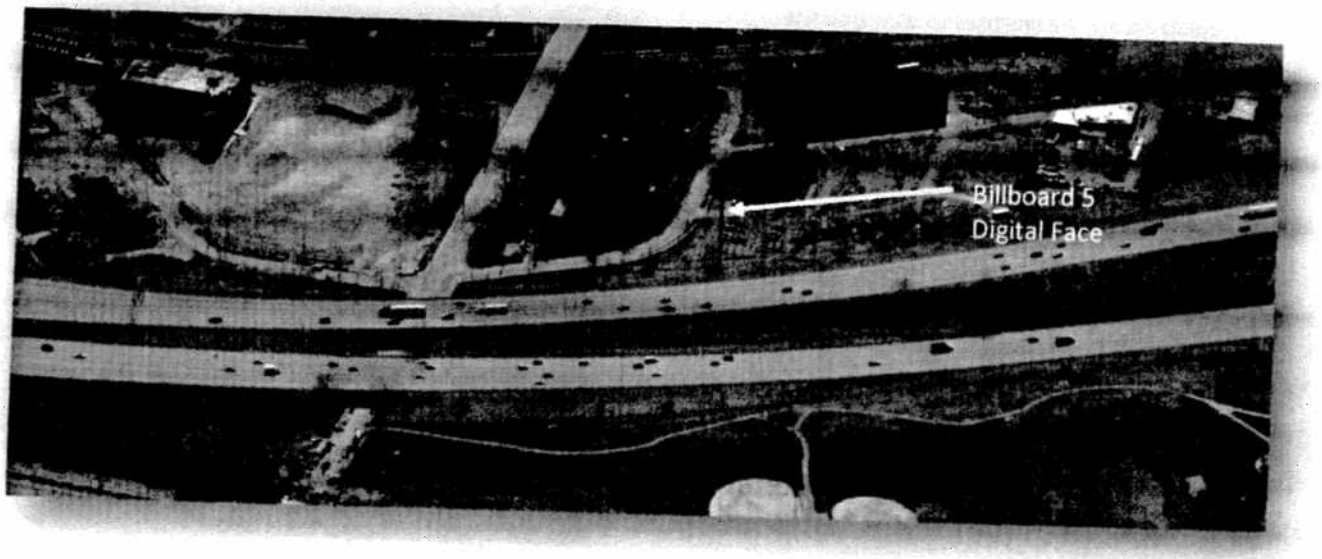

Figure 15. Oblique Aerial of Digital Billboard 5 on I-90

Billboard No. 6 advertises to traffic on the westbound lanes of Interstate Route 90, west of Eddy Street. The digital face is a left-hand cross-reader and has a vee, flag configuration with an overall height of 65± feet and an offset distance of 195.6 feet to the nearest lane to which it advertises. Figure 16 is a photo of the digital face. Figure 18 shows the location in an oblique aerial. The digital face was converted from a conventional face on the existing structure in July 2005.

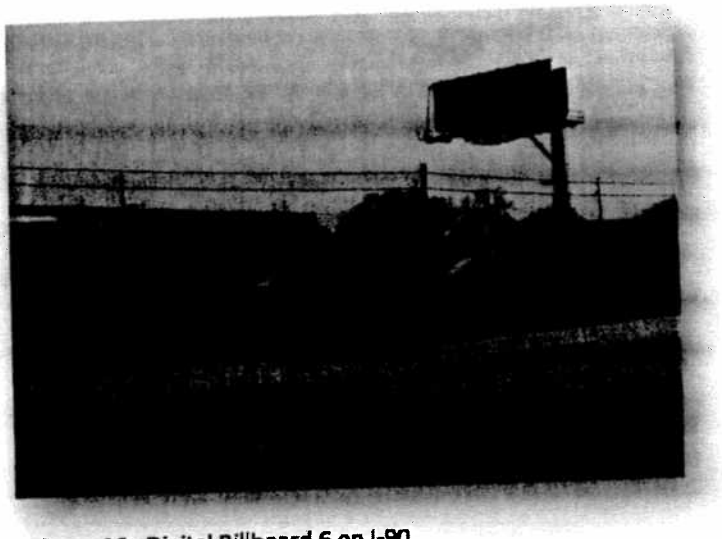

Figure 16. Digital Billboard 6 on I-90

Billboard No. 7 advertises to traffic on the westbound lanes of Interstate Route 480, east of Broadway Avenue (Route 14). The digital face is a right-hand reader and has a vee, flag configuration with an overall height of 87± feet and an offset distance of 174.6 feet to the nearest lane to which it advertises. Figure 17 is a photo of the digital face. Figure 19 shows the location in an oblique aerial. The digital face was converted from a conventional face on the existing structure in July 2005.

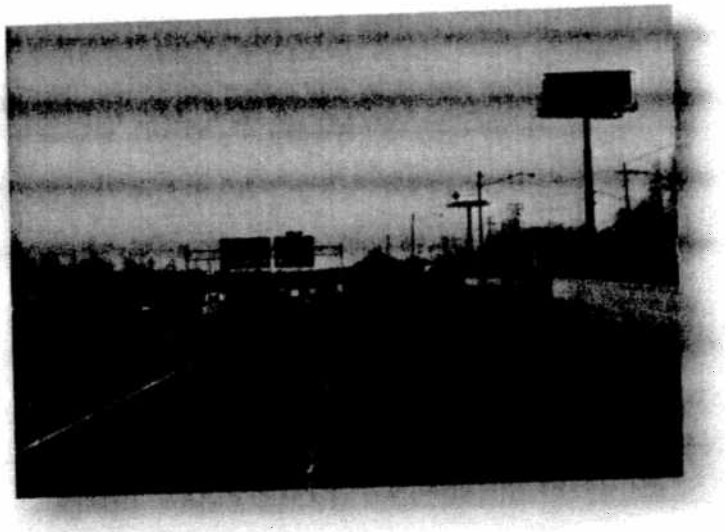

Figure 17. Digital Billboard 7 on I-480

Figure 18. Oblique Aerial of Digital Billboard 6 on I-90

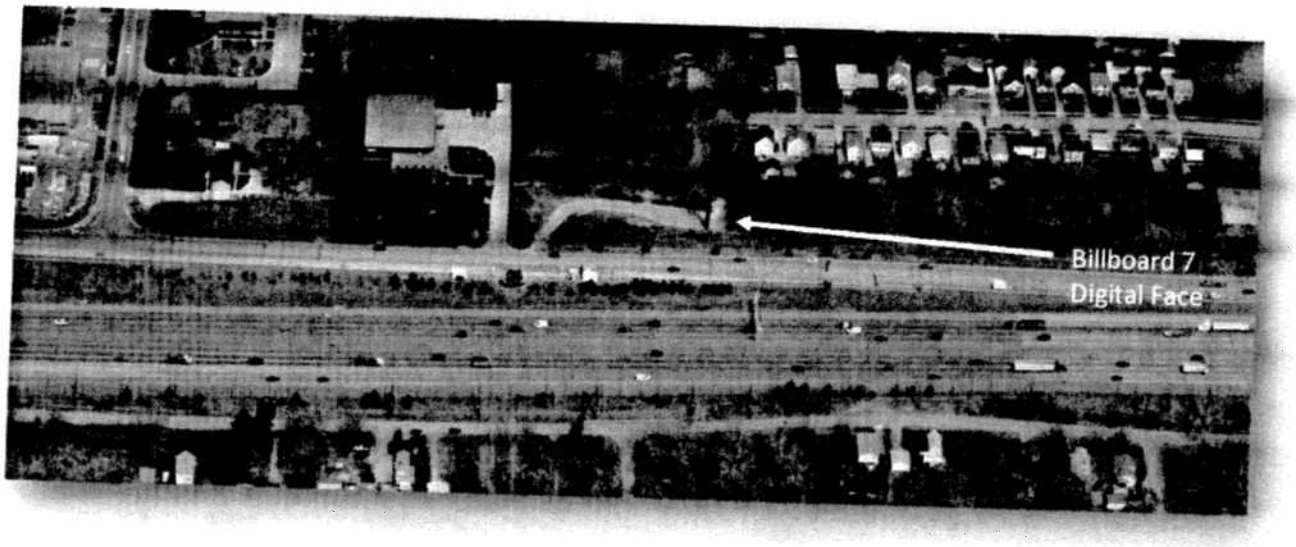

Figure 19. Oblique Aerial of Digital Billboard 7 on I-480

AADT ranges individually near the seven billboards from 118,000 to 160,000 vehicles per day, or equivalently 43 to 58 million vehicles per year.

TRAFFIC VOLUME DATA

Traffic volume data for the Cuyahoga County was obtained from the *Ohio Department of Transportation* (ODOT) and the County Engineer's Office. Traffic-monitoring data includes vehicle volume, vehicle classification, and weigh-in-motion data. The metrics of traffic flow provided by ODOT include short-term (hourly) traffic counts, annual average daily traffic (AADT), and daily vehicle miles traveled (DVMT). This includes the annual average daily traffic (AADT), which is the average of 24-hour counts collected every day in the year. AADT Traffic volumes were recorded in Cuyahoga County between 2000 and 2009.

A sample of the AADT values is summarized in Figure 20. AADT ranges individually near the seven billboards from 118,000 to 160,000 vehicles per day, or equivalently 43 to 58 million vehicles per year. For all seven billboards, this collectively represents 915 thousand vehicles per day or 335 million vehicles per year.

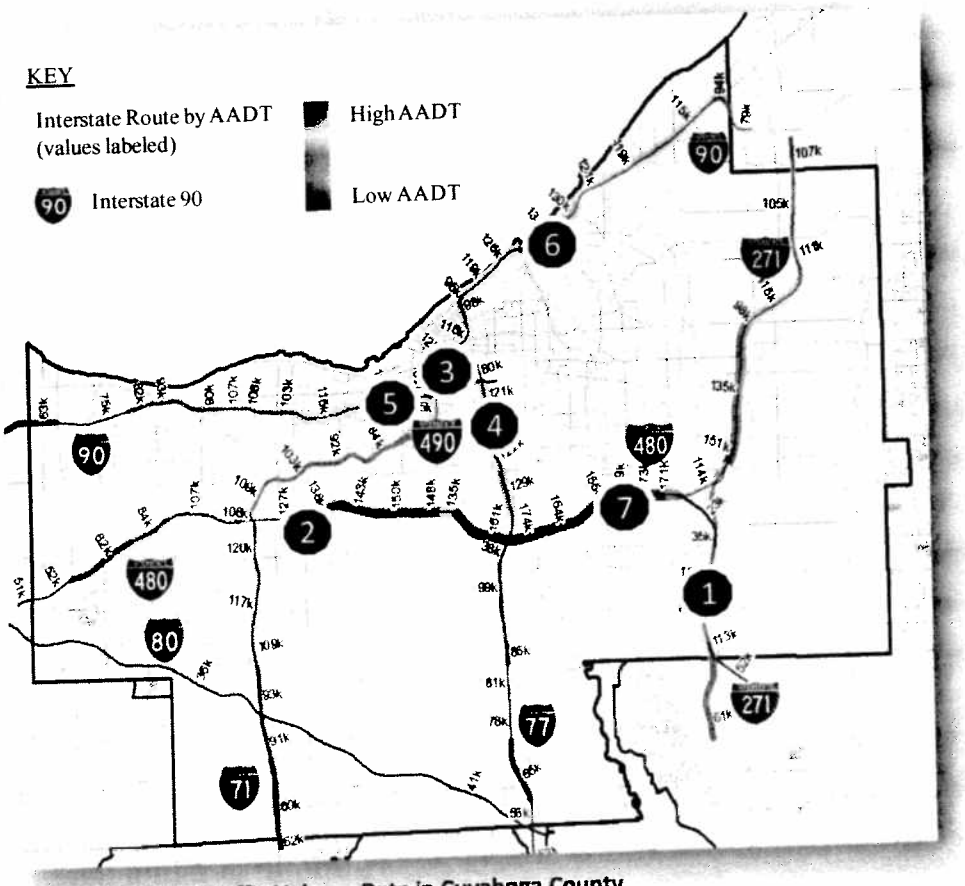

Figure 20. AADT Traffic Volume Data in Cuyahoga County

ACCIDENT DATA

In Ohio, the majority of Interstate accident reports and crash photos are investigated, recorded, and maintained by the *Ohio State Highway Patrol*. Ohio uses the *American National Standards Institute's* (ANSI) Standard D16.1 – 1996, Manual on Classification of Motor Vehicle Traffic Accidents. The reports also provide annually to the *Ohio Department of Public Safety*, which compiles statistical data on crashes that occur on roads and highways.

Figure 21 summarizes the traffic accident data of the past eight years in Cuyahoga County on the Interstate Routes I-71, I-77 and I-90, I-271, I-480, and I-490.

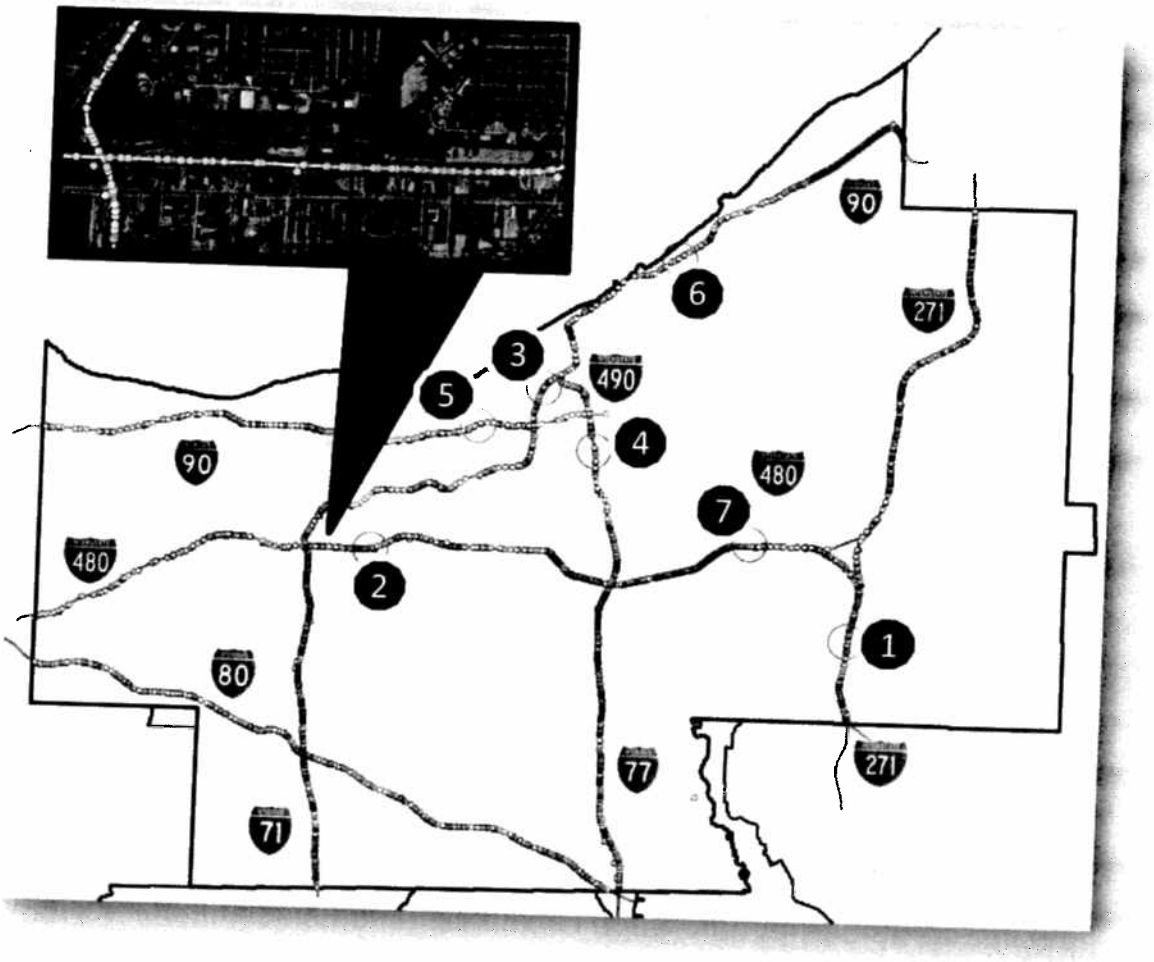

Figure 21. Traffic Accidents (yellow dots) in Cuyahoga County along Interstate Routes, 2001-2009

Figure 22 summarizes the traffic accident data of the past eight years in Cuyahoga County 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), during winter months, and during weekdays.

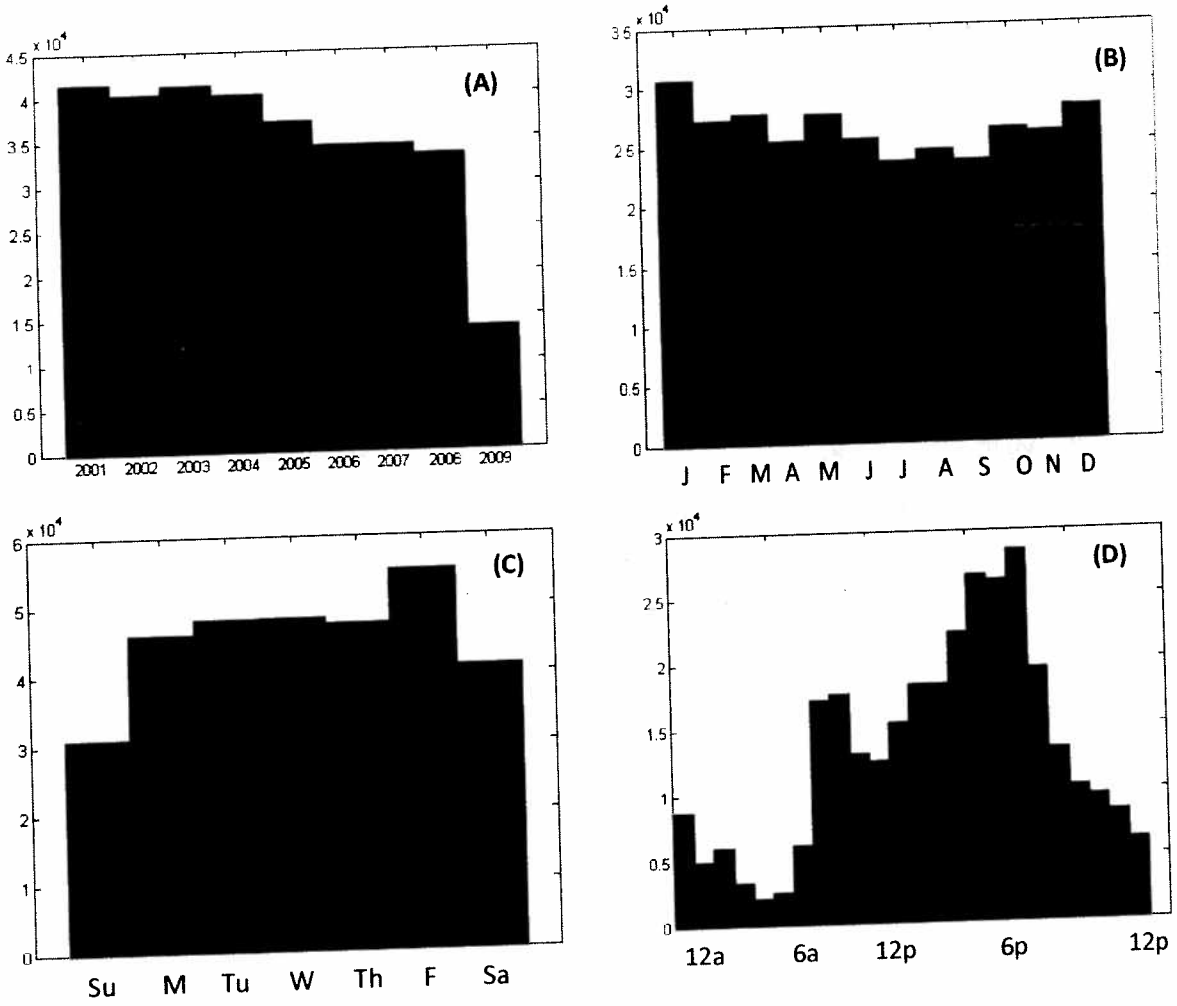

Figure 22. Histogram of traffic accident data of the past eight years in Cuyahoga County for all roads by (A) year, (B) month, (C) day of week and (D) time of day. Note that these figures and related data represent data from 2001 to 2009 and accident reports in 2009 were only available for January to July. This is reflected in Figure 22(A) in the 2009 bar.

The analysis of this robust data, involves an engineering-statistics based approach and uses a widely accepted method to show what happened when these seven digital billboards were installed in Cuyahoga County.

ANALYSIS

The analysis of this robust data involves an engineering-statistics based approach and uses a widely accepted method to show what happened when these seven digital billboards were installed in Cuyahoga County. The analysis has two parts.

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 0.2, 0.4, 0.6, 0.8, and 1.0 miles both upstream and downstream of the billboard. These vicinity ranges also sampled data to include all accidents along the principal Routes to which the digital billboard directly advertises. Accident data for roads in which the digital billboard does not advertise were excluded even if they were within the desired vicinity range.

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 were analyzed for before and after comparisons. For a more lengthy discussion of analysis methods, please refer to previous studies (see References 2 and 3).

The number of accidents and rates of accidents near the seven digital billboards decreased in all vicinity ranges.

RESULTS: ALL SEVEN DIGITAL BILLBOARDS

Figure 23 shows a comparison of the accident metrics for before and after the conversion of and near the seven digital billboards in Cuyahoga County. The statistics are summarized for vicinity ranges within 0.2, 0.4, 0.6, 0.8, and 1.0 miles of the digital billboards. Percent change is calculated and is also normalized by traffic volume and accident rates. Figure 24 shows the distributions of accident statistics near all digital billboards within all vicinities.

The metrics 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.

The number of accidents and rates of accidents near the seven digital billboards collectively decreased in all vicinity ranges. The benchmark 0.6 mile vicinity experienced a 14.9 percent decrease in accidents over the eight-year span for all signs. This consistency is more pronounced when metrics are normalized by year-to-year traffic volume rates and by county-wide accident rates. For example, the 0.6 mile benchmark vicinity experienced a normalized 2.2 percent decrease.

Within the 0.6 mile vicinity, the average number of accidents in any given month decreased from 153.2 to 133.5 collectively for these seven signs; similarly the peak number of accidents in any given month decreased from 262 to 208. Similar decreases and trends in both averages and peaks were observed for both smaller and larger vicinity ranges.

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

Consistent results were obtained for comparisons of daytime and nighttime accidents and for young and elderly drivers in accidents. These results are presented and discussed within this report. Correlation coefficients were calculated and indicated a very strong correlation of accident patterns near digital billboards when compared with the accident patterns near prior to conversion.

		METRIC	DISTANCE RANGE FROM BILLBOARD (MILES)				
			0.2	0.4	0.6	0.8	1.0
(8 years of crash data)	Prior to Installation (4 years before)	Total Accidents as Conventional Billboard	392	551	1835	2138	2443
		Average Number of Accidents in a Month	32.4	44.5	153.2	22.4	203.6
		Standard Deviation	14.9	19.9	399.1	52.0	54.6
		Peak Number of Accidents in any given month	62	85	262	301	334
		Minimum Number of Accidents in any given month	14	21	97	114	143
	Digital Billboard (4 years after)	Total Accidents as Digital Billboard	327	498	1562	1843	2149
		Average Number of Accidents in a month	29.0	44.3	133.5	156.5	181.3
		Standard Deviation	11.9	18.0	40.7	43.6	48.4
		Peak Number of Accidents in any given month	50	79	208	243	271
		Minimum Number of Accidents in any given month	15	23	71	93	104
	% Change	Total Accidents before and after conversion	-16.6%	-9.6%	-14.9%	-13.8%	-12.0%
	Normalized Percent Change (by volume rate and normalized by all accidents within county)	Normalized Percent Change (by all accidents within county)	-0.2%	-8.5%	-2.2%	-3.5%	-5.6%

Figure 23. Summary accident statistics near all seven digital billboards within vicinity ranges in Cuyahoga County, OH

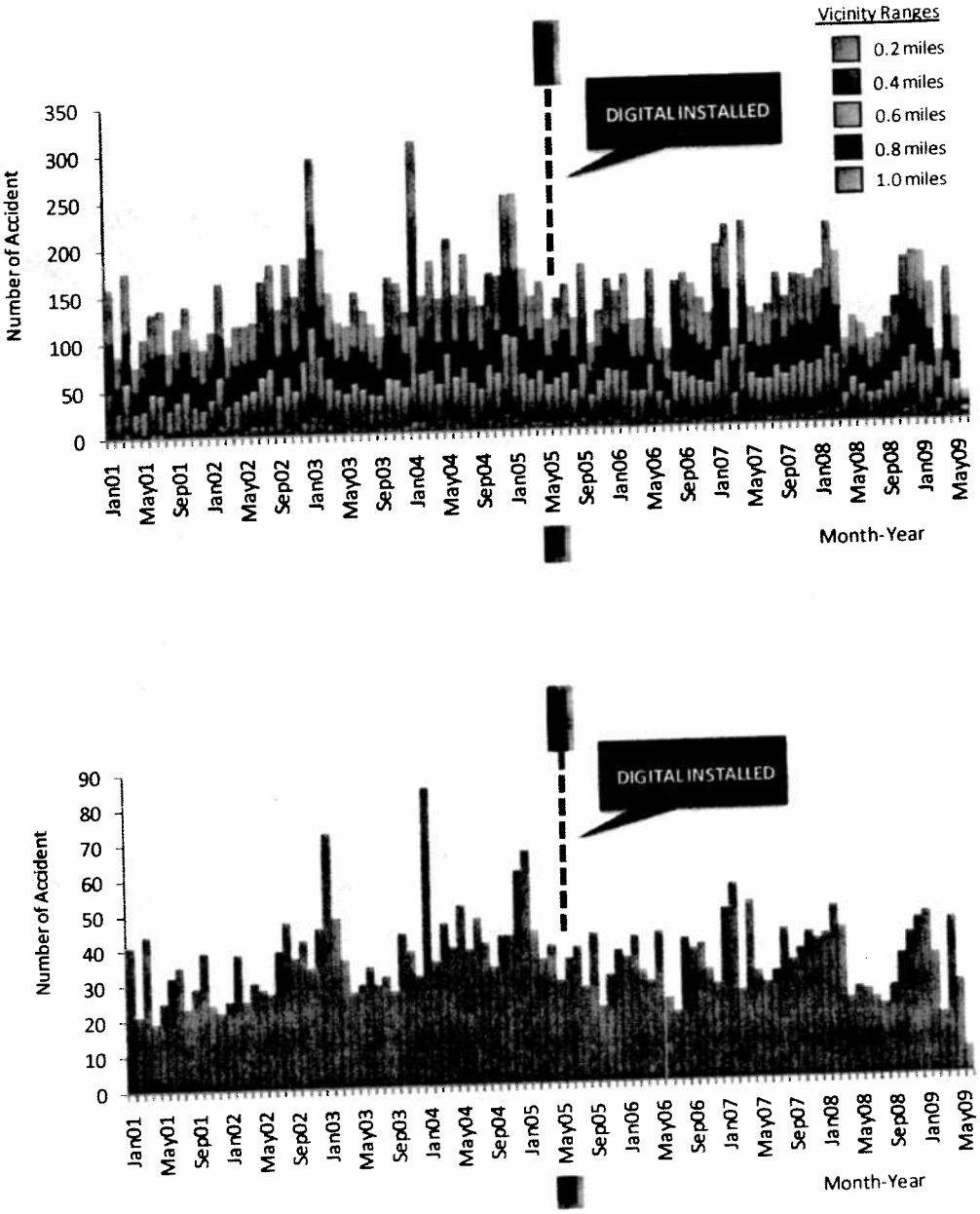

Figure 24. Distributions of accidents near all seven digital billboards (top) within 0.2, 0.4, 0.6, 0.8, and 1.0 mile vicinities and (bottom) within the 0.6 mile benchmark vicinity

Figure 25 also shows that the average rate of accidents per hundred vehicles near the seven digital billboards collectively decreased in all vicinity ranges. The 0.6 mile benchmark vicinity experienced a decrease in accident rates over the eight-year span for all signs. Similar decreases and trends were observed for both smaller and larger vicinity ranges.

		METRIC	DISTANCE RANGE FROM BILLBOARD (MILES)				
			0.2	0.4	0.6	0.8	1.0
(8 years of crash data)	Prior to Installation (4 years before)	Average Accident Rate per 100,000 vehicles average per year prior to installation	0.19	0.33	1.42	1.63	1.88
	Digital Billboard (4 years after)		0.18	0.29	1.18	1.38	1.61
	Change (volume rate)	change in average accident rate per volume	-0.01	-0.04	-0.23	-0.25	-0.28

Figure 25. Summary accident statistics for average rates near all digital billboards within 0.2, 0.4, 0.6, 0.8, and 1.0 mile vicinities

SPECIFIC RESULTS FOR BILLBOARD 1

Figure 26 summarizes the statistics and composite accident metrics for billboard number 1 for all vicinity distances. Figure 27 shows the billboard location, geocoded accident records and approximate vicinity ranges. Figure 28 shows the histogram for all vicinities of before and after accident counts centered on the conversion date of the billboard.

These figures represent a 96 month window (48 before and 48 after) of accidents within various vicinities. A comparison of the histograms of accidents at the location before and after the digital conversion indicates no statistically significant change in accident statistics. A comparison of eight years of data for this location indicates that the total number of accidents on any given month decreased from 25 to 22 within 0.6 miles, after the introduction of the digital billboard at the location; the average number of accidents in any given month also decreased.

			DISTANCE RANGE FROM BILLBOARD (MILES)				
		METRIC	0.2	0.4	0.6	0.8	1.0
(8 years of crash data)	Prior to Installation (4 years before)	Total Accidents as Conventional Billboard	6	18	25	56	59
		Average Number of Accidents in a Month	0.5	1.6	3.6	5.8	6.3
		Standard Deviation	0.5	1.3	1.6	2.6	2.6
		Peak Number of Accidents in any given month	1	4	5	12	12
		Minimum Number of Accidents in any given month	0	0	0	2	2
	Digital Billboard (4 years after)	Total Accidents as Digital Billboard	7	21	22	49	55
		Average Number of Accidents in a month	0.6	1.8	3.5	5.6	6.2
		Standard Deviation	1.1	1.4	1.9	2.5	3.2
		Peak Number of Accidents in any given month	4	7	8	10	13
		Minimum Number of Accidents in any given month	1	2	2	2	2
	Change	Total Accidents before and after conversion	1	3	-3	-7	-4

Figure 26. Summary accident statistics near digital billboard 1 within 0.2, 0.4, 0.6, 0.8, and 1.0 mile vicinities

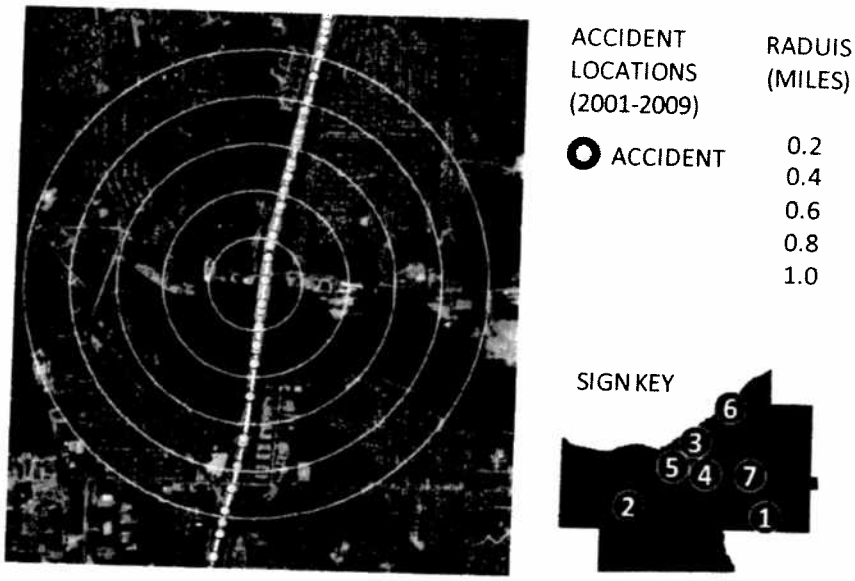

Figure 27. Aerial of Accident data near digital billboard 1 within 0.2, 0.4, 0.6, 0.8, and 1.0 mile vicinities

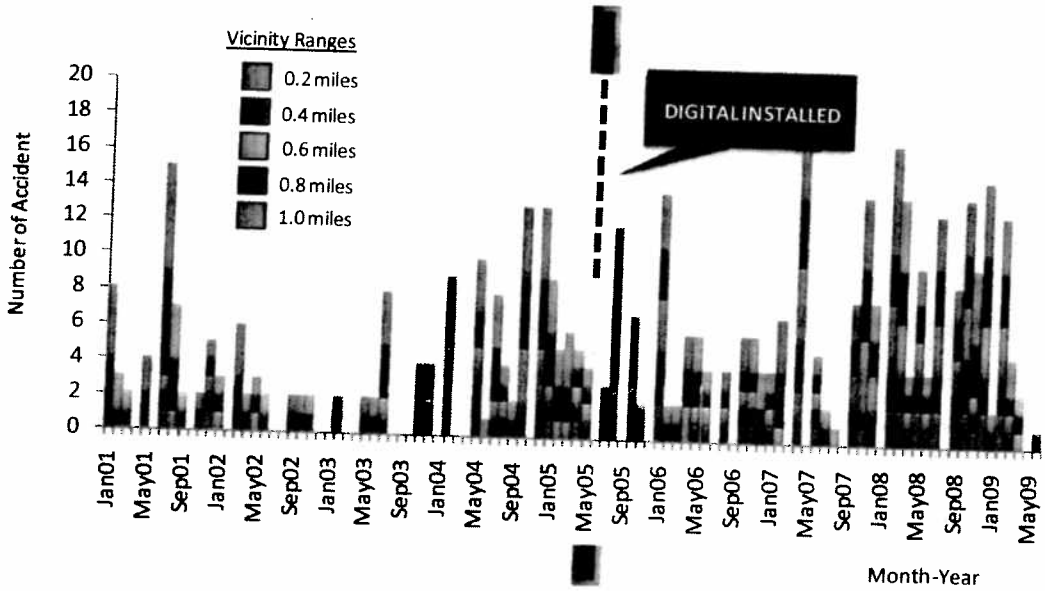

Figure 28. Accident Counts per month near digital billboard 1 within 0.2, 0.4, 0.6, 0.8, and 1.0 mile vicinities

SPECIFIC RESULTS FOR BILLBOARD 2

Figure 29 summarizes the statistics and composite accident metrics for billboard number 2 for all vicinity distances. Figure 30 shows the billboard location, geocoded accident records and approximate vicinity ranges. Figure 31 shows the histogram for all vicinities of before and after accident counts centered on the conversion date of the billboard.

These figures represent a 96 month window (48 before and 48 after) of accidents within various vicinities. A comparison of the histograms of accidents at the location before and after the digital conversion indicates no statistically significant change in accident statistics. A comparison eight years of data for this location indicates that the total number of accidents on any given month decreased from 176 to 165 within 0.6 miles, after the introduction of the digital billboard at the location; the average number of accidents in any given month decreased from 14.7 to 13.8 per month.

		DISTANCE RANGE FROM BILLBOARD (MILES)				
	METRIC	0.2	0.4	0.6	0.8	1.0
(8 years of crash data) Prior to Installation (4 years before)	Total Accidents as Conventional Billboard	158	161	176	186	194
	Average Number of Accidents in a Month	13.2	13.4	14.7	15.5	16.2
	Standard Deviation	5.4	5.6	5.8	5.7	6.2
	Peak Number of Accidents in any given month	21	21	23	23	24
	Minimum Number of Accidents in any given month	5	5	6	7	7
Digital Billboard (4 years after)	Total Accidents as Digital Billboard	136	147	165	171	180
	Average Number of Accidents in a month	11.3	12.3	13.8	14.3	15.0
	Standard Deviation	4.6	4.9	5.6	5.7	6.0
	Peak Number of Accidents in any given month	20	23	25	26	28
	Minimum Number of Accidents in any given month	6	7	7	7	8
Change	Total Accidents before and after conversion	-22	-14	-11	-15	-14

Figure 29. Summary accident statistics near digital billboard 2 within 0.2, 0.4, 0.6, 0.8, and 1.0 mile vicinities

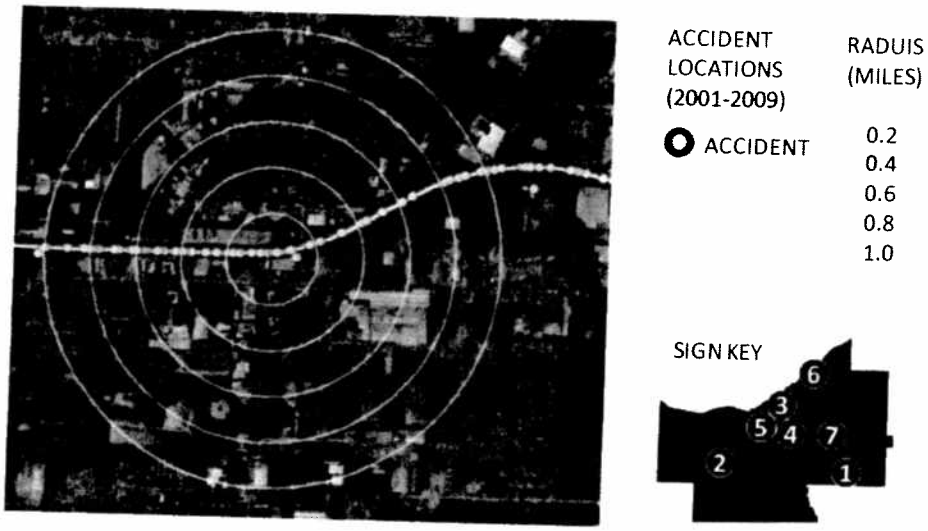

Figure 30. Aerial of Accident data near digital billboard 2 within 0.2, 0.4, 0.6, 0.8, and 1.0 mile vicinities

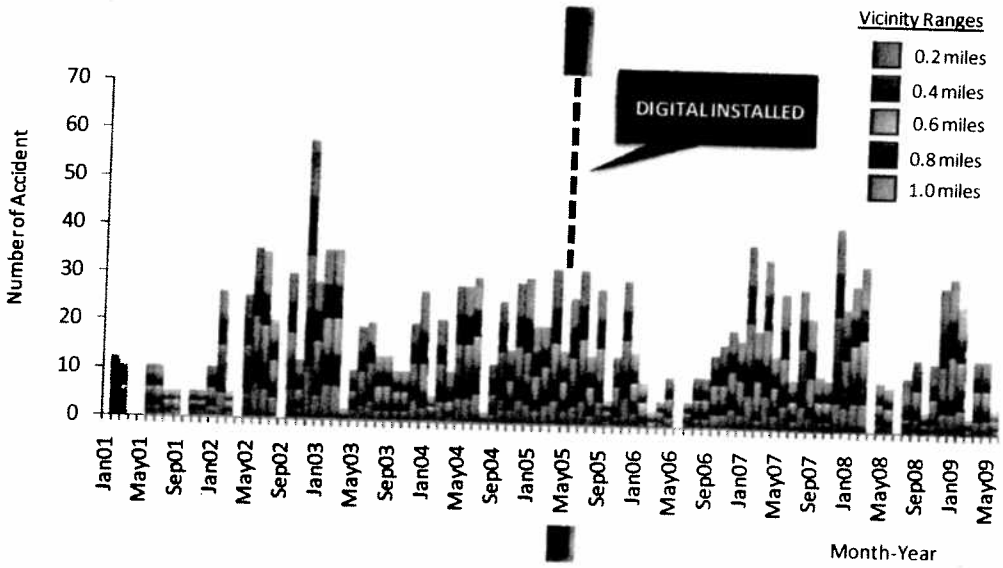

Figure 31. Accident Counts per month near digital billboard 2 within 0.2, 0.4, 0.6, 0.8, and 1.0 mile vicinities

SPECIFIC RESULTS FOR BILLBOARD 3

Figure 32 summarizes the statistics and composite accident metrics for billboard number 3 for all vicinity distances. Figure 33 shows the billboard location, geocoded accident records and approximate vicinity ranges. Figure 34 shows the histogram for all vicinities of before and after accident counts centered on the conversion date of the billboard.

These figures represent a 96 month window (48 before and 48 after) of accidents within various vicinities. A comparison of the histograms of accidents at the location before and after the digital conversion indicates no statistically significant change in accident statistics. A comparison of eight years of data for this location indicates that the total number of accidents on any given month decreased from 357 to 351 within 0.6 miles, after the introduction of the digital billboard at the location; the average number of accidents in any given month decreased from 30.4 to 29.8 per month.

		DISTANCE RANGE FROM BILLBOARD (MILES)				
	METRIC	0.2	0.4	0.6	0.8	1.0
(8 years of crash data) Prior to Installation (4 years before)	Total Accidents as Conventional Billboard	8	86	357	501	611
	Average Number of Accidents in a Month	0.4	5.5	30.4	42.3	50.9
	Standard Deviation	0.5	2.4	362.0	6.7	8.3
	Peak Number of Accidents in any given month	1	11	40	54	69
	Minimum Number of Accidents in any given month	0	2	23	31	40
Digital Billboard (4 years after)	Total Accidents as Digital Billboard	10	88	351	495	594
	Average Number of Accidents in a month	0.9	8.1	29.8	41.8	49.5
	Standard Deviation	0.7	3.6	7.2	9.3	10.0
	Peak Number of Accidents in any given month	2	16	40	57	64
	Minimum Number of Accidents in any given month	0	3	16	27	31
Change	Total Accidents before and after conversion	2	2	-6	-6	-17

Figure 32. Summary accident statistics near digital billboard 3 within 0.2, 0.4, 0.6, 0.8, and 1.0 mile vicinities

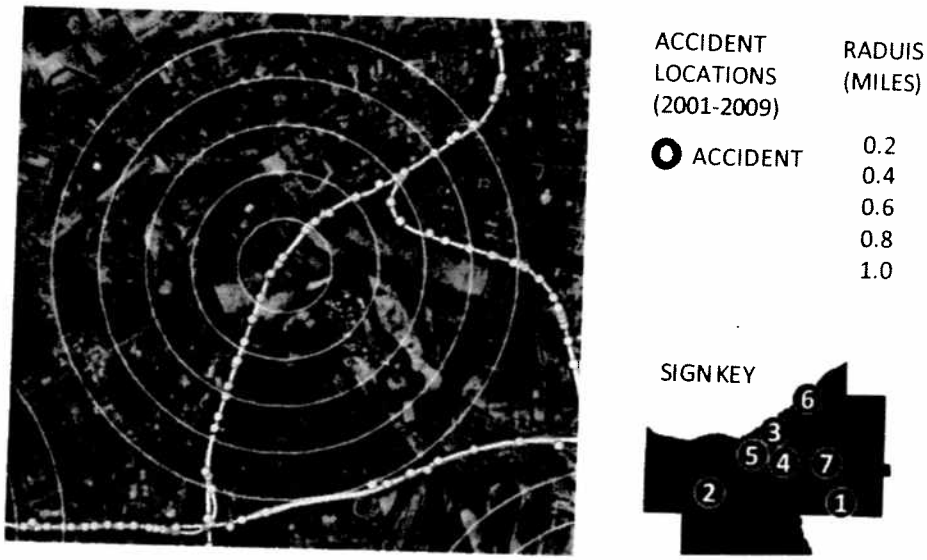

Figure 33. Aerial of Accident data near digital billboard 3 within 0.2, 0.4, 0.6, 0.8, and 1.0 mile vicinities

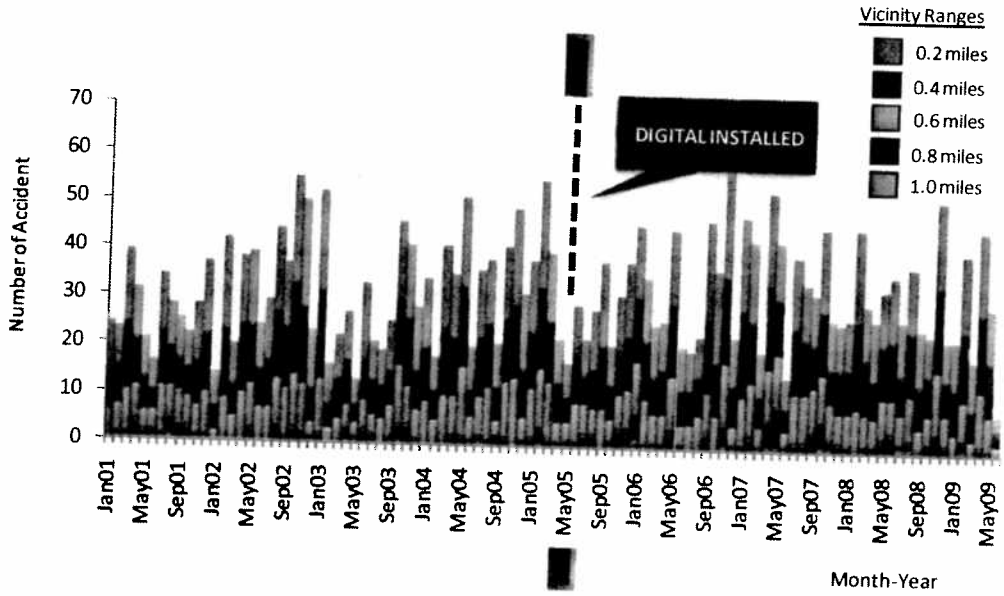

Figure 34. Accident Counts per month near digital billboard 3 within 0.2, 0.4, 0.6, 0.8, and 1.0 mile vicinities

SPECIFIC RESULTS FOR BILLBOARD 4

Figure 35 summarizes the statistics and composite accident metrics for billboard number 4 for all vicinity distances. Figure 36 shows the billboard location, geocoded accident records and approximate vicinity ranges. Figure 37 shows the histogram for all vicinities of before and after accident counts centered on the conversion date of the billboard.

These figures represent a 96 month window (48 before and 48 after) of accidents within various vicinities. A comparison of the histograms of accidents at the location before and after the digital conversion indicates no statistically significant change in accident statistics. A comparison of eight years of data for this location indicates that the total number of accidents on any given month decreased from 232 to 179 within 0.6 miles, after the introduction of the digital billboard at the location; the average number of accidents in any given month decreased from 19.3 to 14.9 per month.

			DISTANCE RANGE FROM BILLBOARD (MILES)				
		METRIC	0.2	0.4	0.6	0.8	1.0
(8 years of crash data)	Prior to Installation (4 years before)	Total Accidents as Conventional Billboard	3	6	232	239	321
		Average Number of Accidents in a Month	0.3	0.5	19.3	19.9	26.8
		Standard Deviation	0.5	0.7	6.8	7.0	7.5
		Peak Number of Accidents in any given month	1	2	34	35	42
		Minimum Number of Accidents in any given month	0	0	11	11	19
	Digital Billboard (4 years after)	Total Accidents as Digital Billboard	3	7	179	212	291
		Average Number of Accidents in a month	0.3	0.8	14.9	17.7	24.3
		Standard Deviation	0.5	0.8	5.3	6.7	6.1
		Peak Number of Accidents in any given month	1	2	23	33	36
		Minimum Number of Accidents in any given month	0	0	6	8	14
	Change	Total Accidents before and after conversion	0	1	-53	-27	-30

Figure 35. Summary accident statistics near digital billboard 4 within 0.2, 0.4, 0.6, 0.8, and 1.0 mile vicinities

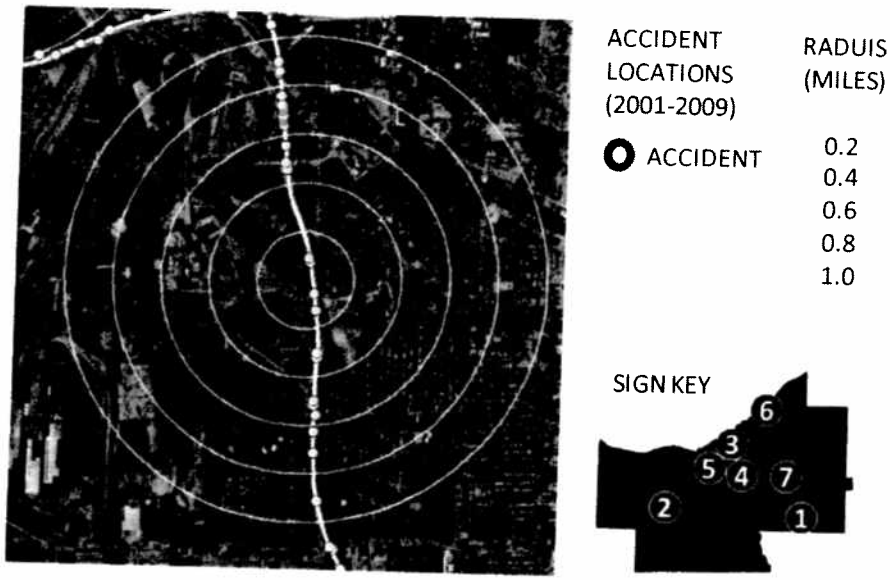

Figure 36. Aerial of Accident data near digital billboard 4 within 0.2, 0.4, 0.6, 0.8, and 1.0 mile vicinities

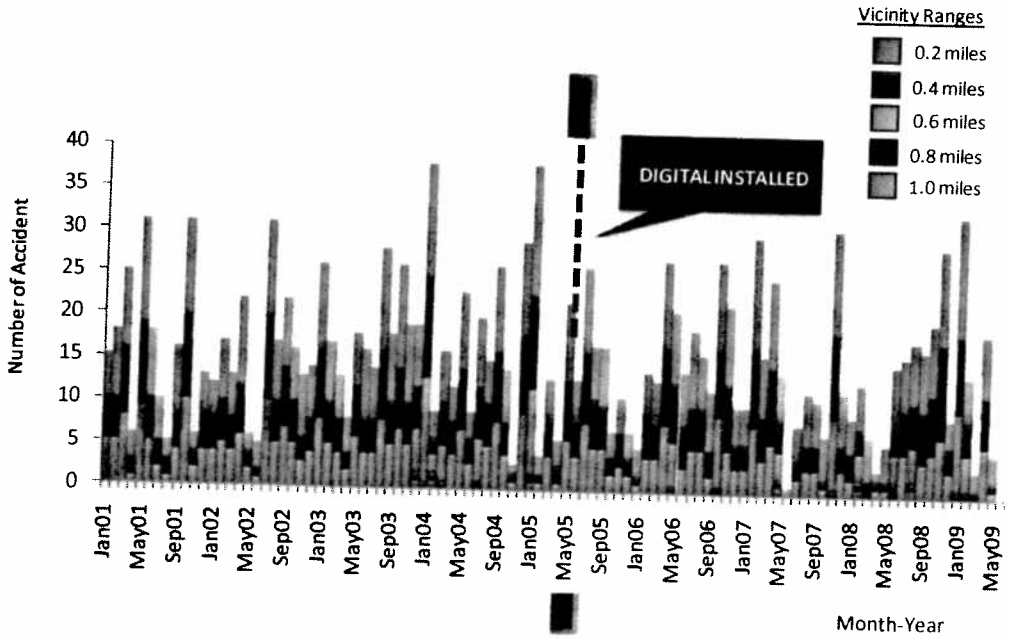

Figure 37. Accident Counts per month near digital billboard 4 within 0.2, 0.4, 0.6, 0.8, and 1.0 mile vicinities

SPECIFIC RESULTS FOR BILLBOARD 5

Figure 38 summarizes the statistics and composite accident metrics for billboard number 5 for all vicinity distances. Figure 39 shows the billboard location, geocoded accident records and approximate vicinity ranges. Figure 40 shows the histogram for all vicinities of before and after accident counts centered on the conversion date of the billboard.

These figures represent a 96 month window (48 before and 48 after) of accidents within various vicinities. A comparison of the histograms of accidents at the location before and after the digital conversion indicates no statistically significant change in accident statistics. A comparison of eight years of data for this location indicates that the total number of accidents on any given month decreased from 442 to 344 within 0.6 miles, after the introduction of the digital billboard at the location; the average number of accidents in any given month decreased from 36.8 to 28.7 per month.

			DISTANCE RANGE FROM BILLBOARD (MILES)				
		METRIC	0.2	0.4	0.6	0.8	1.0
(8 years of crash data)	Prior to Installation (4 years before)	Total Accidents as Conventional Billboard	11	41	442	456	490
		Average Number of Accidents in a Month	0.9	3.4	36.8	38.0	40.8
		Standard Deviation	1.2	2.4	11.8	12.4	11.9
		Peak Number of Accidents in any given month	4	8	71	74	76
		Minimum Number of Accidents in any given month	0	1	26	26	31
	Digital Billboard (4 years after)	Total Accidents as Digital Billboard	10	31	344	349	368
		Average Number of Accidents in a month	0.8	2.6	28.7	29.1	30.7
		Standard Deviation	1.0	2.1	9.3	9.1	9.8
		Peak Number of Accidents in any given month	3	6	49	49	51
		Minimum Number of Accidents in any given month	0	0	16	18	18
	Change	Total Accidents before and after conversion	-1	-10	-98	-107	-122

Figure 38. Summary accident statistics near digital billboard 5 within 0.2, 0.4, 0.6, 0.8, and 1.0 mile vicinities

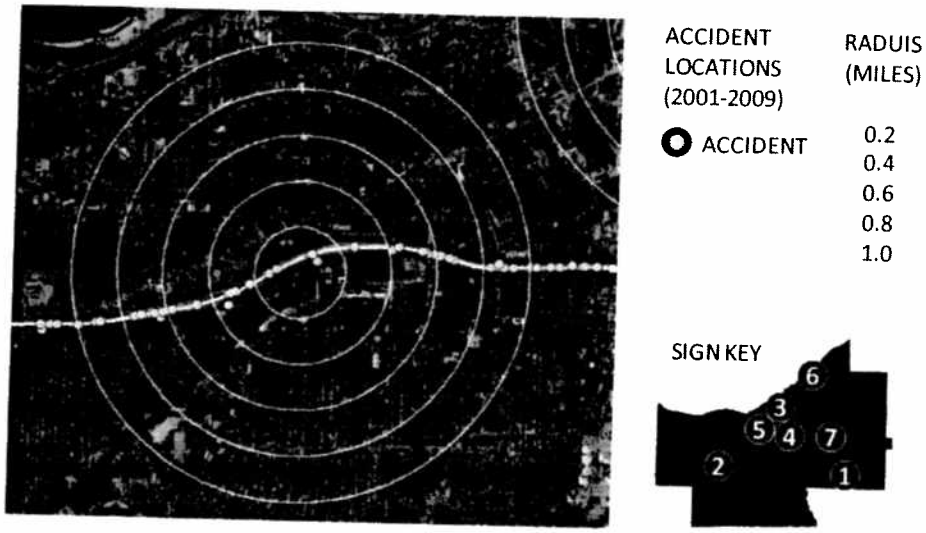

Figure 39. Aerial of Accident data near digital billboard 5 within 0.2, 0.4, 0.6, 0.8, and 1.0 mile vicinities

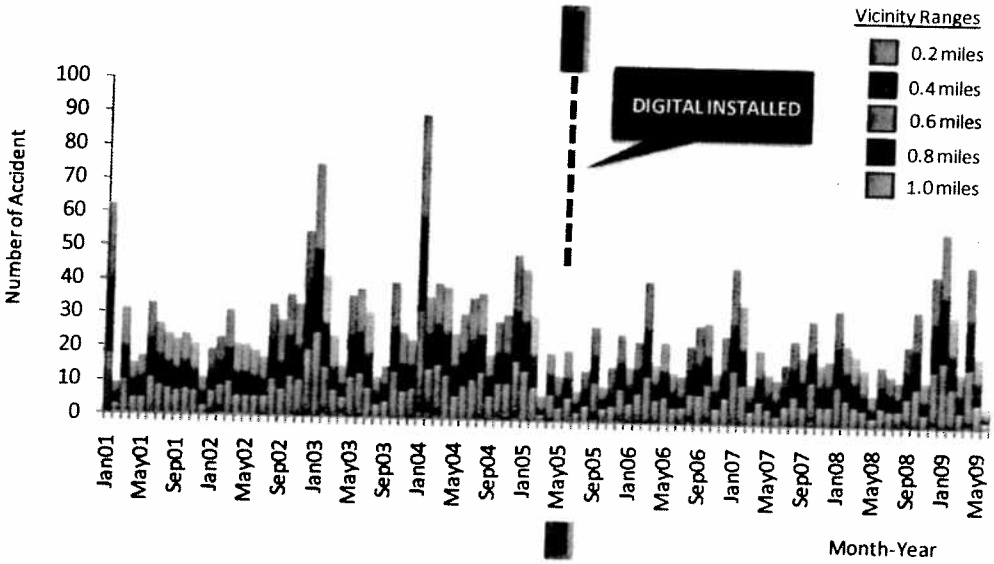

Figure 40. Accident Counts per month near digital billboard 5 within 0.2, 0.4, 0.6, 0.8, and 1.0 mile vicinities

SPECIFIC RESULTS FOR BILLBOARD 6

Figure 41 summarizes the statistics and composite accident metrics for billboard number 6 for all vicinity distances. Figure 42 shows the billboard location, geocoded accident records and approximate vicinity ranges. Figure 43 shows the histogram for all vicinities of before and after accident counts centered on the conversion date of the billboard.

These figures represent a 96 month window (48 before and 48 after) of accidents within various vicinities. A comparison of the histograms of accidents at the location before and after the digital conversion indicates no statistically significant change in accident statistics. A comparison of eight years of data for this location indicates that the total number of accidents on any given month decreased from 268 to 214 within 0.6 miles, after the introduction of the digital billboard at the location; the average number of accidents in any given month decreased from 22.3 to 17.8 per month.

			DISTANCE RANGE FROM BILLBOARD (MILES)				
		METRIC	0.2	0.4	0.6	0.8	1.0
(8 years of crash data)	Prior to Installation (4 years before)	Total Accidents as Conventional Billboard	5	6	268	269	301
		Average Number of Accidents in a Month	0.4	0.5	22.3	22.4	25.1
		Standard Deviation	0.7	0.8	6.1	6.1	6.6
		Peak Number of Accidents in any given month	2	2	35	35	40
		Minimum Number of Accidents in any given month	0	0	14	14	17
	Digital Billboard (4 years after)	Total Accidents as Digital Billboard	4	7	214	220	266
		Average Number of Accidents in a month	0.3	0.8	17.8	18.3	22.2
		Standard Deviation	0.7	0.8	6.7	6.7	8.7
		Peak Number of Accidents in any given month	2	2	32	33	40
		Minimum Number of Accidents in any given month	0	0	8	8	8
	Change	Total Accidents before and after conversion	-1	1	-54	-49	-35

Figure 41. Summary accident statistics near digital billboard 6 within 0.2, 0.4, 0.6, 0.8, and 1.0 mile vicinities

Figure 42. Aerial of Accident data near digital billboard 6 within 0.2, 0.4, 0.6, 0.8, and 1.0 mile vicinities

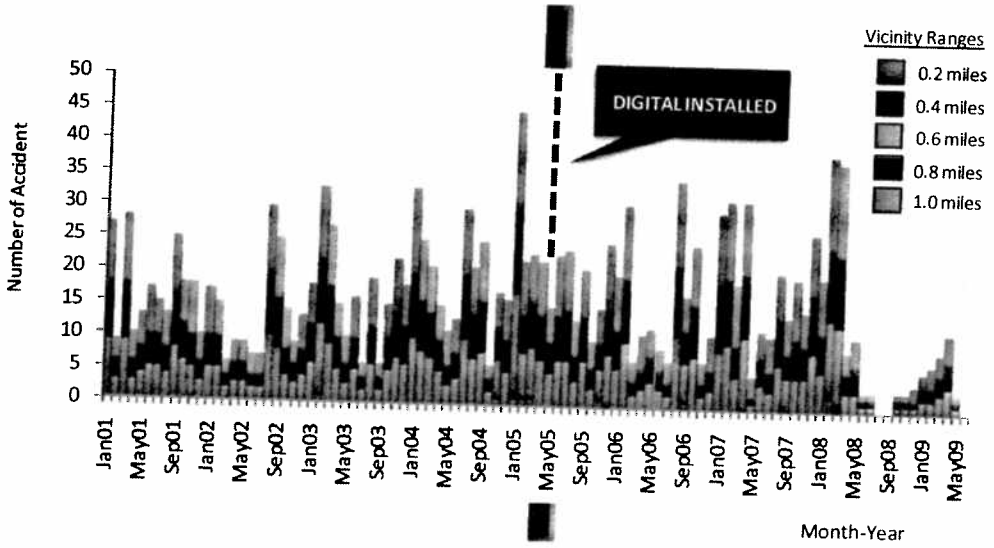

Figure 43. Accident Counts per month near digital billboard 6 within 0.2, 0.4, 0.6, 0.8, and 1.0 mile vicinities

SPECIFIC RESULTS FOR BILLBOARD 7

Figure 44 summarizes the statistics and composite accident metrics for billboard number 7 for all vicinity distances. Figure 45 shows the billboard location, geocoded accident records and approximate vicinity ranges. Figure 46 shows the histogram for all vicinities of before and after accident counts centered on the conversion date of the billboard.

These figures represent a 96 month window (48 before and 48 after) of accidents within various vicinities. A comparison of the histograms of accidents at the location before and after the digital conversion indicates no statistically significant change in accident statistics. A comparison of eight years of data for this location indicates that the total number of accidents on any given month decreased from 330 to 287 within 0.6 miles, after the introduction of the digital billboard at the location; the average number of accidents in any given month decreased from 27.5 to 23.9 per month.

		DISTANCE RANGE FROM BILLBOARD (MILES)				
	METRIC	0.2	0.4	0.6	0.8	1.0
(8 years of crash data) Prior to Installation (4 years before)	Total Accidents as Conventional Billboard	201	233	330	432	467
	Average Number of Accidents in a Month	16.8	19.4	27.5	36.0	38.9
	Standard Deviation	6.2	6.8	10.1	11.6	11.4
	Peak Number of Accidents in any given month	32	37	54	68	71
	Minimum Number of Accidents in any given month	9	13	17	23	27
Digital Billboard (4 years after)	Total Accidents as Digital Billboard	157	197	287	347	395
	Average Number of Accidents in a month	13.1	16.4	23.9	28.9	32.9
	Standard Deviation	3.5	4.3	4.8	3.6	4.6
	Peak Number of Accidents in any given month	18	23	31	35	39
	Minimum Number of Accidents in any given month	8	11	16	23	23
Change	Total Accidents before and after conversion	-44	-36	-43	-85	-72

Figure 44. Summary accident statistics near digital billboard 7 within 0.2, 0.4, 0.6, 0.8, and 1.0 mile vicinities

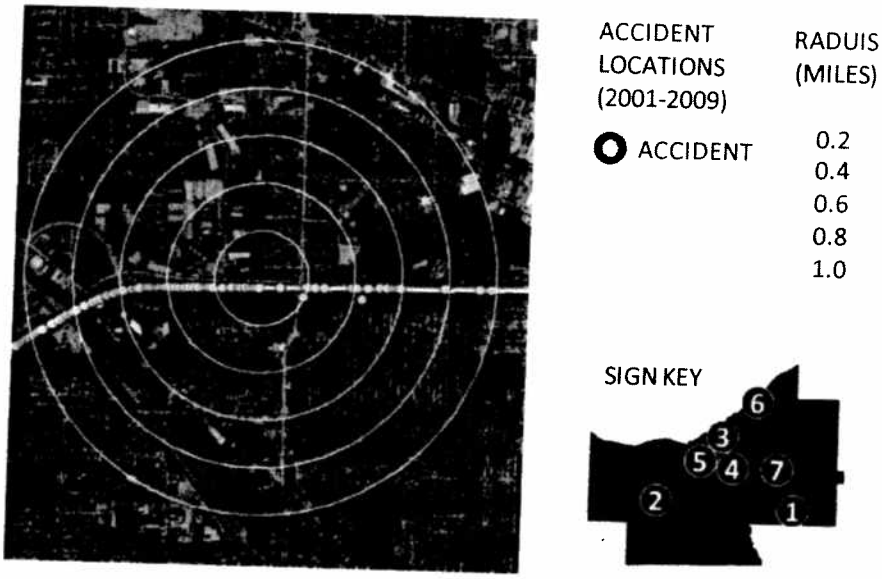

Figure 45. Aerial of Accident data near digital billboard 7 within 0.2, 0.4, 0.6, 0.8, and 1.0 mile vicinities

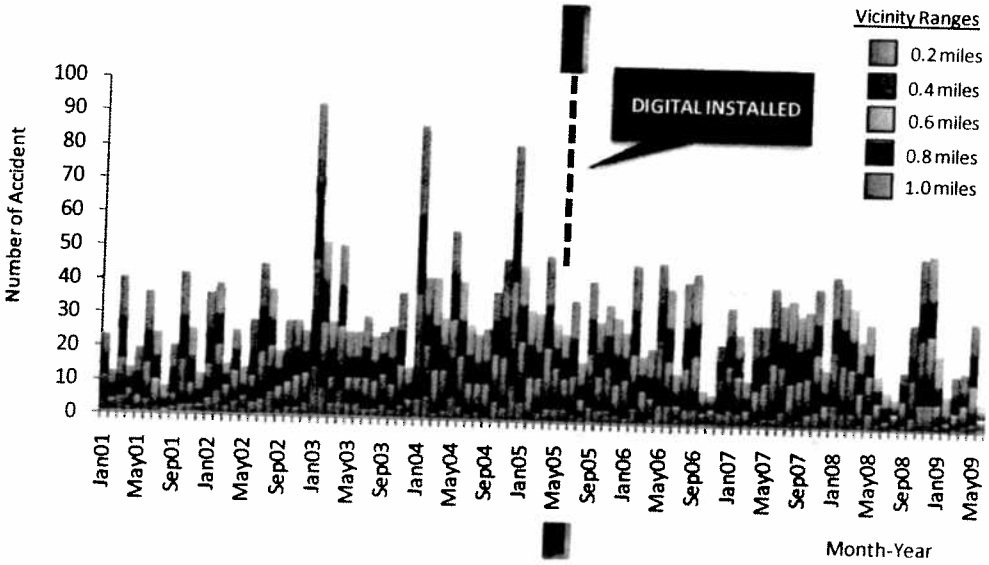

Figure 46. Accident Counts per month near digital billboard 7 within 0.2, 0.4, 0.6, 0.8, and 1.0 mile vicinities

RESULTS: COMPARISONS BY AGE OF DRIVER

The accident statistics were analyzed to determine if the age of the drivers involved in 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 21) or elderly driver (65 and older.

Figure 47 summarizes the distributions of accidents between 2001 and 2009 by age of driver for crashes within Cuyahoga County (blue histogram) and for accidents specifically on Interstate Routes which are within the one mile vicinity range of the digital billboard locations (orange histogram inset). Individual accidents may have multiple cars and drivers involved and this is reflected in the analysis. Figure 48 compares the distributions of ages of drivers in accidents within the one mile vicinity range of the billboard prior to digital conversion (top, red histogram) and subsequent to digital conversion (bottom, blue histogram). In comparing the histograms in Figures 47 and 48, note the typical distribution type (shape) and typical mean values. The average age of drivers in accidents within one mile of these digital billboards are 37.2 years (prior to conversion) and 38.0 years (subsequent to conversion).

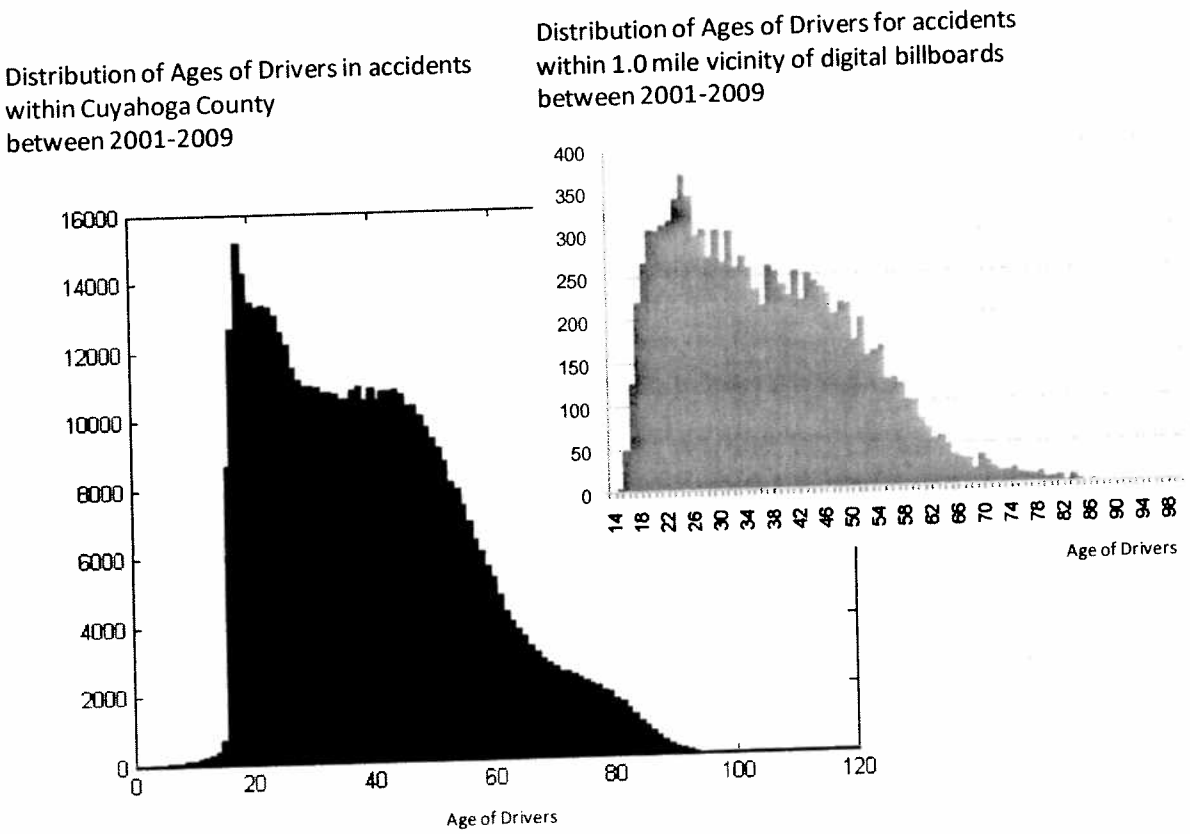

Figure 47. Distributions of accidents between 2001 and 2009 by age of driver for crashes within Cuyahoga County (blue histogram) and for accidents specifically on Interstate Routes which are within the one mile vicinity range of the digital billboard locations (orange histogram inset)

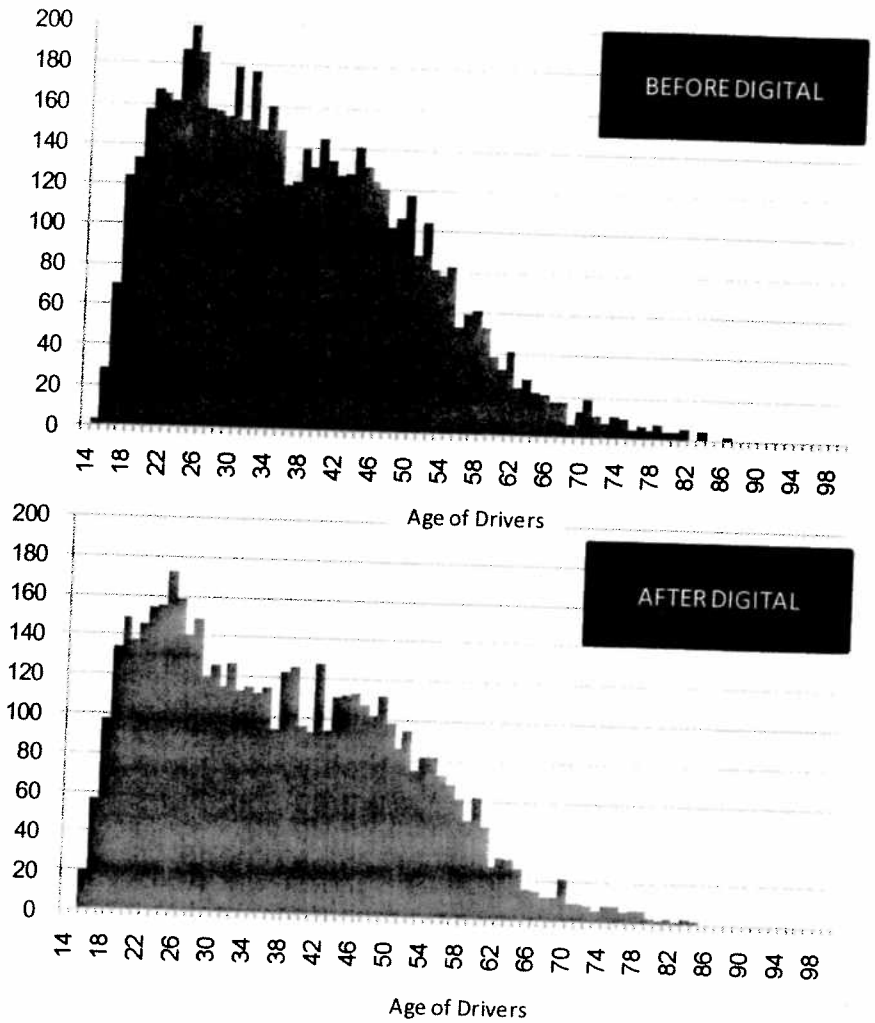

Figure 48. Distributions of ages of drivers in accidents within the one mile vicinity range of the billboard prior to digital conversion (top, red histogram) and subsequent to digital conversion (bottom, blue histogram).

Figure 49 summarizes the number of drivers by age group for accidents within one mile of the digital billboards. The data shows a 12.4% decrease in accidents over eight years for drivers under 21 and a 5.1% decrease in accidents for driver 65 and older.

Correlation coefficients were calculated and indicated a very strong correlation of accident patterns for age-of-driver factors. Figure 50 shows a 0.981 (98.1%) correlation coefficient when comparing accidents before conversion with those after conversion.

	Metric	under 21	21 - 65	over 65
Prior to installation (4 years before)	Number of Accidents within each age group within 1.0 mile vicinity range of locations prior to digital conversion/installation	516	5070	184
Digital Billboard (4 years after)	Number of Accidents within each age group within 1.0 mile vicinity range of locations subsequent to digital conversion/installation	459	4428	175
% Change	Percent Change of Number of Accidents within each age group within 1.0 mile vicinity range of digital locations	-12.4%	-14.5%	-5.1%

Figure 49. Summary accident statistics of groups of ages of drivers in accidents within the one mile vicinity between 2001 and 2009

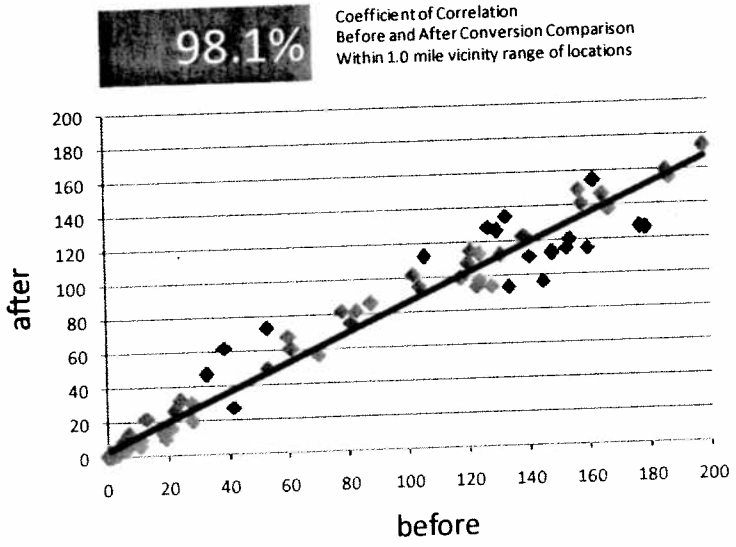

Figure 50. Correlation coefficient and regression by age of driver comparing before (conventional-face billboards) with after (digital-face billboards) within one mile between 2001 and 2009

RESULTS: COMPARISONS BY TIME OF DAY

The accident statistics were also analyzed to determine if the time of day of accidents near digital billboards was a factor. The data was specially studied to determine if there are increases in the accident rates during dawn, daylight, dusk and dark/nighttime conditions near these digital billboards. Accident records include attribute data for time of accident and lighting conditions using the specific four mentioned conditions.

Figure 51 summarizes the distributions of accidents between 2001 and 2009 by time of day for crashes within Cuyahoga County (blue histogram) and for accidents specifically on Interstate Routes which are within the one mile vicinity range of the digital billboard locations (orange histogram inset). Figure 52 compares the distributions of times of day in accidents within the one mile vicinity range of the billboard prior to digital conversion (top, red histogram) and subsequent to digital conversion (bottom, blue histogram). In comparing the histograms in Figures 51 and 52, note the typical bi-modal distribution type (shape) with characteristic peaks (at morning and after-work rush-hour commutes) and valleys (late night to early morning time-periods with light traffic).

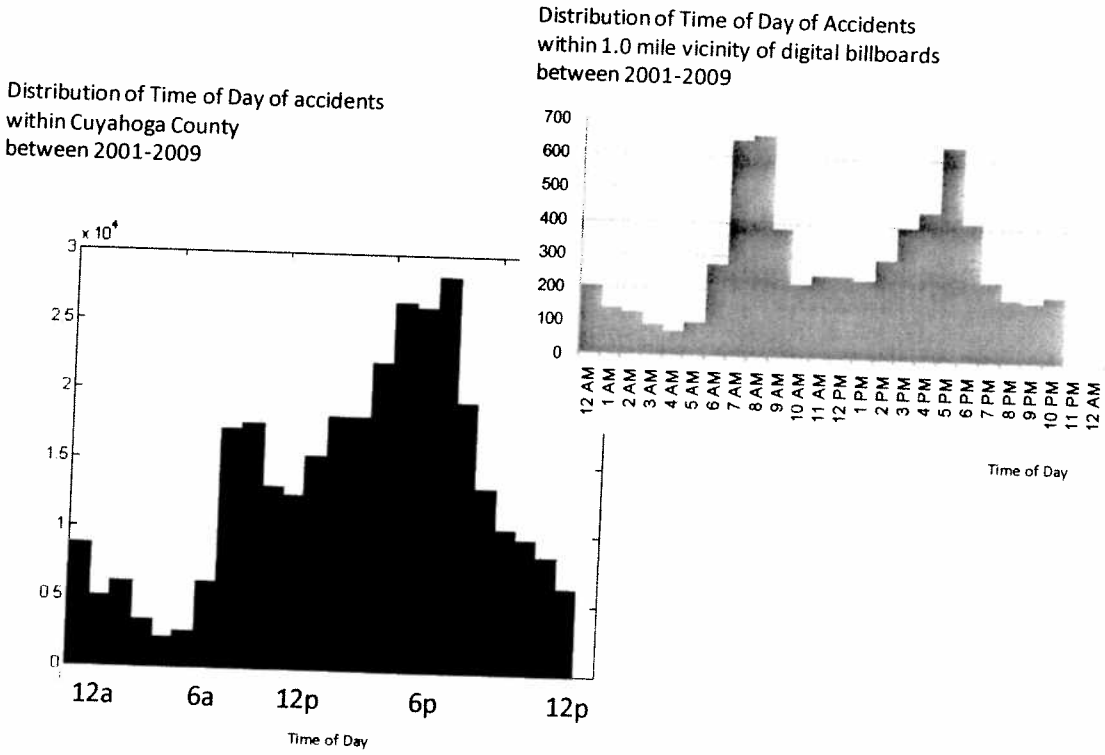

Figure 51. Shows distributions of accidents between 2001 and 2009 by time of day for crashes within Cuyahoga County (blue histogram) and for accidents specifically on Interstate Routes which are within the one mile vicinity range of the digital billboard locations (orange histogram inset).

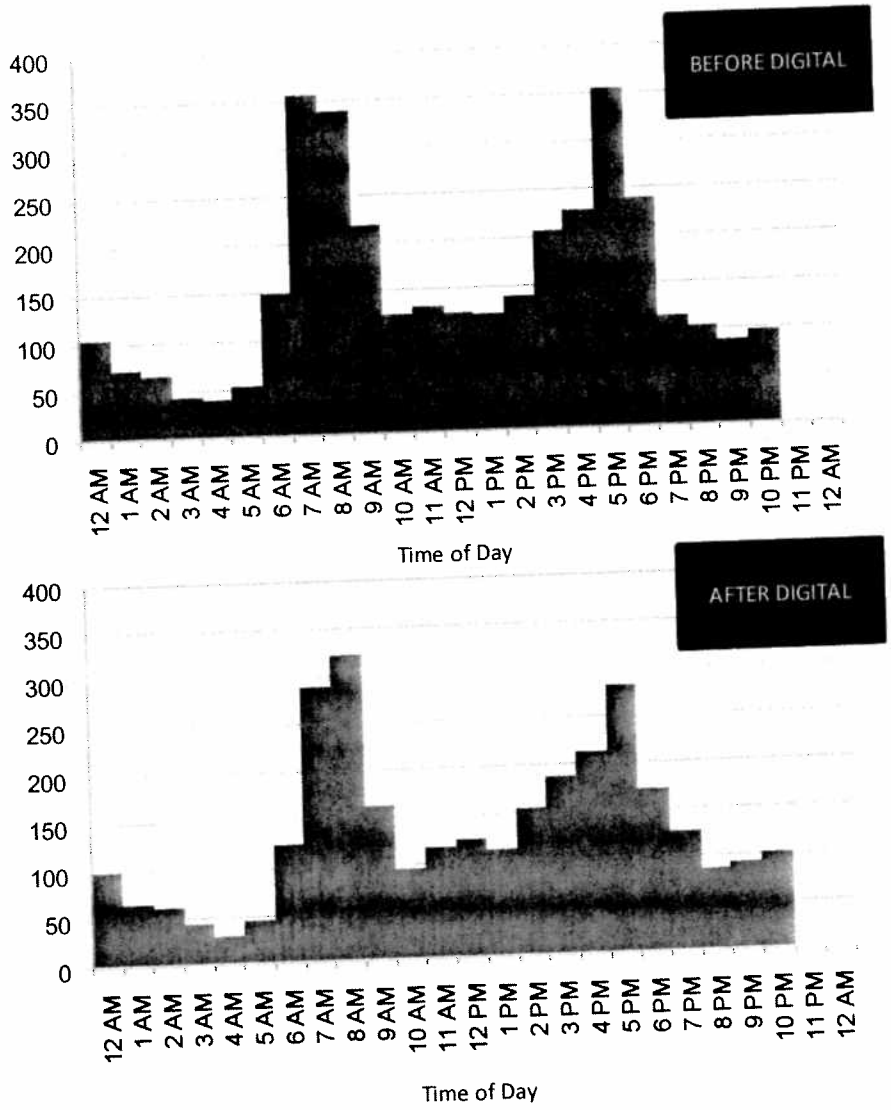

Figure 52. Distributions of time-of-day in accidents within the one mile vicinity range of the billboard prior to digital conversion (top, red histogram) and subsequent to digital conversion (bottom, blue histogram).

Figure 53 summarizes the number of accidents by time-of-day (lighting-condition) groups within one mile of the digital billboards. The data shows a 12.2 percent decrease in daytime accidents over eight years and an 8.6% decrease in nighttime accidents over eight years. Similar decreases were also noted in dawn and dusk conditions.

Correlation coefficients were calculated and indicated a very strong correlation of accident patterns for time-of-day factors. Figure 54 shows a 0.980 (98.0%) correlation coefficient when comparing accidents before conversion with those after conversion.

	Metric	Dawn	Daylight	Dusk	Dark
Prior to Installation (4 years before)	Number of Accidents within each road lighting group within 1.0 mile vicinity range of locations prior to digital conversion/installation	129	2364	113	966
Digital Billboard (4 years after)	Number of Accidents within each road lighting group within 1.0 mile vicinity range of locations subsequent to digital conversion/installation	85	2076	79	882
change	Change of Number of Accidents within each road lighting group within 1.0 mile vicinity range of digital locations	-44	-288	-34	-84

12.2% decrease in daytime

8.6% decrease in night time

Figure 53. Summary accident statistics of by time-of-day (lighting condition) groups in accidents within a one mile vicinity between 2001 and 2009

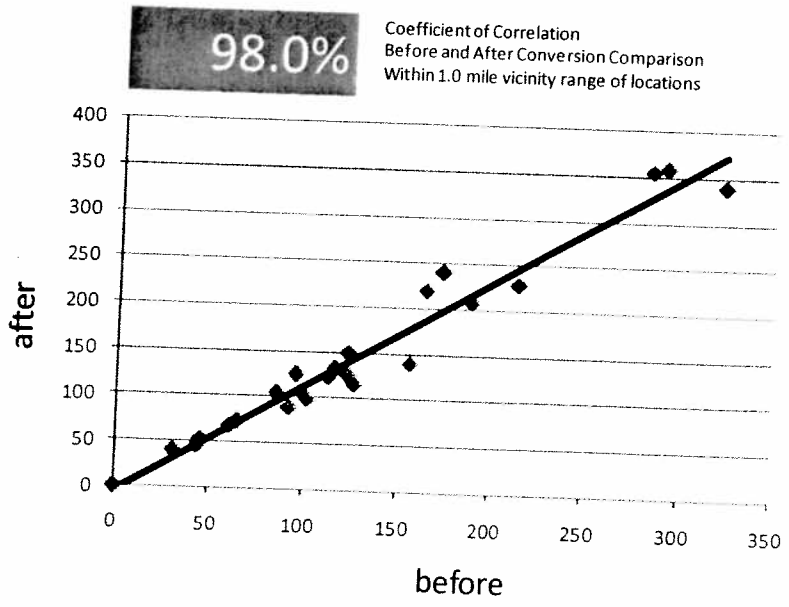

Figure 54. Correlation coefficient and regression by time-of-day comparing before (conventional-face billboards) with after (digital-face billboards) within one mile between 2001 and 2009

Simply stated, the data shows no increase of accident rates near these billboards.

FINDINGS

Cuyahoga County was a unique opportunity for study about the statistical associations between digital billboards and traffic safety and for revisiting the area with a more robust data set to analyze multiple locations for periods in excess of eight years. The overall conclusion is that the digital billboards in Cuyahoga County exhibit no statistically significant relationship with the occurrence of accidents. This conclusion is based on the Ohio Department of Transportation's own data and an objective statistical analysis; the data shows no increase in accident rates.

This study reinforces the findings of our 2007 study with longer periods of time for eight years of data. This study also finds that the age of drivers (younger, older) and the time of day (daytime, nighttime) are neutral factors which exhibit no statistically significant increase in accident rates near digital billboards along Interstates in Cuyahoga County, Ohio.

The specific conclusions of this study of Cuyahoga County indicate the following.

- The number of accidents and rates of accidents near the seven digital billboards collectively decreased in all vicinity ranges. The benchmark 0.6 mile vicinity experienced a 14.9 percent decrease (a normalized 2.2 percent decrease) in accidents over the eight-year span for all signs. Similar decreases and trends in both averages and peaks were observed for both smaller and larger vicinity ranges.

- **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 over an eight-year period, 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.

- Consistent results were obtained for comparisons of daytime and nighttime accidents and for young and elderly drivers in accidents. Correlation coefficients were calculated and indicated a very strong correlation of accident patterns near digital billboards when compared with the accident patterns near the former, conventional-face billboards.

Simply stated, the data shows no increase of accident rates near these billboards.

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TANTALA ASSOCIATES, LLC
CONSULTING ENGINEERS
4903 FRANKFORD AVENUE
PHILADELPHIA, PA 19124-2617
www.TANTALA.com