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

SUBMITTED TO

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STRUCTURAL
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EXECUTIVE SUMMARY

The purpose of this study is to examine the statistical relationship between certain digital billboards and traffic safety, and to determine if any correlation exists. For this study, a study area was identified, data was collected, and an analysis was made. Specifically, this study analyzes the traffic and accident data near seven existing, digital billboards on the 132.07 miles of Interstate routes in Cuyahoga County, Ohio. These seven billboards are located along Interstate routes I-77, I-90, I-271, and I-480. In July 2005, the seven billboards were converted to digital from conventional format; a total of 335 million vehicles drove by these seven billboards in that year.

The analysis has two parts. In the first part, the temporal analysis, the occurrence of traffic accidents near the digital billboards is examined for an equal length of time before and after July 2005, for the purpose of establishing if traffic accidents occurred more or less frequently with the presence of the digital billboards. The second part, the spatial analysis, establishes statistical correlation coefficients between the digital billboards and accidents. Correlation coefficients are statistical measures of the "association" between two sets of data, for example, billboards and traffic accidents. The results are analyzed for various scenarios between accident density to sign density (the number of billboards), to Viewer Reaction Distance (the distance from a billboard that a driver is potentially within the "influence" of a billboard), and to sign proximity (the distance from the accident to the nearest billboard). In each scenario, this study considers accident data, with and without the bias from interchanges or known causes.

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

- At each of the digital billboards, and for periods of 12 months before and after the conversion (a total of 24 months), the accident statistics and metrics are consistent, exhibiting statistically insignificant variations. The same conclusion also applies for periods of 18 months before and after the conversion (a total of 36 months). The metrics include the total number of accidents in any given month, the average number of accidents over the 12- and 18-month periods, 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 vehicle-miles traveled.

- The correlation coefficients demonstrate no statistical relationship between vehicular accidents and billboards (including conventional and the seven, digital billboards). Also, these correlation coefficients strongly suggest no causal relationship between the billboards and vehicular accidents.
- Accidents occur with or without billboards (digital or conventional). The accident statistics on sections of Interstate routes near billboards are comparable to the accident statistics on similar sections that have no billboards.

The overall conclusion of this study is that digital billboards have no statistical relationship with the occurrence of accidents. The frequency of traffic accidents may be much more likely attributable to, and correlated with, other factors, such as DUIs, deer hits, adverse weather conditions, excessive speeding, *inter alia*.

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1.0 GENERAL COMMENTS

Digital billboards are a relatively new technology in outdoor advertising. Digital billboards display static messages which, when viewed, resemble conventional painted or printed billboards. With digital technology, a static copy "dwells" for typically eight seconds, and includes no animation, flashing lights, scrolling, or full-motion video. It is logical to ask *what is the statistical relationship between digital billboards and traffic safety*? Are accidents more, less, or equally likely to occur near digital billboards compared to conventional billboards?

1.1 Purpose.

The purpose of this study is to examine the relationship between certain digital billboards and traffic safety. For this study, a study area was identified, data was collected, and an analysis was made of the area's digital billboards, traffic, and accidents. Specifically, this study analyzes the traffic and accident data near seven existing, digital billboards on the Interstate routes in Cuyahoga County, Ohio. These seven billboards are located along four major, Interstate Routes (I-77, I-90, I-271, and I-480), and were converted in July 2005 to digital billboards from conventional billboards.

1.2 Study Region.

Cuyahoga County was used as the region for this area, because the county has multiple digital billboards in service for more than two years in the same market area (5% of the Interstate billboards in Cuyahoga County are digital), and the Interstate routes adjacent to these billboards are heavily traveled (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 Cleveland City, and is part of the Greater Cleveland metropolitan area. According to the U.S. Census Bureau, the county has a total area of 1,246 square miles with a land area of 458.3 square miles; 36.8% of the total area is land, and the remainder of the county is mostly Lake Erie. 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. Cuyahoga County has three commercial airports.

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.

Section 2 of this study is a detailed discussion of the seven, digital billboards in Cuyahoga County. Section 3 includes a discussion of the routes and accidents in the county. Section 4 discusses the methodology and analyses of this study. Section 5 summarizes the conclusions.

1.3 Overview of Methods and Analysis.

The methods of this study incorporate a unique union of disciplines: engineering, traffic safety analysis, and applied statistics.

First, the project methodology was formulated. This included a review of research methods, digital-billboard characteristics, and the study of regional and local details for potential study areas.

Second, data was collected for the study region. This included the review, acquisition, and compilation of traffic flow and accident data, transportation geometry, aerial and oblique imagery, available sign design, specifications and construction documentation, content-history information, *inter alia*. This included on-site confirmation of each digital billboard during morning, day, and night conditions, for observation of traffic flow, location verification, site characteristics, etc.

Third, an analysis of the data was conducted. This analysis of the study data included two parts: a temporal analysis and a spatial analysis. The first part, a temporal analysis, examines the incidence of traffic accidents at the converted digital billboards and for an equal period of time both before and after the conversion of the billboards. Metrics analyzed included the traffic volume, the accident rates (APV) values and the maximum number of accidents in any given month. Each part of the analyses accounts for various situations studying the results, with and without known statistical biases, such as, bias due to interchanges, and bias from known specific, accident causes (for example, a deer-hit accident as recorded in the police reports). The second part, a spatial analysis, establishes statistical correlation coefficients between advertising signs and accidents along the Interstate routes in Cuyahoga County. The results were analyzed for a variety of scenarios relating accident density to sign density (the number of signs), to Viewer Reaction Distance (the distance from a billboard that the driver is potentially within the "influence" of a billboard), and to sign proximity (the distance from the accident is from the nearest billboard).

2.0 Digital Billboards

Digital billboards display static messages that resemble conventional painted/printed billboards when viewed, and include no video animation, no flashing lights, and no scrolling messages. The digital billboard is very much like its conventional-print counterpart, with a convenient changeover to the next message.

2.1 Locations

This study focuses on the seven, digital billboards in Cuyahoga County, Ohio, that advertise in the Cleveland Metropolitan market. These digital billboards are owned by *Clear Channel*, were converted from existing conventional billboards, and are located along major Interstate routes (I-77, I-90, I-271, and I-480). The digital billboards replaced existing conventional billboards that used printed vinyl stretched across their display faces. The digital-billboard locations are shown in Figure 2-1, and are listed with location information in Table 2-1.

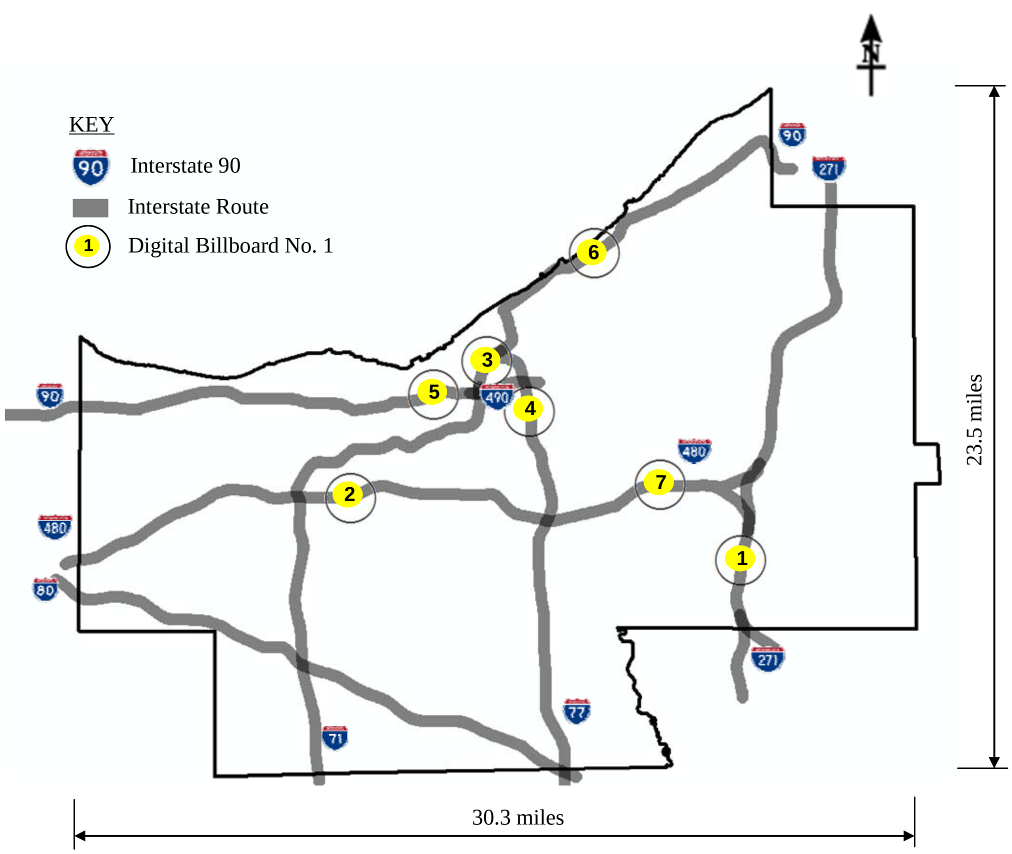


Figure 2-1. Location of Digital Billboards in Cuyahoga County, Ohio

BILLBOARD No.	ROUTE	REFERENCE	DIGITAL FACE	APPROXIMATE STATE MILEMARKER	LATITUDE LONGITUDE
1	INTERSTATE 271	**West side of I-271** **125 feet South of Solon Road** (Clear Channel Location Number 215)	**North**	**24.28**	**81°30'46.784"W** **41°23‘05.471"N**
2	INTERSTATE 480	**South side of I-480** **2 miles East of I-71** (Clear Channel Location Number 421)	**East**	**12.59**	**81°46'59.516"W** **41°25'11.988"N**
3	INTERSTATE 90	**South side of Innerbelt Freeway** **100 feet East of West 3rd Street** (Clear Channel Location Number 456)	**South**	**171.78**	**81°41'15.405"W** **41°29'24.147"N**
4	INTERSTATE 77	**West side of I-77** **0.3 miles South of Pershing Avenue** (Clear Channel Location Number 461)	**North**	**160.33**	**81°39'30.54"W** **41°27'49.34"N**
5	INTERSTATE 90	**South side of I-90** **70 feet East of West 55th Street** (Clear Channel Location Number 468)	**West**	**168.91**	**81°43'26.526"W** **41°28'23.621"N**
6	INTERSTATE 90	**South side of I-90** **0.5 miles West of Eddy Street** (Clear Channel Location Number 489)	**East**	**178.07**	**81°36'43.407"W** **41°32'47.13"N**
7	INTERSTATE 480	**North side of I-480** **0.5 miles East of Broadway Avenue** (Clear Channel Location Number 493)	**East**	**24.92**	**81°34‘05.964"W** **41°25'30.594"N**

Table 2-1. Digital Billboards Location Data along Interstate in Cuyahoga County, Ohio

In addition to the digital billboards, conventional billboard locations along the Interstate routes were noted, geocoded, and confirmed by aerial imagery and on-site observation. Figure 2-2 shows the locations of the 131 billboards in Cuyahoga County. Most of the conventional billboards are double faced, have faces that measure 14-feet high and 48-feet wide, are freestanding structures, and have a parallel-face or Vee configuration. A few billboards are irregularly faced or stacked.

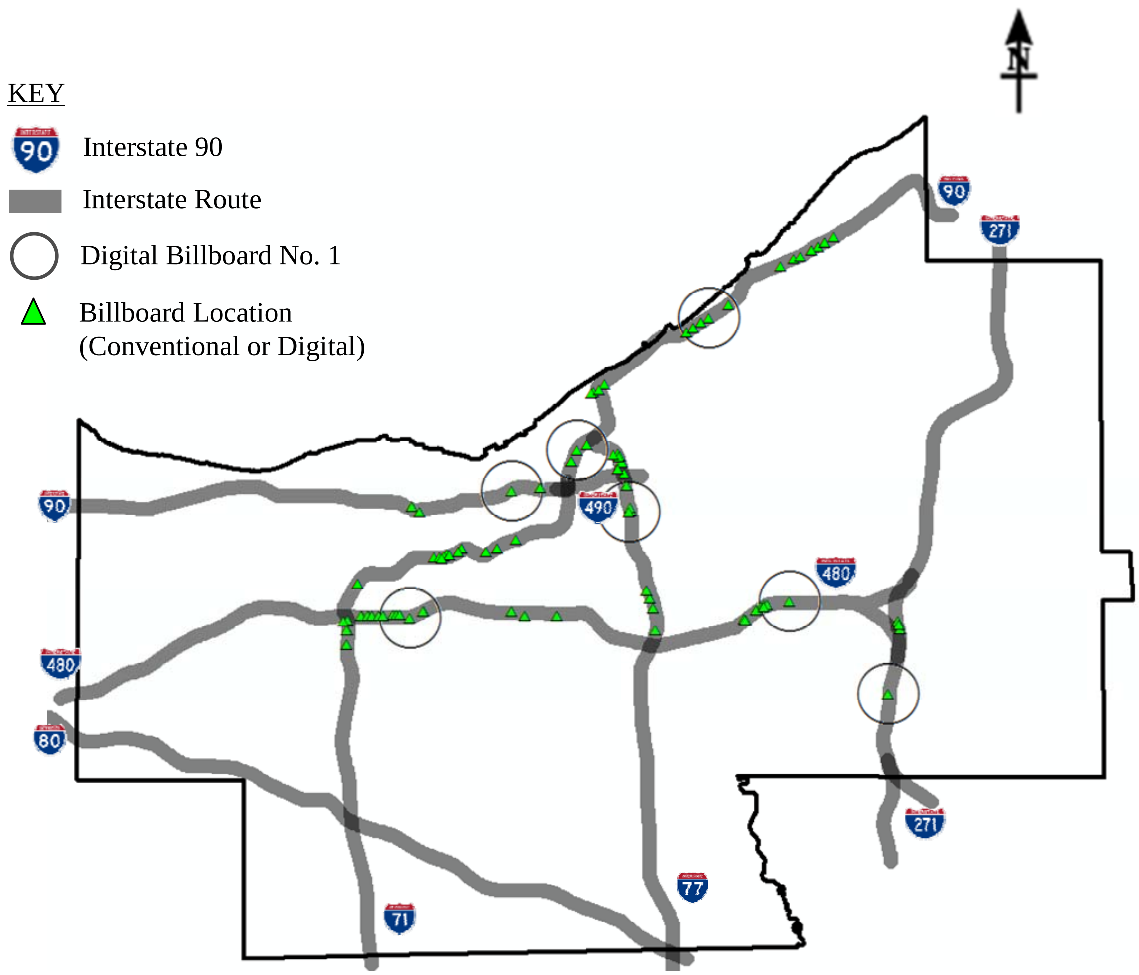


Figure 2-2. Location of Conventional and Digital Billboards in Cuyahoga County, Ohio

Interstate Route 71 has 26 conventional billboards; none are digital. Interstate Route 77 has 22 conventional billboards; one is digital. Interstate Route 90 (including the Innerbelt Freeway, Route 456) has 36 conventional billboards; three are digital. Interstate Route 271 has eight conventional billboards; one is digital. Interstate Route 480 has 39 conventional billboards; two are digital. The Interstate routes have many other types of visible signage, to include directional, informational, regulatory, accessory, *inter alia*.

2.2 Billboard Characteristics.

Each of the seven digital billboards is a freestanding, single-pole, double-faced structure with one digital face that measure 14-feet high and 48-feet wide (a face area of 672 square feet).

Table 2-2 summarizes the digital-billboard, face characteristics. The numbering of the digital billboards in this study are arbitrary. Table 2-3 summarizes the digital-billboard geometry characteristics, including overall height, height above grade level (HAGL), distance to nearest advertising and opposite lanes. Sign-location photos, aerials, and references for each billboard number are included within this section.

BILLBOARD No.	ROUTE	SIGN CONFIGURATION	DIGITAL FACE ADVERTISES TO DIRECTION	FACE SIZE (FEET)	READ
1	INTERSTATE 271	Free Standing, Vee Flag Double Faced	Southbound	14x48	Right Hand Reader
2	INTERSTATE 480	Free Standing, Parallel Faced Double Faced	Westbound	14x48	Cross Reader
3	INTERSTATE 90	Free Standing, Parallel Faced Double Faced	Eastbound	14x48	Right Hand Reader
4	INTERSTATE 77	Free Standing, Parallel Faced Double Faced	Southbound	14x48	Right Hand Reader
5	INTERSTATE 90	Free Standing, Vee Flag Double Faced	Eastbound	14x48	Right Hand Reader
6	INTERSTATE 90	Free Standing, Vee Flag Double Faced	Westbound	14x48	Cross Reader
7	INTERSTATE 480	Free Standing, Vee Flag Double Faced	Westbound	14x48	Right Hand Reader

Table 2-2. Digital Characteristics of Digital Billboards along Interstate in Cuyahoga County, Ohio

Billboard No. 1 advertises to traffic on the southbound lanes of Interstate route 271 south of the Solon Road overpass. Billboard No. 1 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 2-3 shows the location in an oblique aerial taken 10Apr06. Figure 2-4 is a photo of the digital face taken on 1May07.

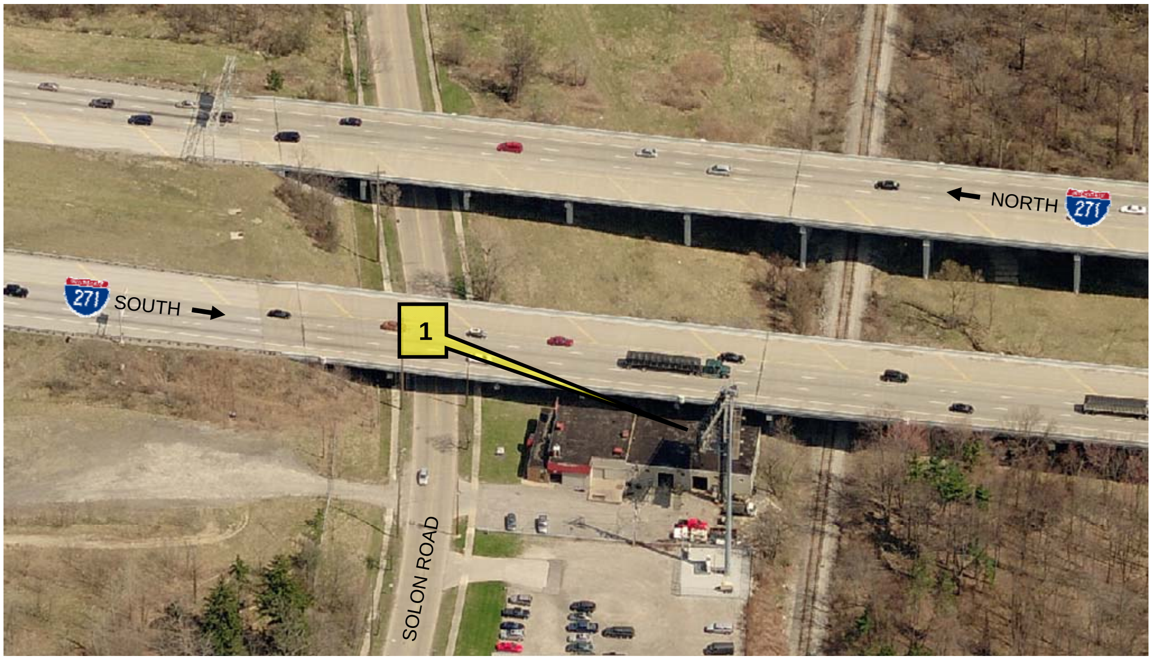
Billboard No.	Interstate Route No.	Number of Lanes	Interstate Width Breakdowns (feet)	Overall Height	Height Above Grade Line (HAGL)	Distance from Upright to Nearest Lane	Distance from Upright to Nearest Lane in Opposite Direction
				(All dimensions in feet ±)			
1	I-271	6 total 3 NB 3 SB	10-36-4 181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

(Note: Interstate width breakdowns include widths in feet of outer shoulder, lanes, inner shoulder, median and then opposite direction inner shoulder, lanes and outter shoulder.)

Table 2-3. Digital Billboard Geometry Characteristics in Cuyahoga County, Ohio

Billboard No. 2 advertises to traffic on the westbound lanes of Interstate route 480 about two miles east of I-271. Billboard No. 2 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 2-5 shows the location in an oblique aerial taken 9Apr06. Figure 2-6 shows a photo of the digital face taken on 1May07.

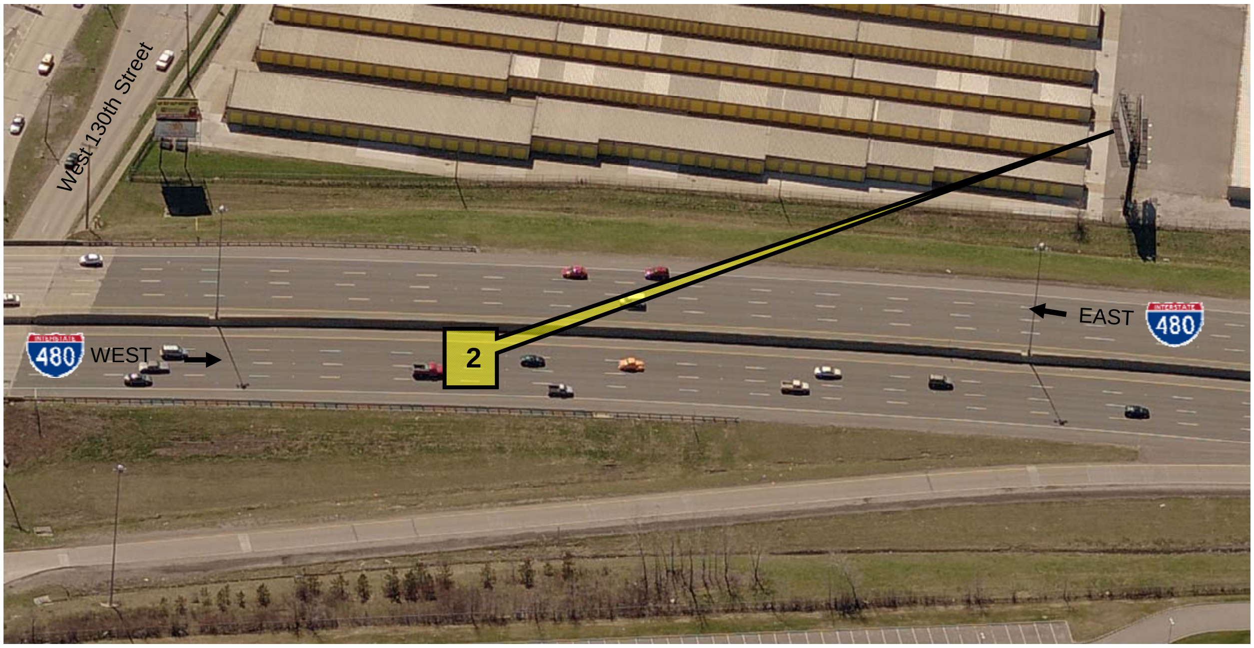
Billboard No. 3 advertises to traffic on the eastbound lanes of Interstate route 90, east of West 3rd Street. Billboard No. 3 is a right-hand reader and has a parallel-faced configuration with an overall height of 180 feet ± and an offset distance of 55.4 feet to the nearest lane to which it advertises. Figure 2-7 shows the location on an oblique aerial taken 11Apr06. Figure 2-8 shows a photo of the digital face taken on 1May07.



1 Digital Billboard 1 from Direction of Advertising Lanes

Figure 2-3. Oblique Aerial of Digital Billboard No. 1 on I- 271

Figure 2-4. Photo of Digital Billboard No. 1 on I-271



2 **Digital Billboard 2 from Direction of Advertising Lanes**

Figure 2-5. Oblique Aerial of Digital Billboard No. 2 on I-480

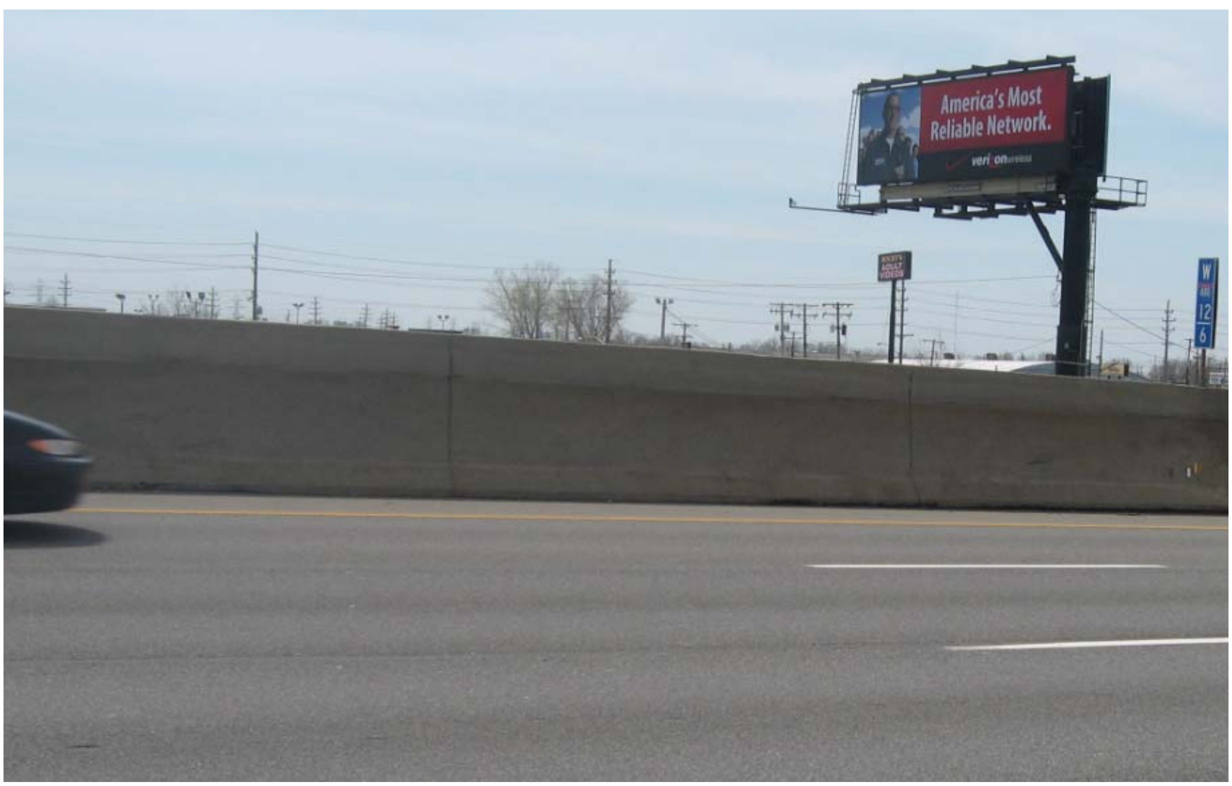
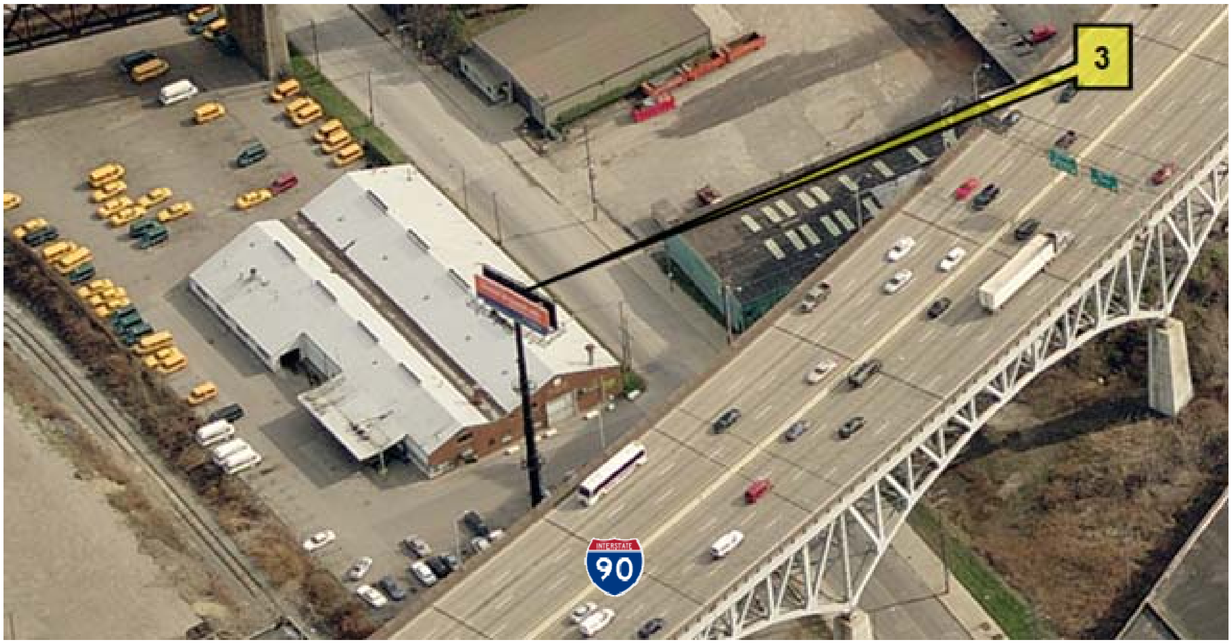


Figure 2-6. Photo of Digital Billboard No. 2 Display on I-480

Billboard No.	Interstate Route	Visible Range from Route including Viewer Reaction Zone	
		miles	feet
1	I-271	0.69	3,622
2	I-480	0.33	1,751
3	I-90	0.52	2,753
4	I-77	0.28	1,489
5	I-90	2.15	11,331
6	I-90	0.45	2,387
7	I-480	0.83	4,387

Table 2-3. Visible Range of Billboards along Interstate Routes

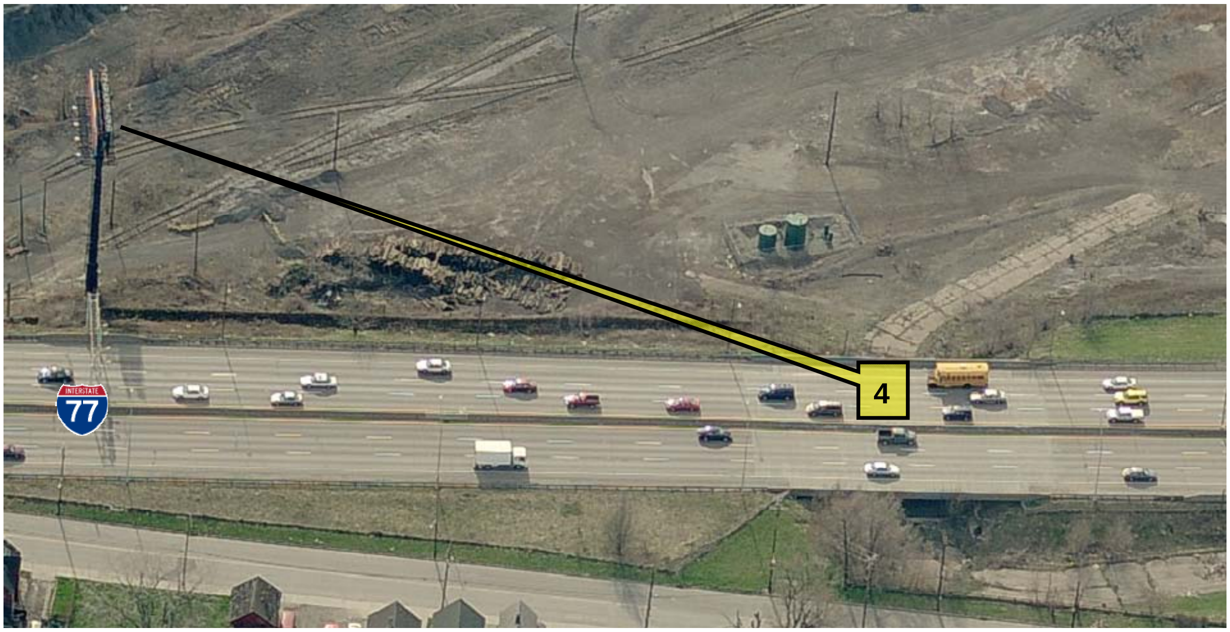
Billboard No. 4 advertises to the traffic on southbound lanes of Interstate route 77, south of Pershing Avenue. Billboard No. 4 is a right-hand reader and has a parallel-faced configuration with an overall height of 83 feet ± and an offset distance of 80.4 feet to the nearest lane to which it advertises. Figure 2-9 shows the location on an oblique aerial taken 11Apr06. Figure 2-10 shows a photo of the digital face taken on 1May07.



3 **Digital Billboard 2 from Direction of Advertising Lanes**

Figure 2-7. Oblique Aerial of Digital Billboard No. 3 on I-90

Figure 2-8. Photo of Digital Billboard No. 3 on I-90



4 **Digital Billboard 4 from Direction of Advertising Lanes**

Figure 2-9. Oblique Aerial of Digital Billboard No. 4 on I-77

Figure 2-10. Photo of Digital Billboard No. 4 on I-77

Billboard No. 5 advertises to traffic on the eastbound lanes of Interstate route 90, east of West 55th Street. Billboard No. 5 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 2-11 shows the location on an oblique aerial taken 13Apr06. Figure 2-12 shows a photo of the digital face taken on 1May07.

Billboard No. 6 advertises to traffic on the westbound lanes of Interstate route 90, west of Eddy Street. Billboard No. 6 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 2-13 shows the location on an oblique aerial taken 13Apr06. Figure 2-14 shows a photo of the digital face taken on 1May07.

Billboard No. 7 advertises to traffic on the westbound lanes of Interstate route 480, east of Broadway Avenue (Route 14). Billboard No. 7 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 2-15 shows the location on an oblique aerial taken 11Apr06. Figure 2-16 shows a photo of the digital face taken on 1May07.

The location of the billboards was confirmed by on-site investigation and GPS recording. The following were also used to analyze the location and characteristics of the billboards: Ohio Department of Transportation route straight-line diagrams (SLD), high-resolution orthographic and oblique aerial photographs, GIS information, and other on-site data.

5 Digital Billboard 5 from Direction of Advertising Lanes

Figure 2-11. Oblique Aerial of Digital Billboard No. 5 on I-90

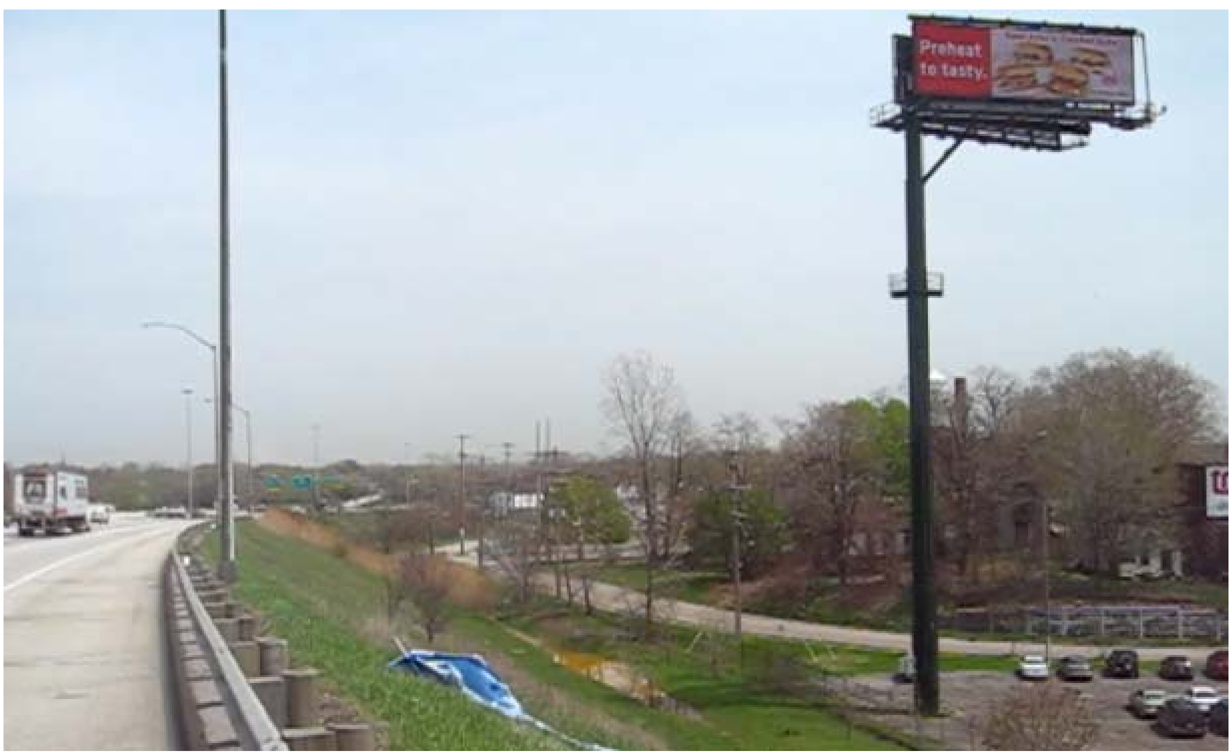


Figure 2-12. Photo of Digital Billboard No. 5 on I-90

6 Digital Billboard 6 from Direction of Advertising Lanes

Figure 2-13. Oblique Aerial of Digital Billboard No. 6 on I-90

Figure 2-14. Photo of Digital Billboard No. 6 on I-90

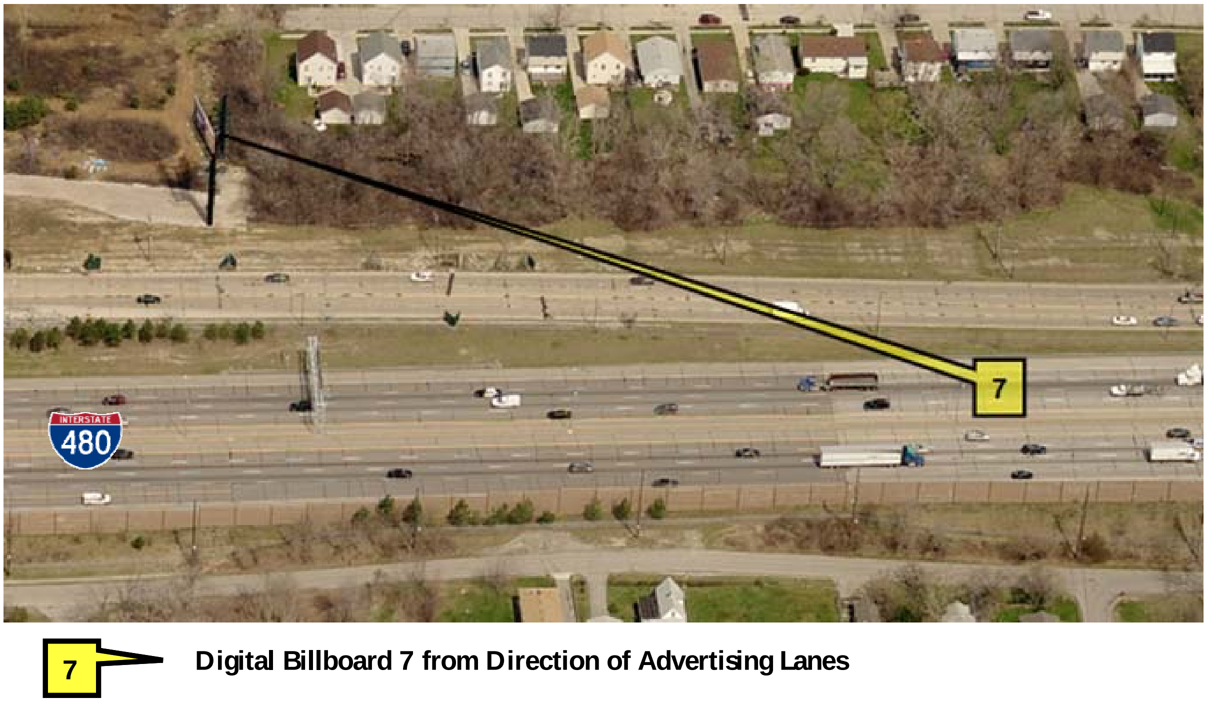


Figure 2-15. Oblique Aerial of Digital Billboard No. 7 on I-480

Figure 2-16. Photo of Digital Billboard No. 7 Display on I-480

2.3 Digital Billboard Technology.

The digital billboards were designed and manufactured by *Daktronics*, are the ProStar® model, and use red, green, and blue light-emitting-diode (LED) technology to present text and graphics. The digital billboards feature a 20 mm pitch with a 208 by 720 matrix, and were designed to 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 of the digital billboards to measure ambient light. Light levels are continuously monitored and communicated back to the control system. Temperature sensing and other diagnostic capabilities are also included within the display systems. These seven digital billboards have no animation, flashing lights, scrolling, or full-motion video.

2.4 Copy Information.

The static display on each of these digital billboards has a "dwell time" of eight seconds. The images which are displayed, are remotely created and downloaded to each digital billboard remotely through high-speed internet connections. The control system is comprised of a central V-Net(R) controller located at the *Daktronics* headquarters in Brookings, South Dakota, with remote controllers at each display. The V-Net(R) control system is used to create, upload, display, schedule, and log the content shown on the seven digital billboards. The V-Net(R) controller offers advanced scheduling and logging features.

3.0 Routes and Accidents

The United States Interstate system is part of The Dwight D. Eisenhower National System of Interstate and Defense Highways. Even though Interstate routes have substantial federal funding and comply with federal standards, they are owned, built, and operated by their state. Traditionally, east-west highways were assigned even numbers (increasing from south to north), and north-south highways were assigned odd numbers (increasing from east to west). Traffic signs and lane markings on Interstates are specified and detailed in the Manual on Uniform Traffic Control Devices (MUTCD). Ohio has a highly developed network of Interstate highways; many major west-east highway corridors go through Ohio. In Ohio, exit numbers correspond to the mile markers on the Interstates. In Ohio the statutory speed limit, unless otherwise posted, is 65 mph; trucks have a statutory speed limit of 65 mph on the Ohio Turnpike and 55 mph on all other freeways. Figure 3-1 shows the Interstate routes and county boundaries in Ohio; the routes are coded by the amount of daily traffic they carry.

3.1 Interstate Routes in Cuyahoga County.

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). The length of all Interstate routes within Cuyahoga County total 183.22 miles. Figure 3-2 shows the Interstate routes in Cuyahoga County; the routes are color coded by annual average daily traffic that they carry.

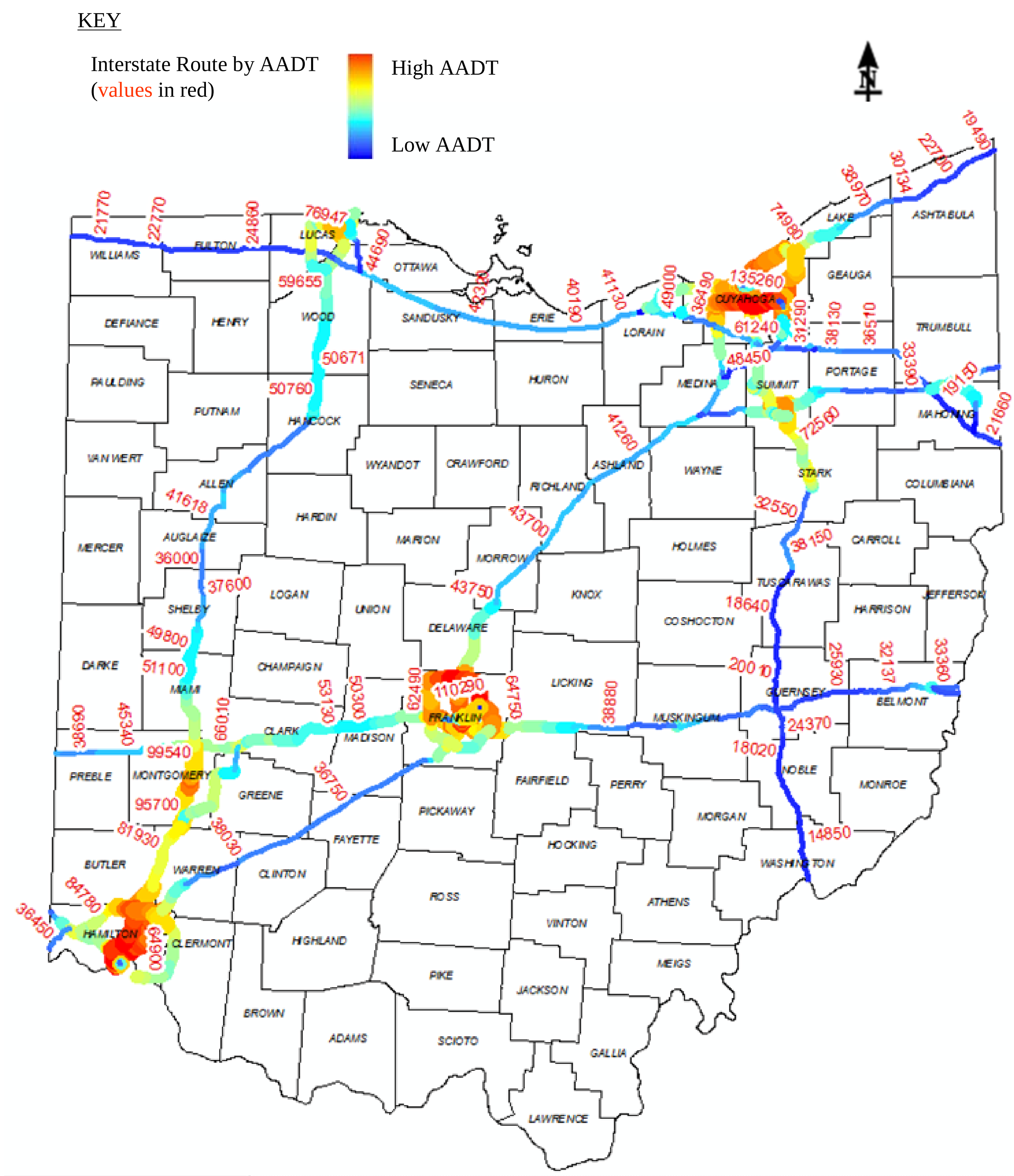


Figure 3-2. Counties, Interstate Routes and Traffic
Annual Average Daily Traffic (AADT) in Ohio

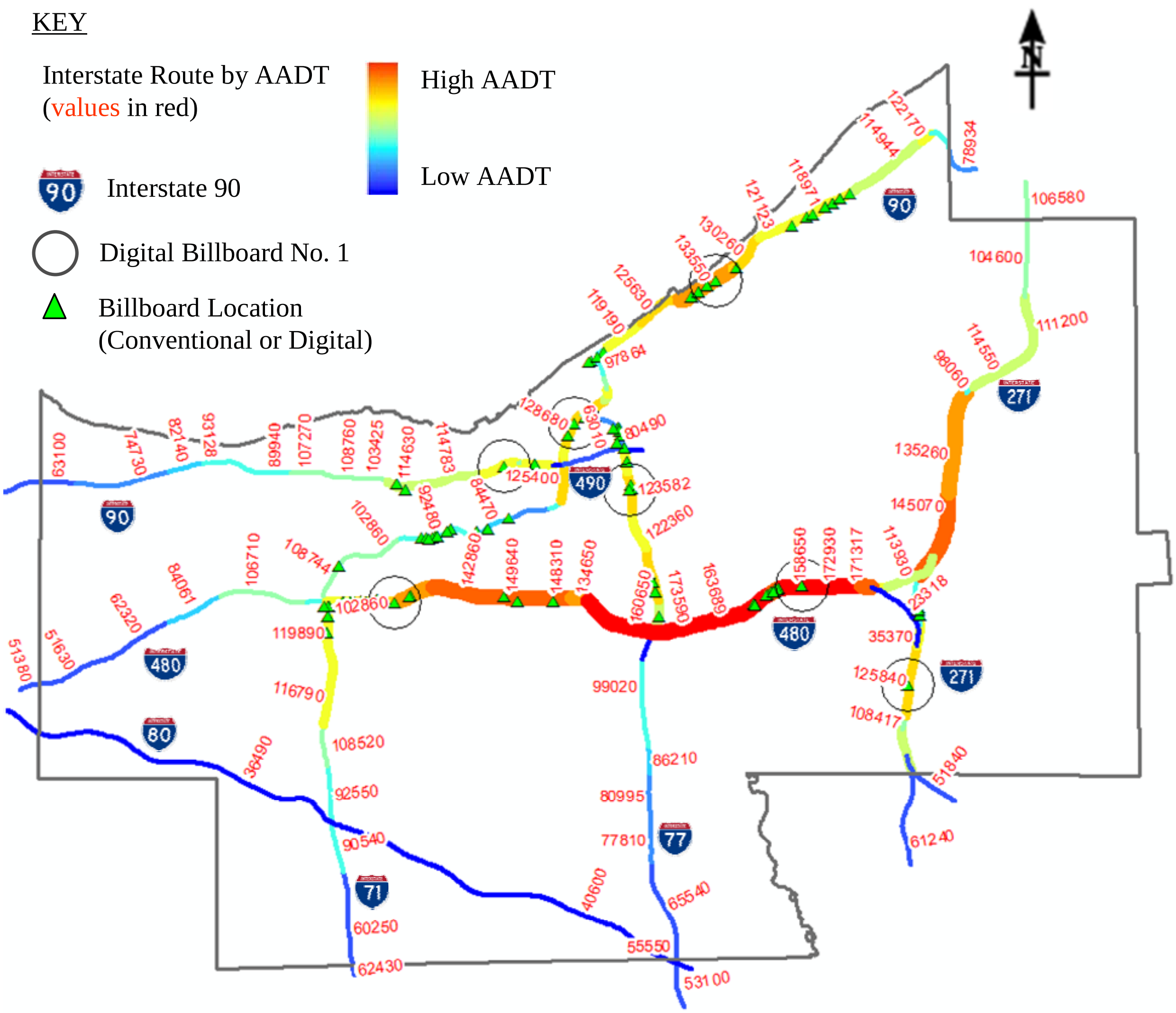


Figure 3-2. Interstate Routes with Traffic Annual Average Daily Traffic (AADT) within Cuyahoga County

Interstate 71 begins just southwest of the downtown of Cleveland and is the major route from Cleveland to its airport. I-71 runs through the southwestern suburbs and eventually connects Cleveland and Columbus. I-71 has a length of 19.12 miles in Cuyahoga County.

Interstate 77 begins in downtown Cleveland and extends due south through the southern suburbs. I-77 has the lowest traffic count of the three primary Interstates routes, and connects Cleveland and Akron. I-77 has a length of 15.97 miles in Cuyahoga County. I-77 largely supplants the old U.S. Highway 21 between Cleveland, Ohio, and Columbia, South Carolina, as one of the best north-south corridors through the middle Appalachians. The northern terminus of I-77 in Cleveland is at its junction with I-90. I-77 is known as the "Vietnam Veterans Memorial Highway".

Interstate 90 is the longest Interstate route in the United States. In Cleveland, I-90 connects the two sides of Cleveland, serves as the Innerbelt at the confluence of the northern termini of I-71 and I-77, and is called the Lakeland Freeway. In Cuyahoga County, I-90 has a length of 30.20 miles. Running due east and west through the west suburbs, I-90 runs northeast at its junction with I-71 and I-490, and is known as the Innerbelt Freeway through the downtown. At its junction with the Shoreway, I-90 makes a 90-degree turn, then runs northeastward. Even though many large directional signs and flashing lights alert motorists to this turn, the turn has a large number of accidents.

Interstate 271 is a major spur highway in the suburbs of Cleveland and Akron, Ohio, and is officially designated the Cleveland Outerbelt East, but is rarely referred to by that name. I-271 extends from its junction with I-71 in Weymouth, Ohio, to I-90 in Willoughby Hills, Ohio, and intersects I-480 (and running jointly with it for a short length). I-271 has a length of 30.00 miles in Cuyahoga County. The roadway width varies, but is mostly four to six lanes, south of I-480, and eight to twelve lanes wide north of I-480, where I-271 has express and local lanes. The I-271 local and express lanes begin at the complex I-480 and U.S. 422 interchange, and continues northward slightly beyond the terminus of I-271. The northbound express lanes allow access to all exits (excluding Chagrin Boulevard, Harvard Road, and OH 175). The southbound express lanes bypass all exits and have only one combined exit for Chagrin Boulevard, Harvard Road, Richmond Road and the U.S. 422 (west) interchange.

Interstate 480, which enters Cleveland at a few points, is a busy, loop highway that connects the Ohio Turnpike (I-80) with suburban Cleveland, and is officially designated the Outerbelt South Freeway, but is rarely referred to by that name. The roadway width varies from four to ten lanes. I-480 has a length of 30.00 miles in Cuyahoga County. I-480 provides access to the Cleveland

Hopkins International Airport via OH 237. I-480 runs concurrent with I-271 for several miles. I-271 and I-480 are the only two auxiliary (three-digit) interstates in the U.S. to be concurrent with each other. They run concurrent near Bedford Heights in Cuyahoga County. The most notable portion of I-480 is the Valley View Bridge which is 212-feet high and spans 4,150 feet across the Cuyahoga River valley.

Interstate 490 is a 2.43-mile highway in Cleveland. The western terminus is its junction with I-90 and I-71 on Cleveland's west side. After spanning the Cuyahoga River, the eastern terminus is its junction with East 55th Street, just east of I-77. I-490’s entire length of 2.43 miles is in Cuyahoga County.

3.2 Interstate Route Characteristics near Digital Billboards.

The location of the digital billboards and the Interstate routes to which they advertise are shown in Figure 2-1. The geometry, characteristics, and lengths of the sections of Interstates routes near the digital billboards are summarized in Tables 3-1 and 3-2.

Billboard No.	Interstate Route No.	Number of Lanes	Interstate Breakdown Widths (Feet)	Surface Type and Width	Base Type and Width	Median Width (Feet)	Recent Project Year	ODOT Project No.	Previous Project Years
1	I-271	6 total 3 NB 3 SB	10-36-4 181 4-36-10	G36△G36'	P36'△P36'	181	1993	687	1983 1962
2	I-480	8 total 4 WB 4 EB	10-48-11 4 11-48-10	G48'△G48'	L48'△L48'	4	1997	621	1983
3	I-90	8 total 4 NB 4 SB	0-52-6 4 6-52-0	G52'△G52'	P52'△P52'	4	1972	546	-
4	I-77	6 total 3 NB 3 SB	10-36-4 2 4-36-10	G36'△G36'	N12',P24'△ P24',N12'	2	1993	117	1990 1972
5	I-90	10 total 5 WB 5 EB	10-60-3 70 3-60-10	G60'△G60'	P60'△P60'	70	1999	180	1975
6	I-90	8 total 4 WB 4 EB	10-48-3 3 3-48-10	G48'△G48'	P48'△P48'	3	2002	21	1993 1975
7	I-480	8 total 4 WB 4 EB	10-48-6 26 6-48-10	G48'△G48'	P48'△P48'	26	1999	525	1987 1971

(Note: Interstate width breakdowns include widths in feet of outer shoulder, lanes, inner shoulder, median and then opposite direction inner shoulder, lanes and outter shoulder. Surface types are denoted as G as bituminous concrete surface, P as reinforced concrete base and L as plant mix bituminous concrete or penetration macadam base.)

Table 3-1. Characteristics of Interstate Routes near Digital Billboards

Digital Billboard No. 1 advertises to a section of the southbound lanes of I-271 and is near the common underpass of Solon Road, the N&W Railroad, and Metropolitan Park Road. This billboard is near state log milemarker 24.28 (county log 2.46). The adjacent, Interstate-route has three lanes (36 feet wide) in each direction, is separated by a 181-foot-wide median, and has a bituminous concrete surface on a reinforced-concrete base. ODOT reports resurfacing of this section in 1993 as part of Project No. 687, with previous work in 1983 and 1962.

		Length (miles)		
Billboard No.	Interstate Route	State Wide	in Cuyahoga County	Section at Digital Billboard
1	I-271	46.06	16.65	0.89
2	I-480	42.97	30.00	0.68
3	I-90	244.75	30.20	0.95
4	I-77	162.00	15.97	1.10
5	I-90	244.75	30.20	0.89
6	I-90	244.75	30.20	2.66
7	I-480	42.77	30.00	0.69

(Note: Section lengths are portions of Interstate with common features as recorded by the Ohio DOT)

Table 3-2. Lengths of Interstate Routes near Digital Billboards

Digital Billboard No. 2 advertises to a section of the westbound lanes of I-480 (the Outer South Freeway). This billboard is east of Ramp BR-2 connecting SR 17, and east of the underpasses for West 130th Street and the Conrail Railroad line. This billboard is near state log milemarker 12.59 (county log 10.42). The adjacent, Interstate-route section has four lanes (48 feet wide) in each direction, is separated on a 4-foot-wide median, and has a bituminous concrete surface on a bituminous-concrete base. ODOT reports resurfacing of this section in 1997 as part of Project No. 621, with previous work in 1983.

Digital Billboard No. 3 advertises to a section of the eastbound lanes I-90 (the elevated bridge portion of the Innerbelt Freeway). This billboard is east of the Norfolk Southern Railroad (12 tracks), the Cuyahoga River, and West 3rd Street, and is west of Canal Street. This billboard is located near state log milemarker 171.78 (county log 15.86). The adjacent, Interstate-route section has four lanes (52 feet wide) in each direction, is separated by a four-foot-wide median, and has a bituminous concrete surface on a reinforced-concrete base. ODOT reports resurfacing of this section in 1972 as part of Project No. 546.

Digital Billboard No. 4 advertises to a section of the southbound lanes of I-77 (the Willow Freeway). This section is south of the Pershing Avenue overpass and the Ruffin Street underpass, and near the W&LE (formerly Norfolk Southern) rail line; this billboard is north of a pedestrian overpass. This billboard is near state log milemarker 160.33 (county log 13.25). The adjacent, Interstate-route section has three lanes (36 feet wide) in each direction, is separated by a two-foot-wide median, and has a bituminous concrete surface on a reinforced-concrete base. ODOT reports resurfacing of this section in 1993 as part of Project No. 117, with previous work in 1990 and 1972.

Digital Billboard No. 5 advertises to a section of the eastbound lanes of I-90 (the Northwest Freeway). This section is east of the West 65th Street overpass and west of the West 53rd Street underpass. This billboard is near state log milemarker 168.91 (county log 12.99). The adjacent, Interstate-route section has five lanes (60 feet wide) in each direction, is separated by a 70-foot-wide median, and has a bituminous concrete surface on a reinforced-concrete base. ODOT reports resurfacing of this section in 1999 as part of Project No. 180, with previous work in 1975.

Digital Billboard No. 6 advertises to a section of the westbound lanes of I-90 (the Lakeland Freeway). This section is east of the East 105th Street underpass, and west of the Eddy Road underpass. This billboard is near state log milemarker 178.07 (county log 22.15). The adjacent, Interstate-route section has four lanes (48 feet wide) in each direction, is separated by a three-foot-wide median, and has a bituminous concrete surface on a reinforced-concrete base. ODOT reports resurfacing of this section in 2002 as part of Project No. 21, with previous work in 1993 and 1975.

Digital Billboard No. 7 advertises to a section of the westbound lanes of I-480 (the Outer South Freeway). This section is east of the Lee Road underpass, and west of the Camden Road overpass; further west are ramps for Greenhurst Road and McCracken Road. This billboard is near state log milemarker 24.92 (county log 22.75). The adjacent, Interstate-route section has four lanes (48 feet wide) in each direction, is separated by a 26-foot-wide median, and has a bituminous concrete surface on a reinforced-concrete base. ODOT reports resurfacing of this section in 1999 as part of Project No. 525, with previous work in 1987 and 1971.

3.3 Traffic-Count Data.

Traffic-count data for Cuyahoga County was obtained from the Ohio Department of Transportation (DOT) and the County Engineer’s Office. Traffic-monitoring data includes vehicle volume, vehicle classification, and weigh-in-motion data. Data was collected using manual, portable (road tube), permanent Automatic Traffic Recorders (ATR), and Intelligent Transportation Systems (ITS) methods. 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).

Billboard No.	Interstate Route	AADT Passenger Vehicles	 Truck Vehicles	 Total Vehicles	kDVMT (thousands DVMT) on Route within State	 on Route within County	 Percentage of County to State
1	I-271	110,750 [88.0%]	15,090 [12.0%]	125,840	2,939	2,278	77.5%
2	I-480	116,800 [90.0%]	13,050 [10.1%]	129,850	3,915	3,469	88.6%
3	I-90	118,090 [91.8%]	10,590 [8.2%]	128,680	6,233	3,518	56.4%
4	I-77	113,037 [91.5%]	10,545 [8.5%]	123,582	6,860	1,542	22.5%
5	I-90	108,200 [91.4%]	10,190 [8.61%]	118,390	6,233	3,518	56.4%
6	I-90	125,670 [94.1%]	7,880 [5.9%]	133,550	6,233	3,518	56.4%
7	I-480	145,320 [91.6%]	13,330 [8.4%]	158,650	3,915	3,469	88.6%

Table 3-3. AADT and DVMT values near Digital Billboards

The annual average daily traffic (AADT) is the total volume of vehicle traffic in both directions of a highway or road for one year divided by 365 days. AADT is a useful measurement of how busy the road is, and is sometimes also called "average annual daily traffic". Short-term traffic counts are adjusted to the Average Daily Traffic (AADT) values by ODOT using seasonal adjustment factors (by functional classification). Daily vehicle miles traveled (DVMT) is a measure of how much traffic flows along a roadway during an average 24-hour period. DVDT is a multiple of the Average Annual Daily Traffic (AADT) and the length of the roadway.

The AADT and DVMT values of the sections of Interstate route adjacent to the digital billboards are summarized in Table 3-3.

3.4 Accident Records and Data

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

Figure 3-3 summarizes the traffic accident data of the past six years in Cuyahoga County, including the Interstate routes I-71, I-77 and I-90, I-271, I-480, and I-490. Figure 3-4 shows the distribution of accidents on Interstate routes by day of week and time of day and illustrates that more accidents occur on weekdays and at rush hour (before and after work).

Figure 3-5 shows the distribution of the age of drivers involved in accidents on Cuyahoga Interstates (upper) and the distribution over time between 2001 and 2007 of accidents. These figures show that the median age of drivers involved in an accident are 23 and that the winter months of 2005 had the most accidents on Interstates.

A statistical anatomy of Cuyahoga County accidents by Interstate are illustrated in Figures 3-6 through 3-12. Figure 3-6 shows the occurrence of accidents by intersection type; the majority of interstates accidents occur along the route, relative to ramps and crossings. Figure 3-7 shows the frequency of accidents by Interstate and light conditions at the time of accident; the majority occurs during dawn and daylight conditions. Figure 3-8 shows the frequency of Interstate accidents by weather condition; the majority occurs during clear conditions. Figure 3-9 shows the frequency of Interstate accidents by the condition of the road; dry road conditions are the predominate category. Figure 3-10 shows accident frequency by road geometry and Figure 3-11 shows accidents by impact type; most accidents occur on straight and level conditions and are predominately rear-end collisions. Figure 3-12 shows the year and month occurrence of accidents by specific Interstate route.

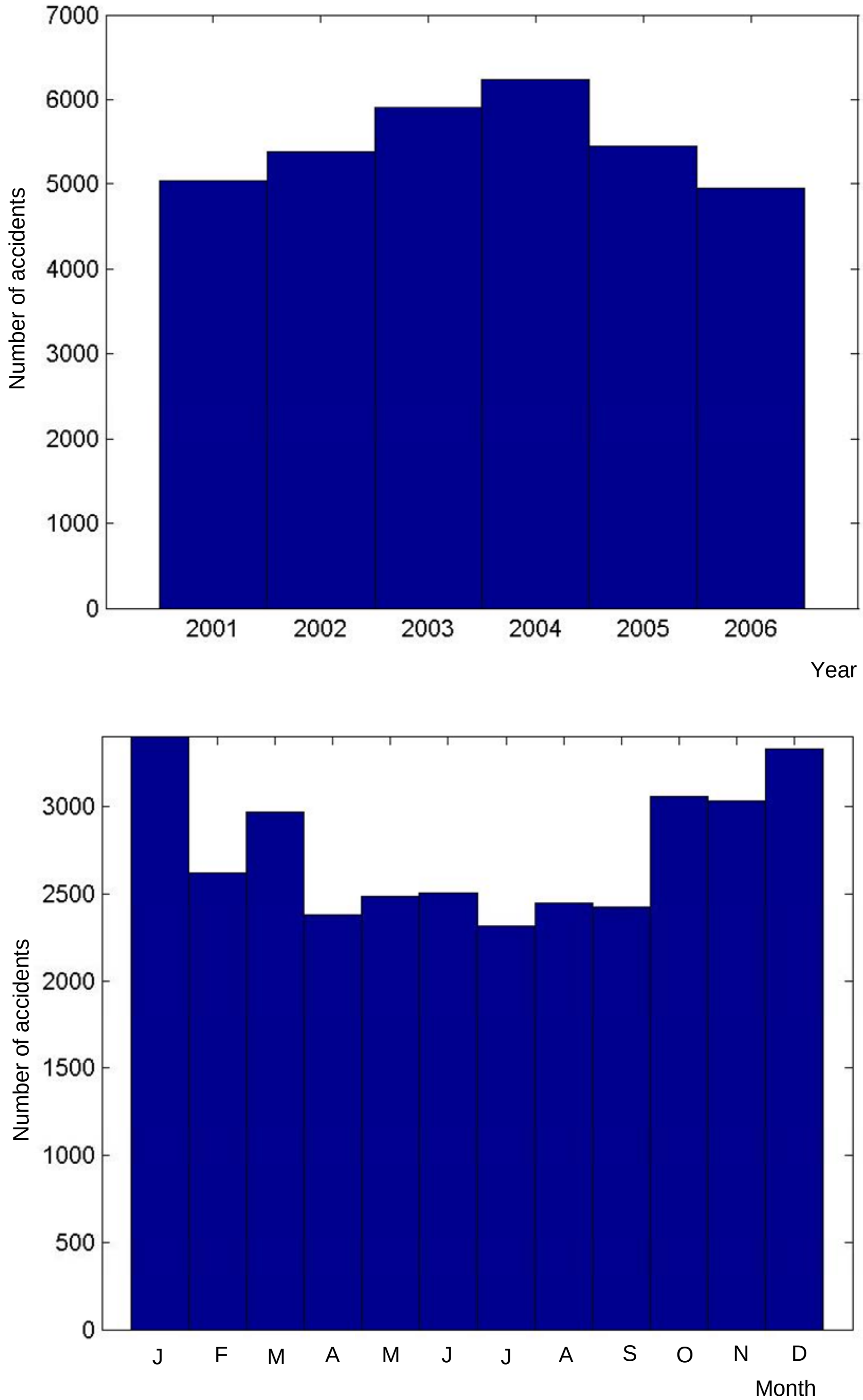
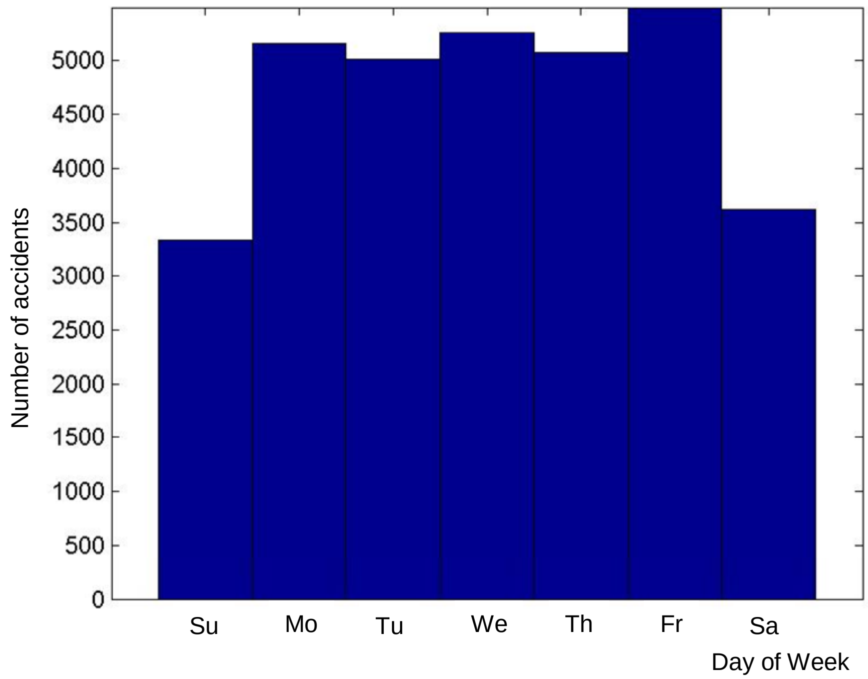


Figure 3-3. Summary Statistics of Interstate Accidents within Cuyahoga County: Total by Year (upper), Total by Months aggregated between 2001 and 2006 (lower)



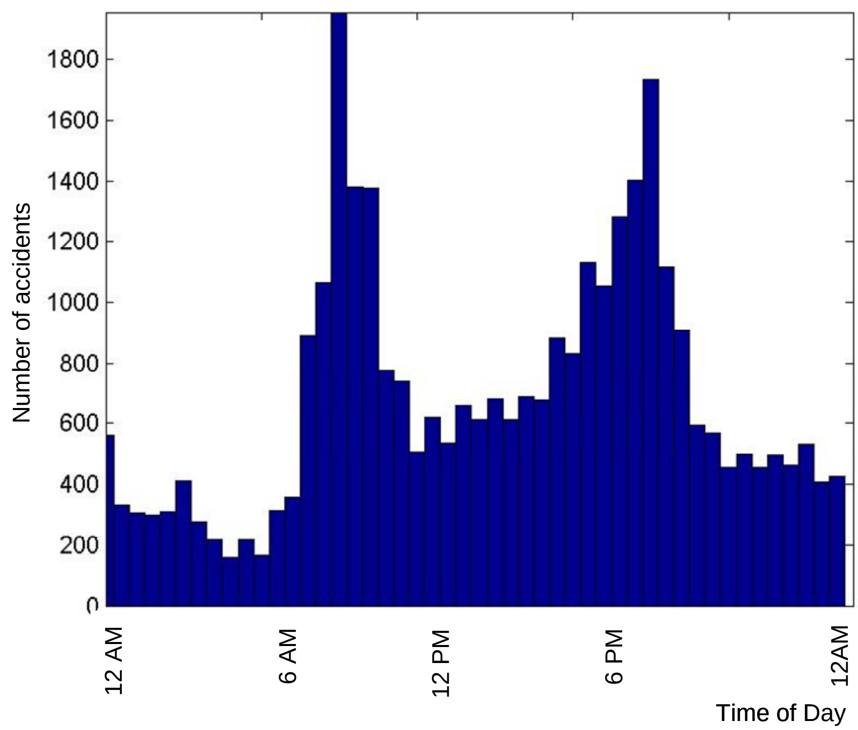


Figure 3-4. Summary Statistics of Interstate Accidents within Cuyahoga County:
Total by Day of Week (upper), Total by Time of Day aggregated between 2001 and 2006 (lower)

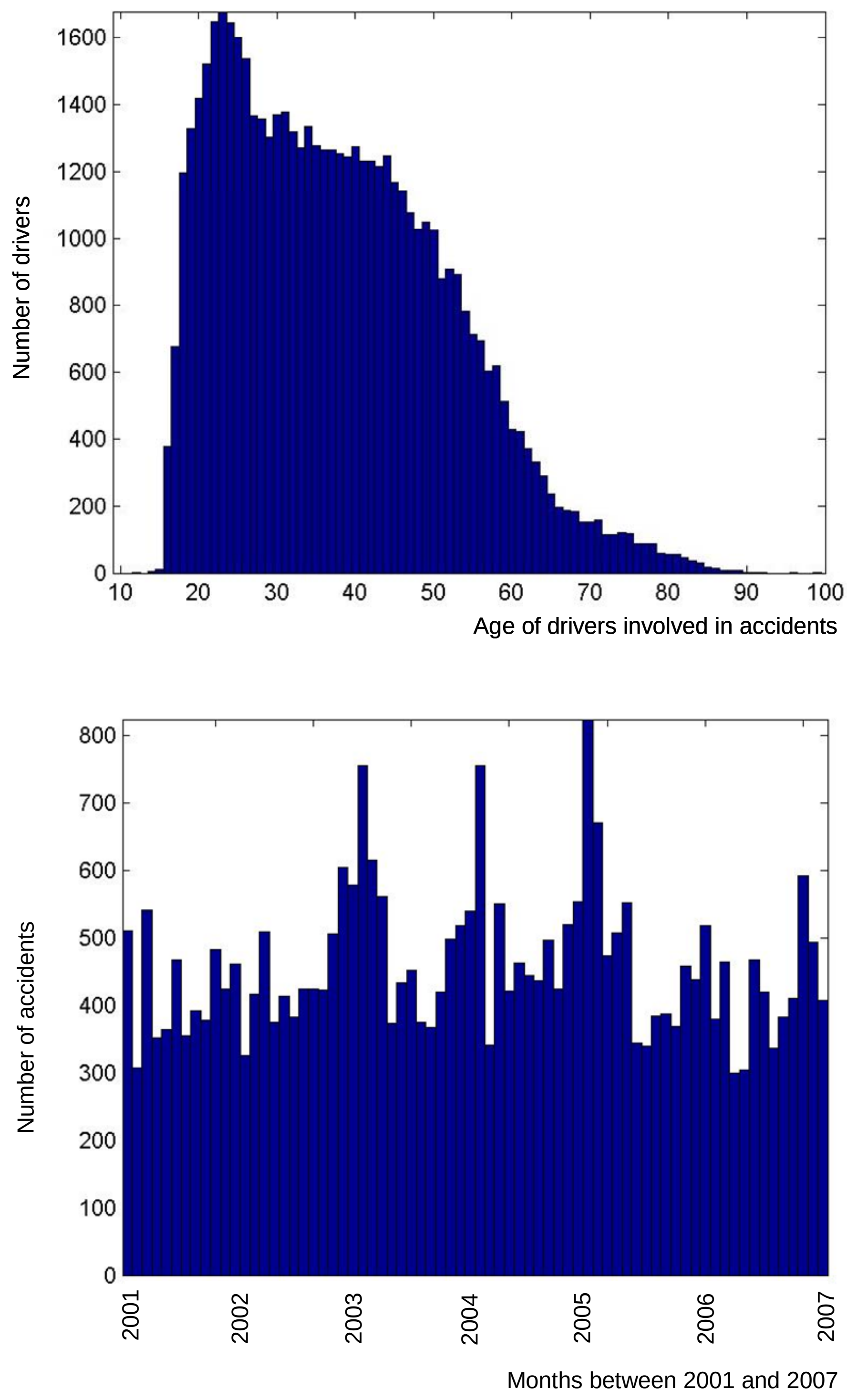


Figure 3-5. Summary Statistics of Interstate Accidents within Cuyahoga County: Total by Age of Drivers involved (upper), Total by Months (lower) each aggregated between 2001 and 2006

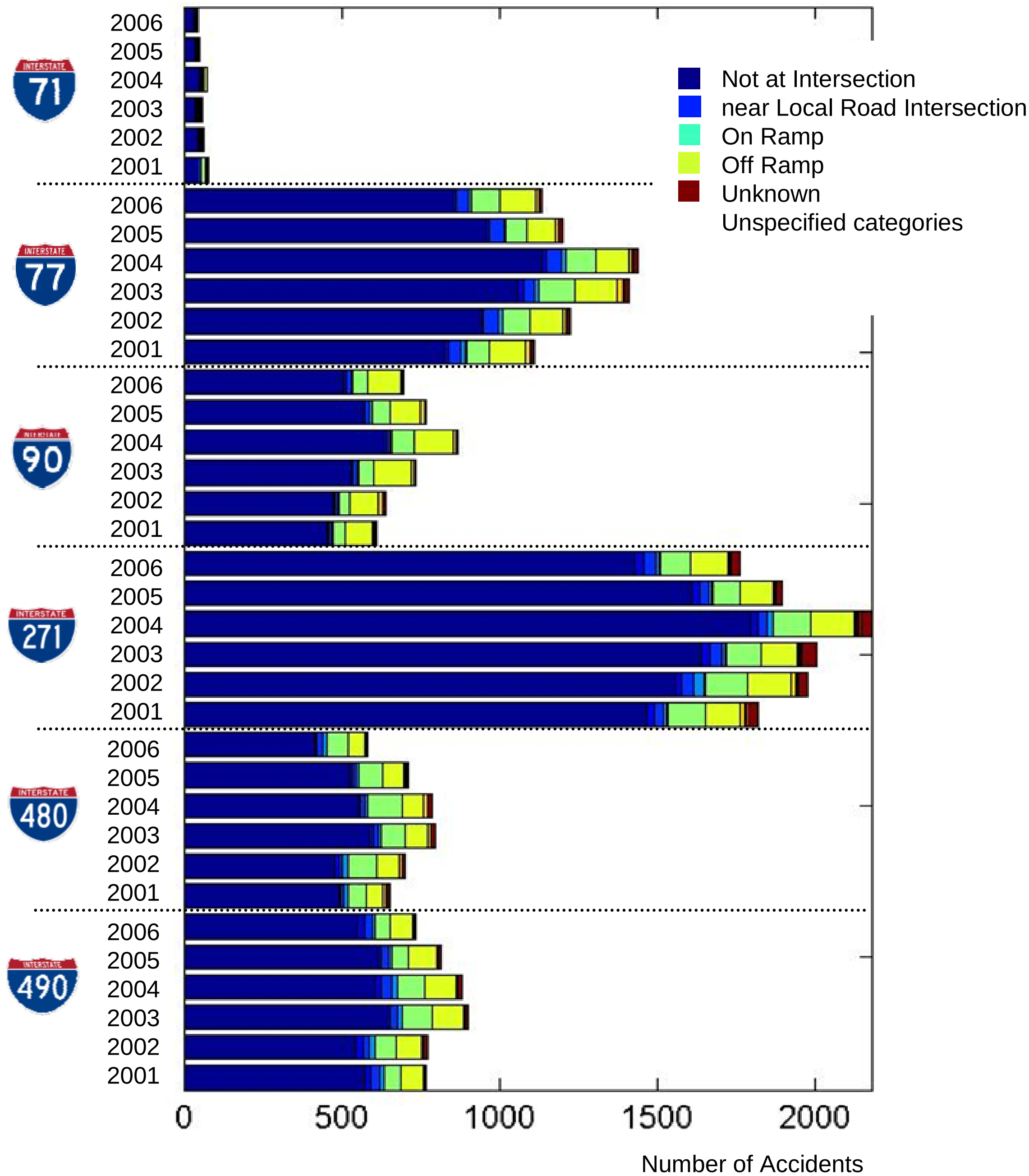


Figure 3-6. Summary Statistics of Accidents by Interstate by Year within Cuyahoga County and Color Stacked by Intersection Type of Accident

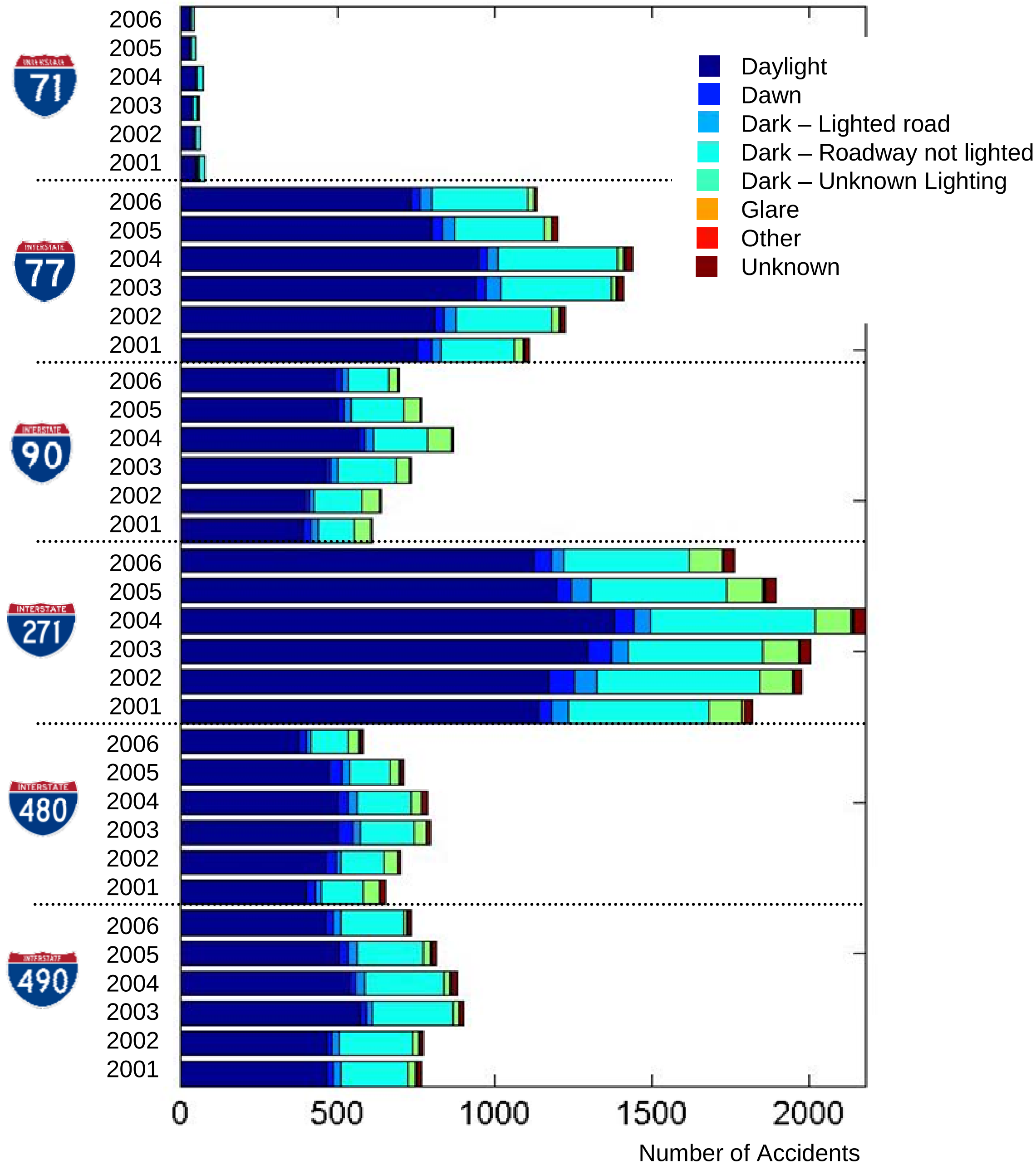


Figure 3-7. Summary Statistics of Accidents by Interstate by Year within Cuyahoga County and Color Stacked by Light Conditions at Time of Accident

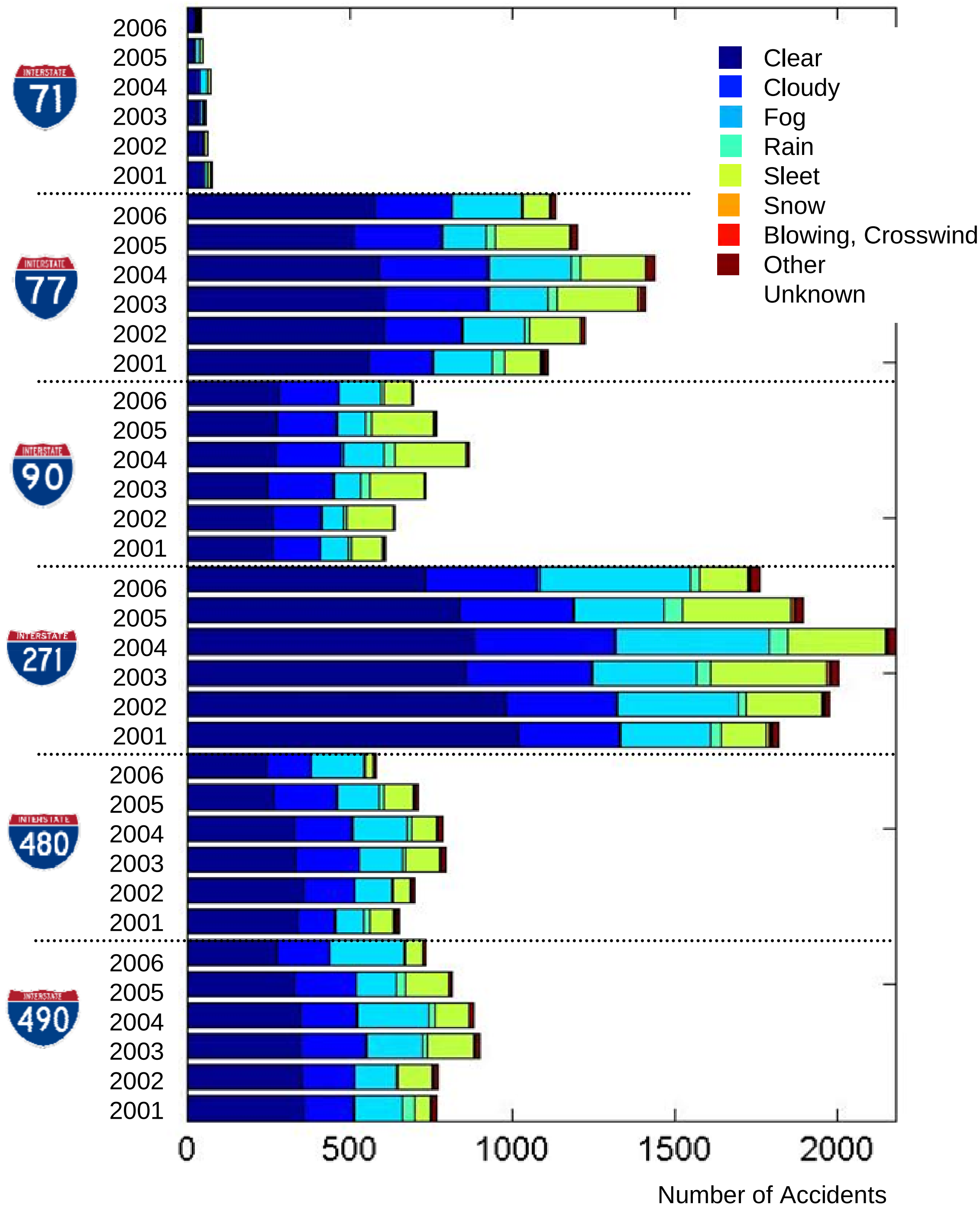


Figure 3-8. Summary Statistics of Accidents by Interstate by Year within Cuyahoga County and Color Stacked by Weather Conditions at Time of Accident

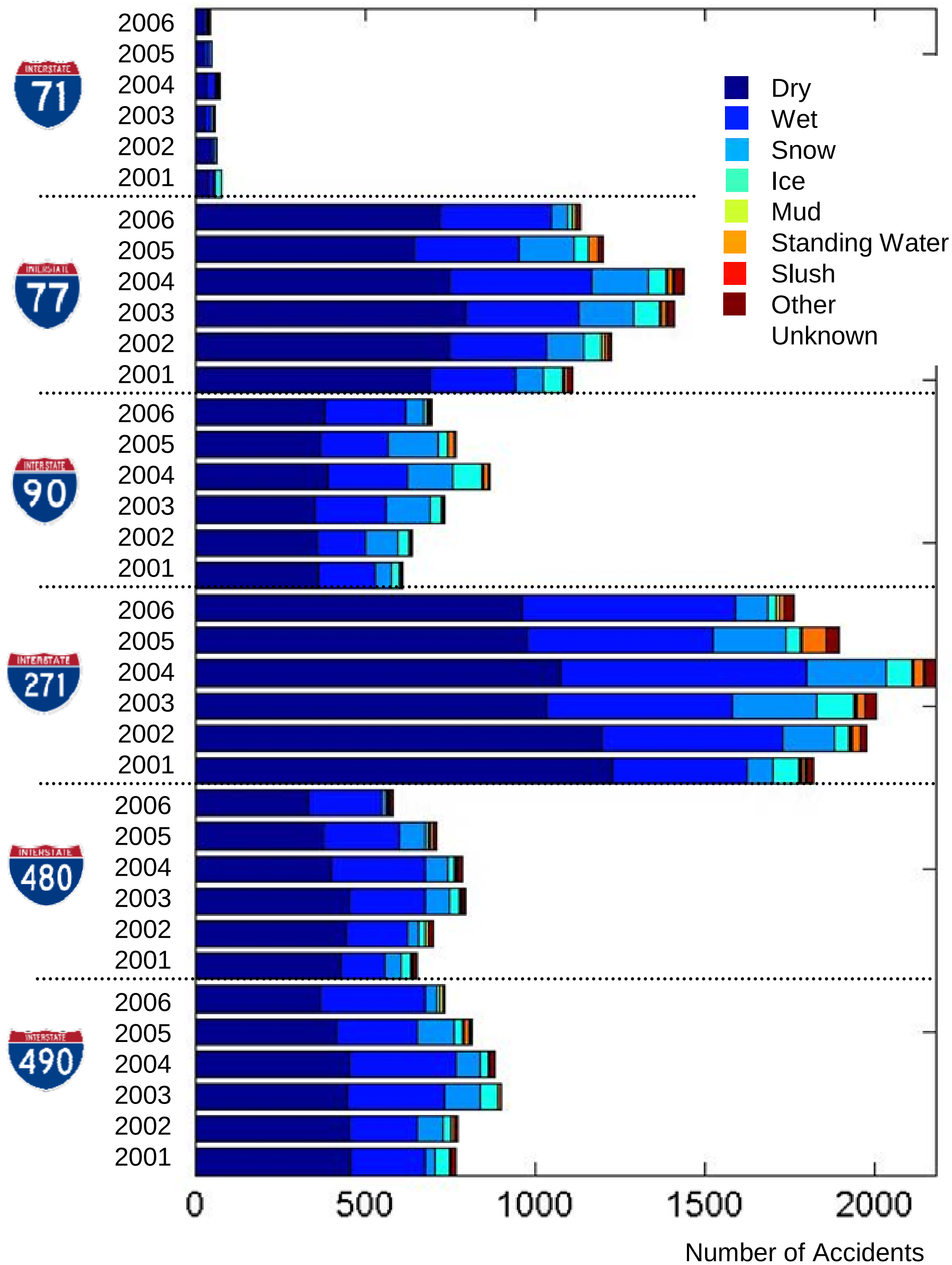


Figure 3-9. Summary Statistics of Accidents by Interstate by Year within Cuyahoga County and Color Stacked by Condition of Road at Time of Accident

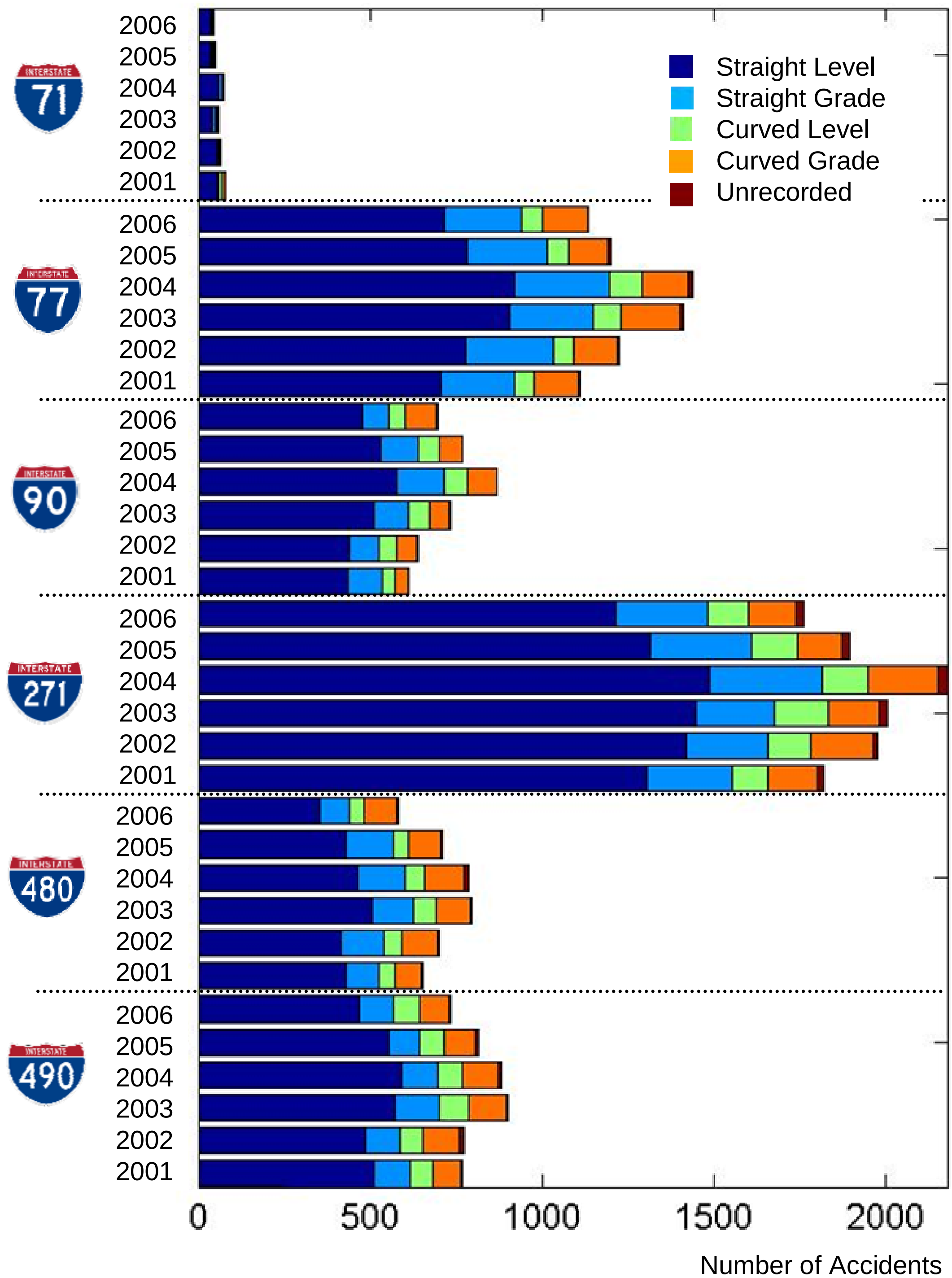


Figure 3-10. Summary Statistics of Accidents by Interstate by Year within Cuyahoga County and Color Stacked by Road Contour Geometry at Location of Accident

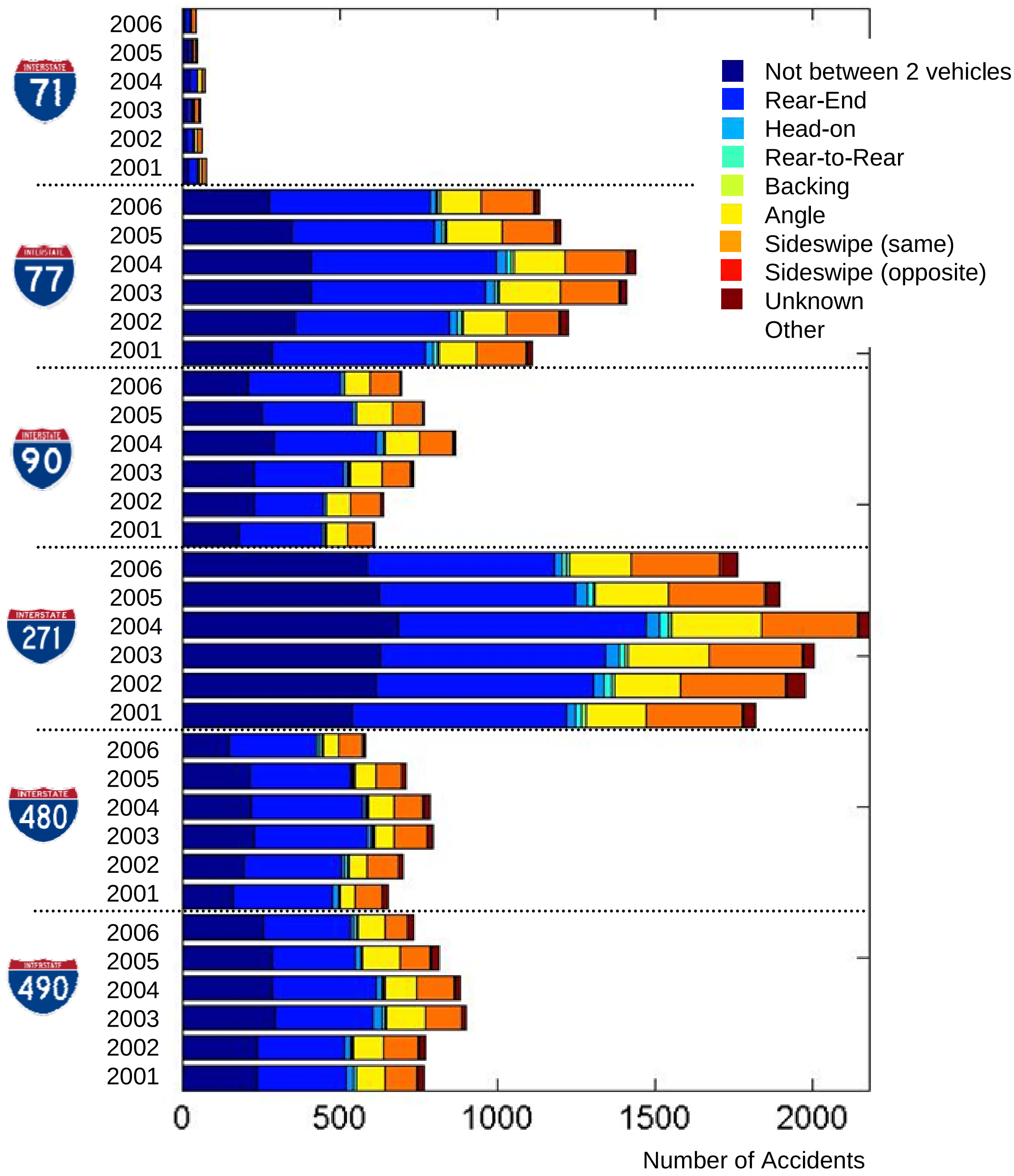


Figure 3-11. Summary Statistics of Accidents by Interstate by Year within Cuyahoga County and Color Stacked by Manner of Impact at Location of Accident

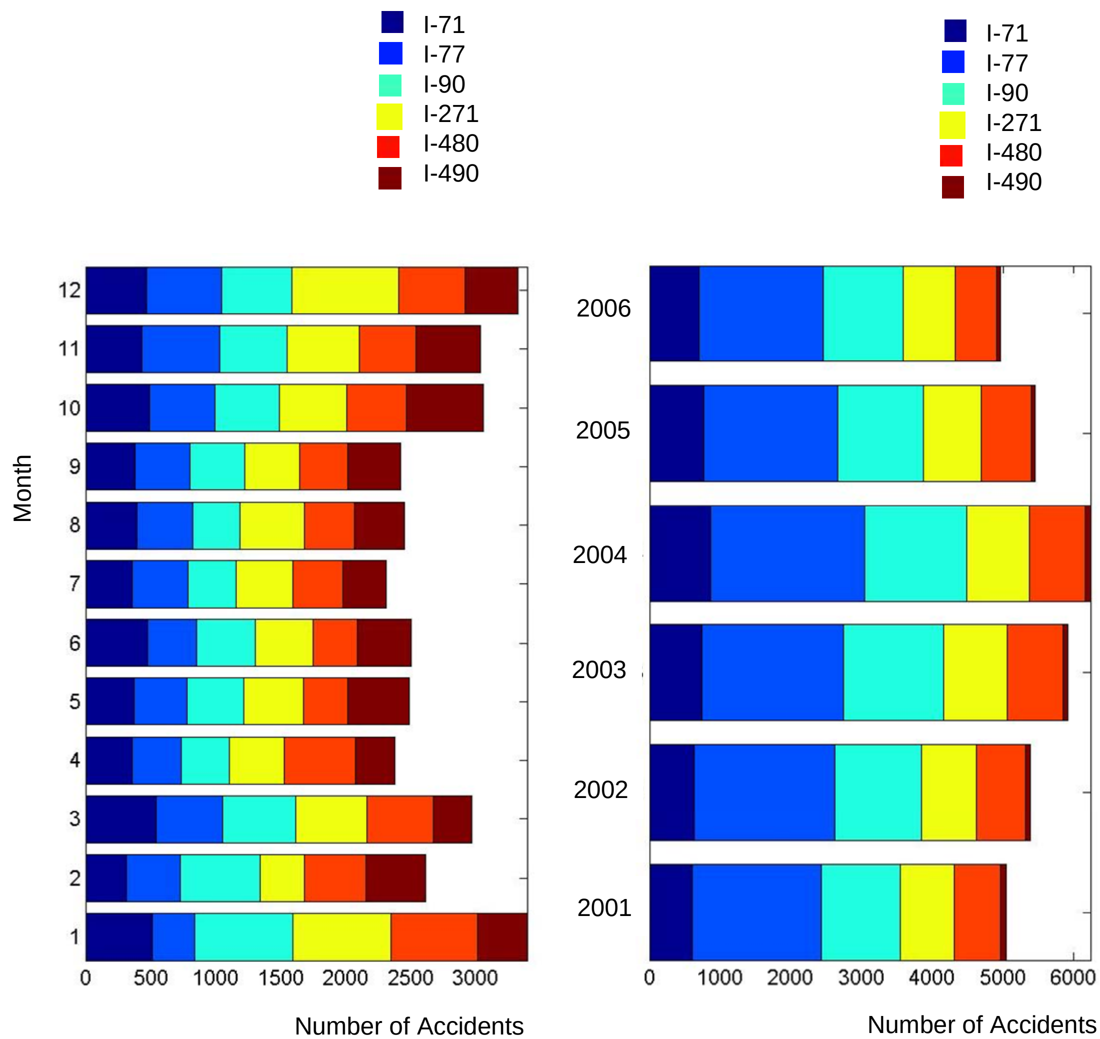


Figure 3-12. Summary Statistics of Accidents by Color Stacked Interstate within Cuyahoga County and by aggregated Months (left) and by Year (right)

4.0 ANALYSIS

4.1 Overview.

Evaluation of the relationships between the digital billboards and traffic safety requires careful study of the interaction of many parameters, to include billboard characteristics (size, height, illumination), accident characteristics (when, where, weather conditions, contributory causes), location and geometry, flow (traffic volumes, frequency, speed, seasonal effects), traffic control measures and devices, viewer reactions (times and distances from signs). The analysis in this study includes two parts: a temporal analysis and a spatial analysis. Each part of the analyses accounts for results with and without statistical bias factors, such as, bias from interchanges, bias from known accident causes (for example, a deer-hit accident as recorded in the police report, or an accidents caused by a driver under the influence of drugs or alcohol).

The first part is a temporal analysis which examines the incidence of traffic accidents at the specific and recently converted digital billboards and for a length of time before and after the conversion of the billboards (using 36 and 24 month “windows”). From information collected from police accident reports, the temporal analysis uses metrics such as traffic volumes, the accident rates values (APV) and the maximum number of accidents during any given month.

The second part is a spatial analysis which establishes statistical correlation coefficients between advertising billboards, and specifically digital billboards, and accidents along the Interstate routes in Cuyahoga County. The results are analyzed for a variety of scenarios relating accident density to billboard-density (the number of billboards), to Viewer Reaction Distance (how far from a billboard that the driver is potentially within the “influence” of a billboard), and to billboard proximity (how far the accident is from the nearest billboard). Figure 4-1 shows a conceptual view of the viewer reaction distance zone.

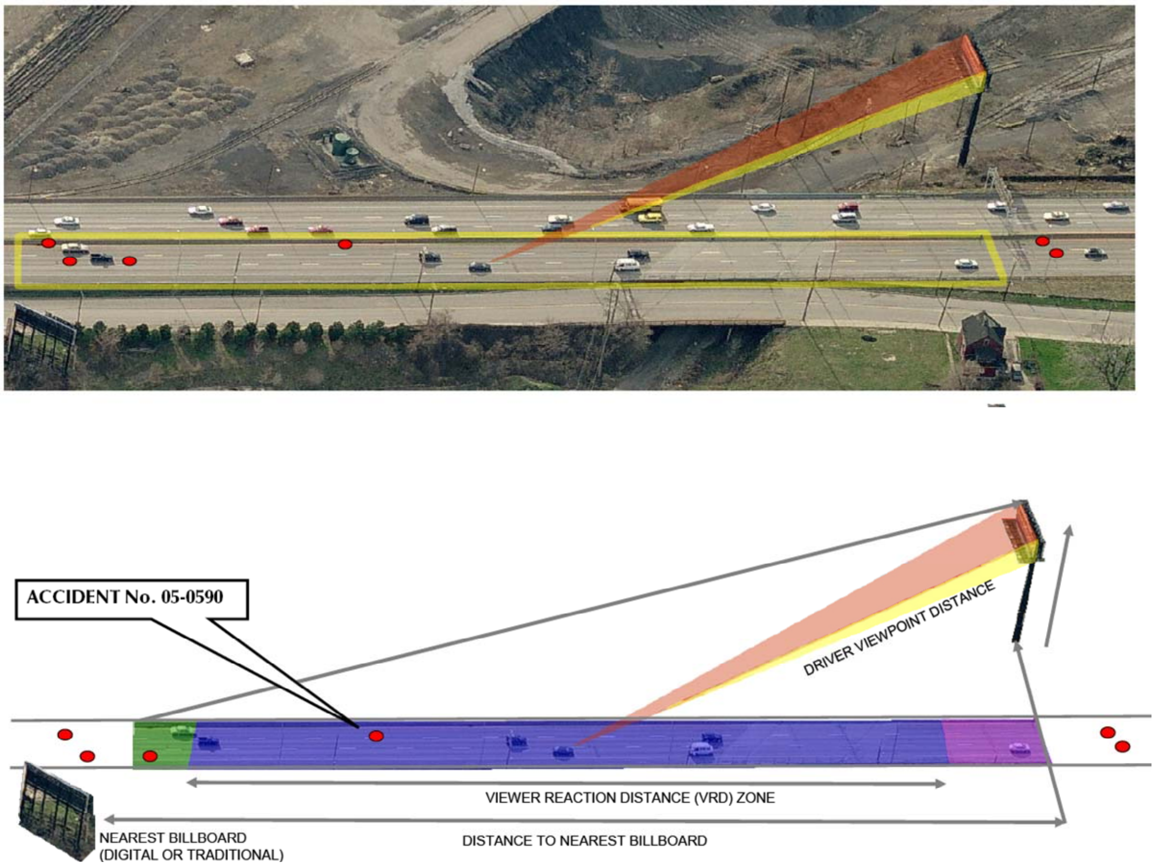


Figure 4-1. Conceptual View of Sign Accident Range to include Visible Range, and Viewer Reaction Distance (VRD) zone.

4.2 Methodology: Temporal Analysis.

The objective of the temporal-comparison part of this analysis is to examine the incidence of traffic accidents at locations of the recently converted, digital billboards, for an equal length of time before and after the conversion of the billboard, and to determine if traffic accidents occurred more frequently or less frequently with the presence of the digital billboard. Digital billboard data are statistically compared using histograms, average accident-per-volume (APV) ratios, and accidents per vehicle-miles-traveled ratios for one year before the billboard was converted and for one year after the billboard was converted; a larger 18 month before and 18 month after analysis was also studied. Variations for seasonal traffic flow and vehicle-miles traveled are accounted for; raw accident counts are weighted by these values. It should be emphasized that there were no other, substantial changes at the locations where the digital billboards are located, other than the conversion of the digital billboards, a slight increase in traffic volume, and seasonal effects.

The accident data assembled for this part of the study are based on the proximity to the billboard and on when an accident occurred. To examine how a specific location is impacted by the conversion of the billboard, comparisons were made of

- changes in traffic accidents-per-volume (APV) ratios,
- changes in percentage of traffic accidents-per-million-daily miles traveled (PMDVMT) ratios,
- histograms of the accident data on a temporal basis, and
- similar analysis for a data set excluding known statistical bias effects.

A quantitative measure of comparing traffic safety is to use accidents-per-volume (APV) ratios. The APV ratio is calculated by

$$\text{APV} = \frac{\text{Number of accidents}}{\text{Annual Traffic Volume}}$$

The Annual Traffic volume is approximated by the AADT multiplied by 365 days. AADT values include both a single traffic count for both directions in all lanes; flow in lanes in a single direction is approximated by half of the AADT. Table 4-5 summarizes accidents, annual traffic volumes and APV ratios for the digital-billboard locations with and without bias for a year after the billboard was converted. The number of accidents within the seven signs visible ranges for one year was 174 accidents for an estimated 85 million vehicles that drove by; this represents one accident for every 481,000 vehicles. If we exclude statistical bias (accidents from known causes), there are only 53 accident in the year after the seven signs were converted for 85 million vehicles; this represents one accident for every 1.5 million vehicles. The values per sign suggest an average of 7 accidents near a digital billboard per year for the same 85 million vehicles; this represents a rate of one accident per 12 million vehicles per year.

4.3 Results: Temporal Analysis.

Using the summarized accident-report data, Tables 4-1 through 4-6 and Figures 4-2 through 4-9 shows the summary statistics and composite distribution of accidents before and after the conversion of the billboards (on or about July 1, 2005) as monthly histograms; these figures represent 36 and 24 month windows and accidents with and without statistical bias. A comparison of the histograms of accidents at the location 18 months before the digital conversion and 18 months after the digital conversion indicates no substantial change in accident patterns. Comparing a year before and after, the peak number of accidents on any given month decreased from 247 to 174, after the introduction of the digital billboard at the location; the peak number on any given month decreased from 14 to 8. Similar results were obtained for the longer 36-month windows. Based on the data and analysis, no significant change in accident occurrences can be attributed to the conversion of these billboards to digital format. It should also be noted that the winter months had more snowfall in the 18 months prior to the conversion.

For these billboards, the results suggest that digital billboards in and of themselves have no influence on the occurrence of traffic accidents. The temporal comparison also suggests that digital billboards are no more likely to increase or decrease the accident frequency than conventional billboards, or than stretches of the Interstate routes with no billboards. Tables 4-1 and 4-2 summarize the accident count for 36-month and 24-month windows centered on July 1, 2005, the conversion date. Tables 4-3 and 4-4 summarize the same data for 36 and 24 month windows, and also account for seasonal trends in the County and account for vehicle-miles traveled during the specific months at the specific sign locations. The most useful measures of traffic-accident occurrence at any specific location are evaluated and compiled in Tables 4-3 and 4-4; only a 0.6% decrease in accident percent per Route per million vehicle-miles traveled for both 24 and 36 month windows exists. The number of accidents was relatively steady during the 36 month period centered around the conversion of these billboards. No large increases or decreases occurred in the values from year to year. With the exception of the existence of a digital billboard, there were no notable changes on these routes near the billboards. No new buildings, changes in lane topography, or zoning were introduced. This analysis reinforces the results of the spatial analysis part of this study and further suggests that digital billboards in and of themselves have no influence on the occurrence of traffic accidents. Accident data was analyzed using all recorded Interstate accidents; the same analysis was additionally conducted by also excluded data with known bias. A fair and unbiased comparison of accident data would exclude accidents from known causes, as recorded in police accident reports. In this subset analysis of unbiased data, the excluded accidents were those recorded (1) with drivers under the influence of alcohol or drugs, (2) animal-related accidents (typically drivers hitting deer), (3) drivers in accidents located at on-ramps and off-ramps (drivers undertaking additional operations for lane-changes, decelerating), and (4) accidents during adverse weather conditions (specifically only accidents recorded during snowfall or with icy roads). These bias-exclusion criteria were used in bias-data subset analyses in this study.

		Digital Billboard 1	2	3	4	5	6	7	All
Conventional Billboard (18 months prior to conversion)	Total Accidents as Conventional Billboard	23	31	33	15	135	70	38	345
	Average Number of Accidents in a Month	1.3	1.7	1.8	0.8	7.5	3.9	2.1	2.7
	Standard Deviation	1.2	1.0	1.7	0.8	4.0	2.0	1.6	2.9
	Peak Number of Accidents in Any Given Month	4	3	5	2	16	8	5	16
	Minimum Number of Accidents in Any Given Month	0	0	0	0	3	1	0	0
Digital Billboard (18 months after conversion)	Total Accidents as Digital Billboard	21	27	40	14	89	53	27	271
	Average Number of Accidents in a Month	1.2	1.5	2.2	0.8	4.9	2.9	1.5	2.2
	Standard Deviation	0.9	1.2	1.4	0.8	2.2	2.1	1.2	2.0
	Peak Number of Accidents in Any Given Month	3	4	5	3	9	7	4	9
	Minimum Number of Accidents in Any Given Month	0	0	0	0	1	0	0	0
Difference (prior to and after conversion)	Number of Accidents	-2	-4	7	-1	-46	-17	-11	-74
	percent difference	-8.7%	-12.9%	21.2%	-6.7%	-34.1%	-24.3%	-28.9%	-21.4%
	Average Per Month	-0.1	-0.2	0.4	-0.1	-2.6	-0.9	-0.6	-0.6
	Peak Number of Accidents in Any Given Month	-1	1	0	1	-7	-1	-1	-7
	Minimum Number of Accidents in Any Given Month	0	0	0	0	-2	-1	0	0

Table 4-1. Accident Count Data for a 36-Month Window (±18 months prior to and after conversion to digital billboard) of Accidents within the Viewer Reaction Zone of Digital Billboards on Interstate Route Sections

		Digital Billboard 1	2	3	4	5	6	7	All
Conventional Billboard (12 months prior to conversion)	Total Accidents as Conventional Billboard	15	22	30	12	92	49	27	247
	Average Number of Accidents in a Month	1.2	1.7	2.3	0.9	7.1	3.8	2.1	2.7
	Standard Deviation	1.0	0.9	1.7	0.8	3.8	2.0	1.7	2.7
	Peak Number of Accidents in Any Given Month	3	3	5	2	14	8	5	14
	Minimum Number of Accidents in Any Given Month	0	0	0	0	3	1	0	0
Digital Billboard (12 months after conversion)	Total Accidents as Digital Billboard	14	16	27	8	53	37	19	174
	Average Number of Accidents in a Month	1.2	1.3	2.3	0.7	4.4	3.1	1.6	2.1
	Standard Deviation	1.0	1.2	1.4	0.9	1.7	2.2	1.3	1.8
	Peak Number of Accidents in Any Given Month	3	4	4	3	8	7	4	8
	Minimum Number of Accidents in Any Given Month	0	0	0	0	2	0	0	0
Difference (prior to and after conversion)	Number of Accidents	-1	-6	-3	-4	-39	-12	-8	-73
	percent difference	-6.7%	-27.3%	-10.0%	-33.3%	-42.4%	-24.5%	-29.6%	-29.6%
	Average Per Month	0.0	-0.4	-0.1	-0.3	-2.7	-0.7	-0.5	-0.6
	Peak Number of Accidents in Any Given Month	0	1	-1	1	-6	-1	-1	-6
	Minimum Number of Accidents in Any Given Month	0	0	0	0	-1	-1	0	0

Table 4-2. Accident Count Data for a 24-Month Window (±12 months prior to and after conversion to digital billboard) of Accidents within the Viewer Reaction Zone of Digital Billboards on Interstate Route Sections

		Digital Billboard 1	2	3	4	5	6	7
Conventional Billboard (18 months prior to conversion)	Percentage of Accidents on Interstate per million DVMT (PMDVMT)	0.073	0.154	0.027	0.171	0.171	0.089	0.280
	Standard Deviation	0.067	0.090	0.026	0.089	0.089	0.047	0.215
	Peak PMDVMT in Any Given Month	0.226	0.288	0.072	0.341	0.341	0.171	0.702
	Minimum PMDVMT in Any Given Month	0.000	0.000	0.000	0.064	0.064	0.021	0.000
Digital Billboard (18 months after conversion)	Percentage of Accidents on Interstate per million DVMT (PMDVMT)	0.076	0.162	0.030	0.132	0.132	0.078	0.243
	Standard Deviation	0.060	0.120	0.031	0.060	0.060	0.055	0.201
	Peak PMDVMT in Any Given Month	0.203	0.384	0.116	0.243	0.243	0.189	0.685
	Minimum PMDVMT in Any Given Month	0.000	0.000	0.000	0.027	0.027	0.000	0.000
Difference (prior to and after conversion)	Percentage of Accidents on Interstate per million DVMT (PMDVMT)	0.003	0.008	0.002	-0.039	-0.039	-0.011	-0.037
	Peak PMDVMT in Any Given Month	-0.007	0.030	0.005	-0.029	-0.029	0.008	-0.013
	Minimum PMDVMT in Any Given Month	-0.023	0.096	0.044	-0.098	-0.098	0.018	-0.017

Table 4-3. Percentage of Interstate Accidents per million Vehicle-Mile Travel Data for a 36-Month Window (±18 months prior to and after conversion to digital billboard) of Accidents within the Viewer Reaction Zone of Digital Billboards on Interstate Route Sections

		Digital Billboard						
		1	2	3	4	5	6	7
Conventional Billboard (12 months prior to conversion)	Percentage of Accidents on Interstate per million DVMT (PMDVMT)	0.870	1.997	0.399	2.152	2.152	1.157	3.645
	Standard Deviation	0.056	0.085	0.026	0.087	0.087	0.047	0.231
	Peak PMDVMT in Any Given Month	0.169	0.288	0.072	0.299	0.299	0.171	0.702
	Minimum PMDVMT in Any Given Month	0.000	0.000	0.000	0.064	0.064	0.021	0.000
Digital Billboard (12 months after conversion)	Percentage of Accidents on Interstate per million DVMT (PMDVMT)	0.896	1.637	0.301	1.398	1.398	0.971	3.007
	Standard Deviation	0.066	0.119	0.034	0.046	0.046	0.058	0.219
	Peak PMDVMT in Any Given Month	0.203	0.384	0.116	0.216	0.216	0.189	0.685
	Minimum PMDVMT in Any Given Month	0.000	0.000	0.000	0.051	0.051	0.000	0.000
Difference (prior to and after conversion)	Percentage of Accidents on Interstate per million DVMT (PMDVMT)	0.025	-0.360	-0.098	-0.755	-0.755	-0.187	-0.638
	Peak PMDVMT in Any Given Month	0.010	0.034	0.008	-0.041	-0.041	0.011	-0.012
	Minimum PMDVMT in Any Given Month	0.034	0.096	0.044	-0.083	-0.083	0.018	-0.017

Table 4-4. Percentage of Interstate Accidents per million Vehicle-Mile Travel Data for a 24-Month Window (±12 months prior to and after conversion to digital billboard) of Accidents within the Viewer Reaction Zone of Digital Billboards on Interstate Route Sections

		All categories				Excluding Bias Categories (DUIs, Adverse Weather, Deer Hits)			
Billboard No.	Interstate Route	Number of Accidents in a Year near Digital Billboard	VPY (Vehicles per Year per Route Section)	APY Rate		Number of Accidents in a Year near Digital Billboard	VPY (Vehicles per Year per Route Section)	APY Rate	
				Rate	Equivalently			Rate	Equivalently
1	I-271	14	22,965,800	0.00000061	1 in 1,640,414	7	22,965,800	0.00000030	1 in 3,280,829
2	I-480	16	23,697,625	0.00000068	1 in 1,481,102	3	23,697,625	0.00000013	1 in 7,899,208
3	I-90	27	23,484,100	0.00000115	1 in 869,781	6	23,484,100	0.00000026	1 in 3,914,017
4	I-77	8	22,553,715	0.00000035	1 in 2,819,214	2	22,553,715	0.00000009	1 in 11,276,858
5	I-90	53	21,606,175	0.00000245	1 in 407,664	17	21,606,175	0.00000079	1 in 1,270,951
6	I-90	37	24,372,875	0.00000152	1 in 658,726	14	24,372,875	0.00000057	1 in 1,740,920
7	I-480	19	28,953,625	0.00000066	1 in 1,523,875	4	28,953,625	0.00000014	1 in 7,238,406
All		174	83,816,958	0.00000208	1 in 481,707	53	83,816,958	0.00000063	1 in 1,581,452

Table 4-5. Accident Rate per Year near Billboards for all Accidents (left) and Bias-Adjusted (right)

Figures 4-2 through 4-9 show the number of accidents within the visible range of all seven digital billboards by count and by rate by daily-vehicle mile traveled. These figures represent both the 24 month and 36 months sets of data centered around the conversion in July 2005.

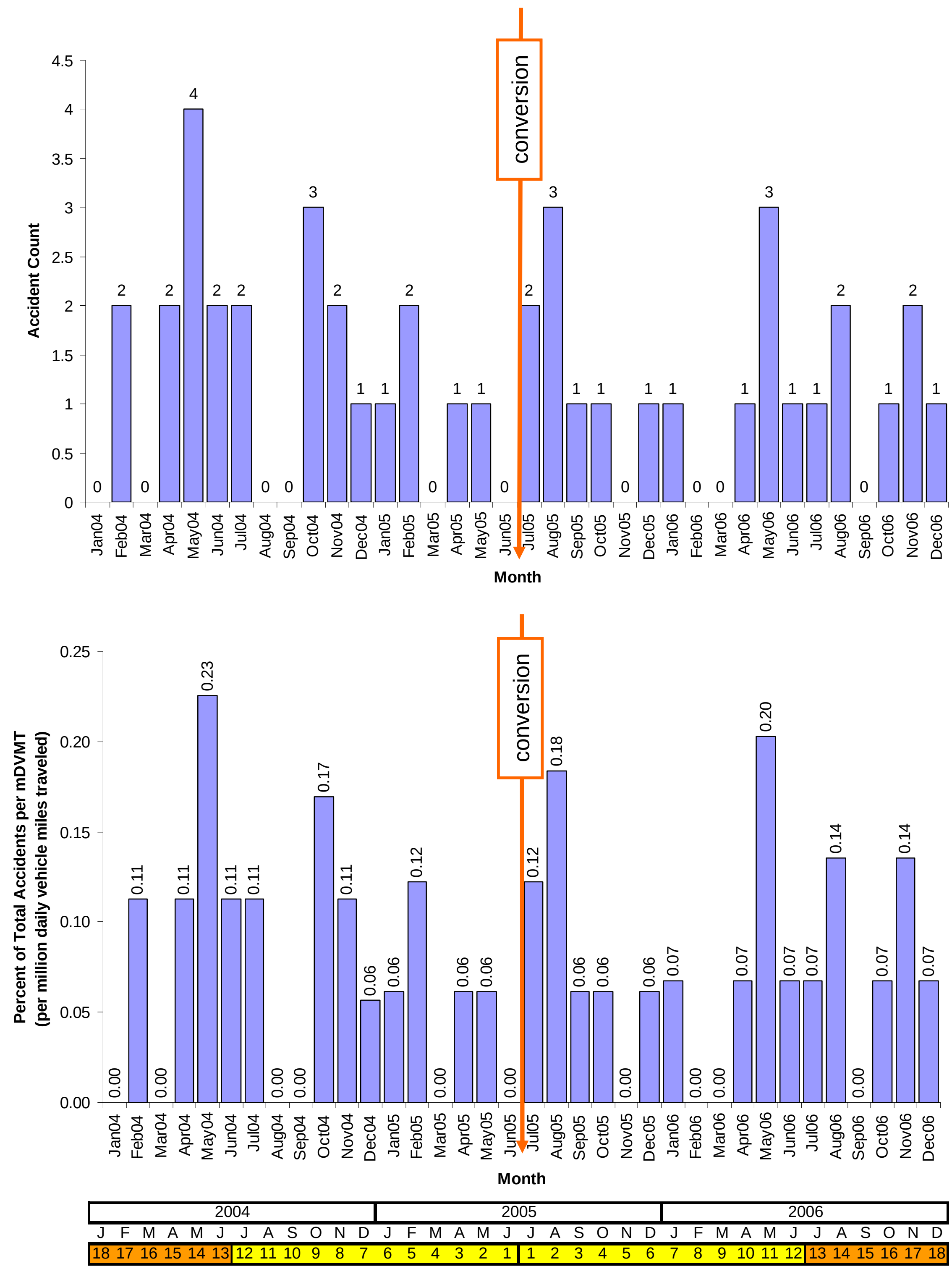


Figure 4-2. Number of Accidents within visible range of Digital Billboard 1 (upper); Percentage of Total Accidents per million daily vehicle mile traveled, DVMT (lower)

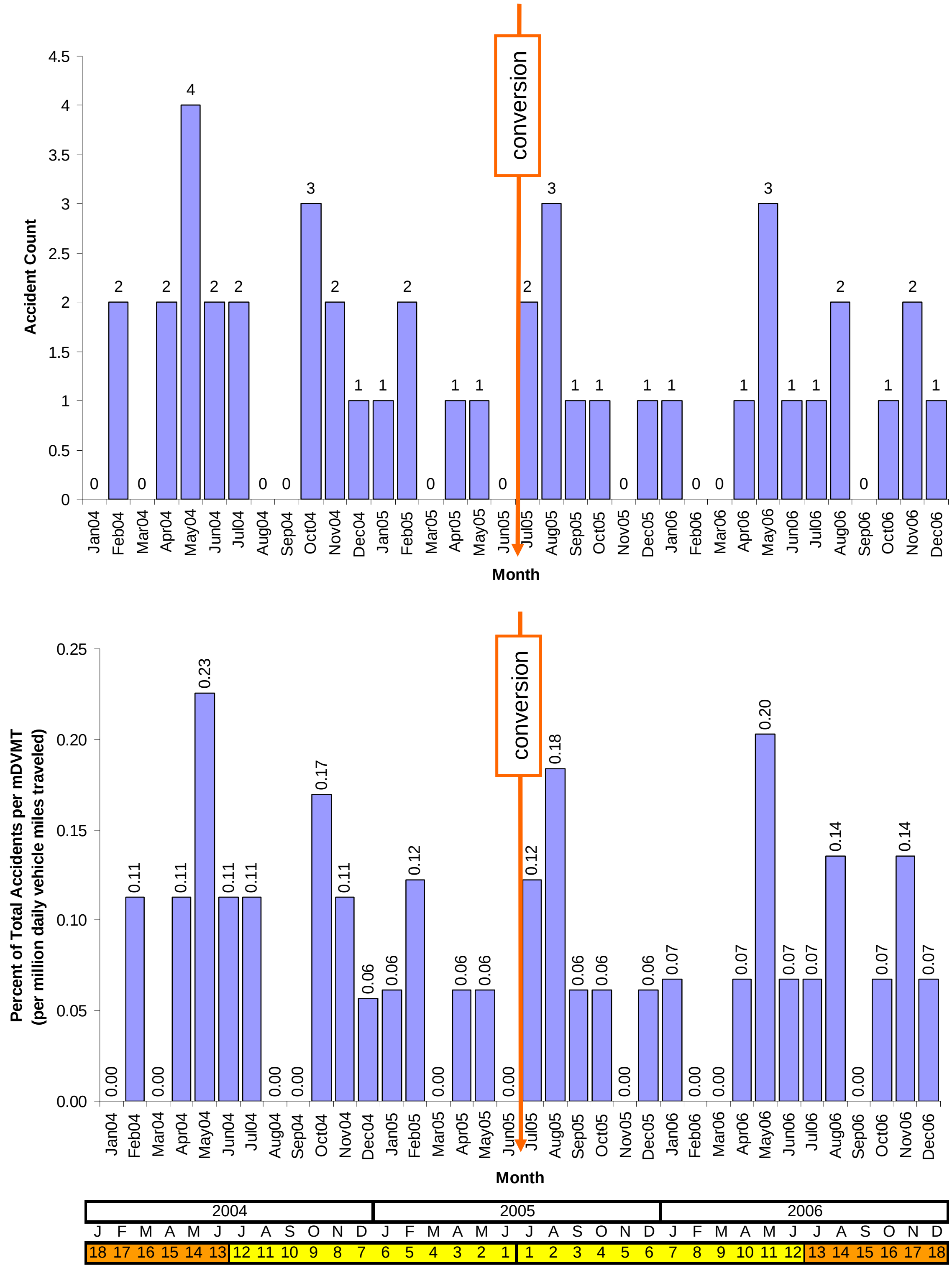


Figure 4-3. Number of Accidents within visible range of Digital Billboard 1 (upper); Percentage of Total Accidents per million daily vehicle mile traveled, DVMT (lower)

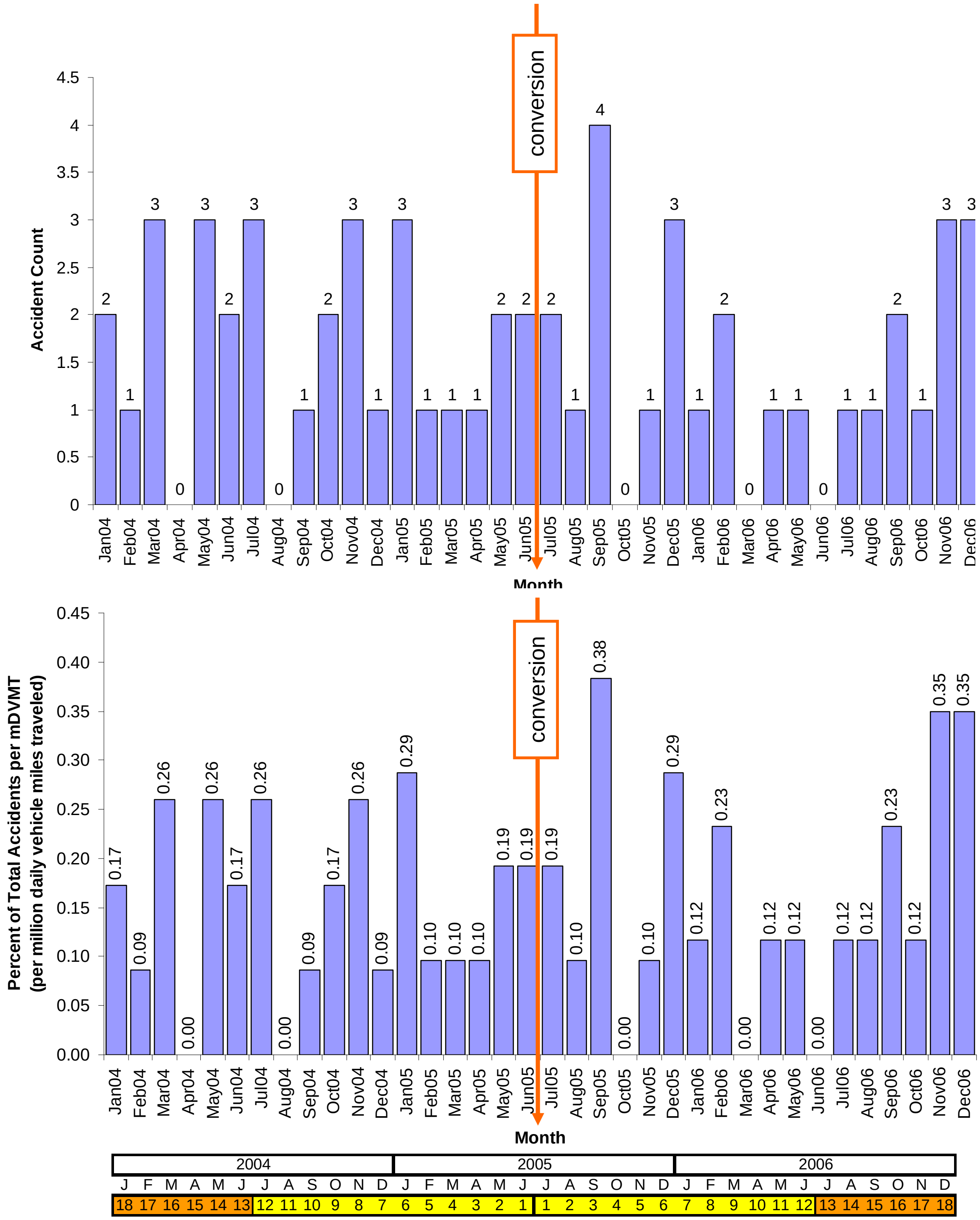


Figure 4-4. Number of Accidents within visible range of Digital Billboard 2 (upper); Percentage of Total Accidents per million daily vehicle mile traveled, DVMT (lower)

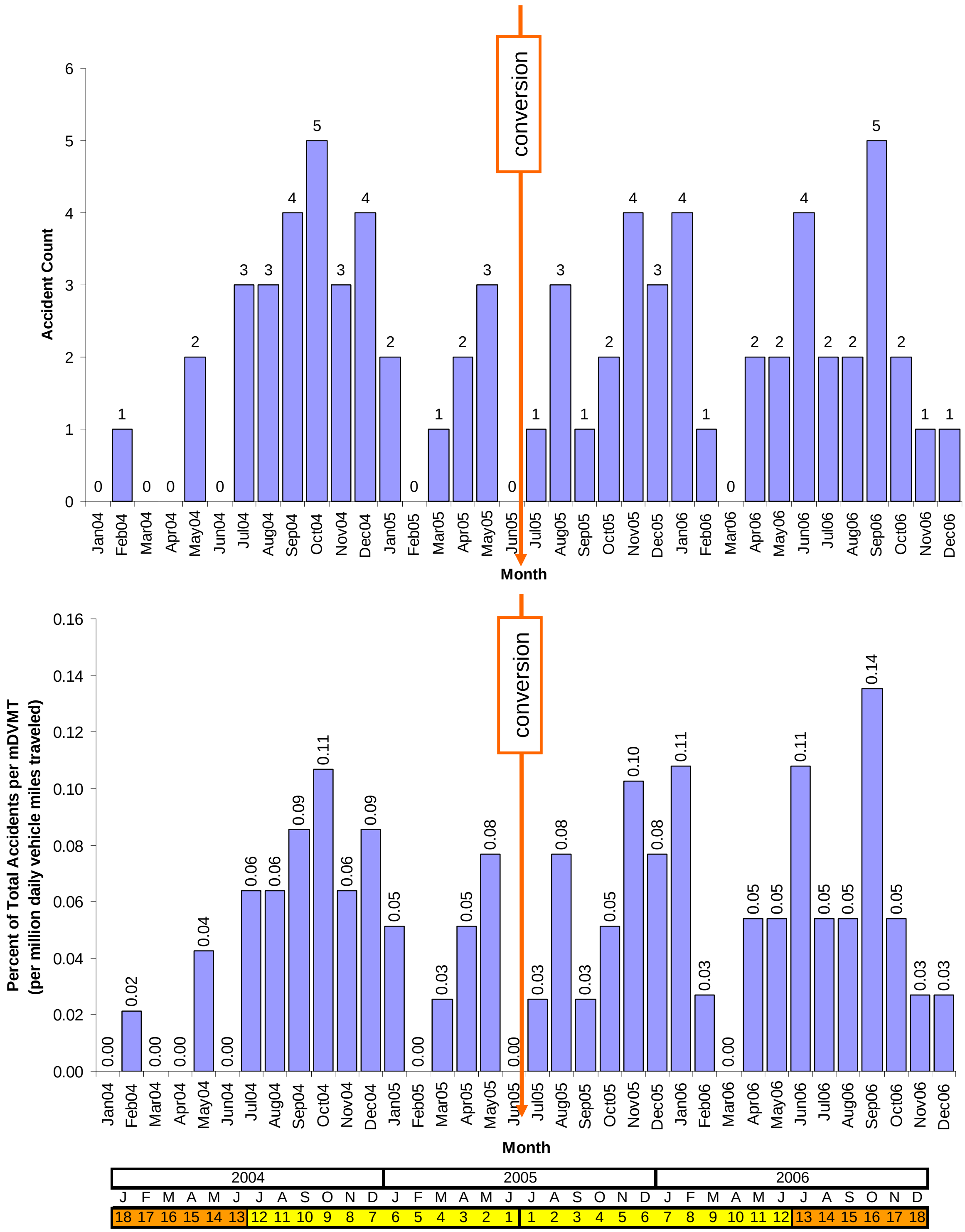


Figure 4-5. Number of Accidents within visible range of Digital Billboard 3 (upper); Percentage of Total Accidents per million daily vehicle mile traveled, DVMT (lower)

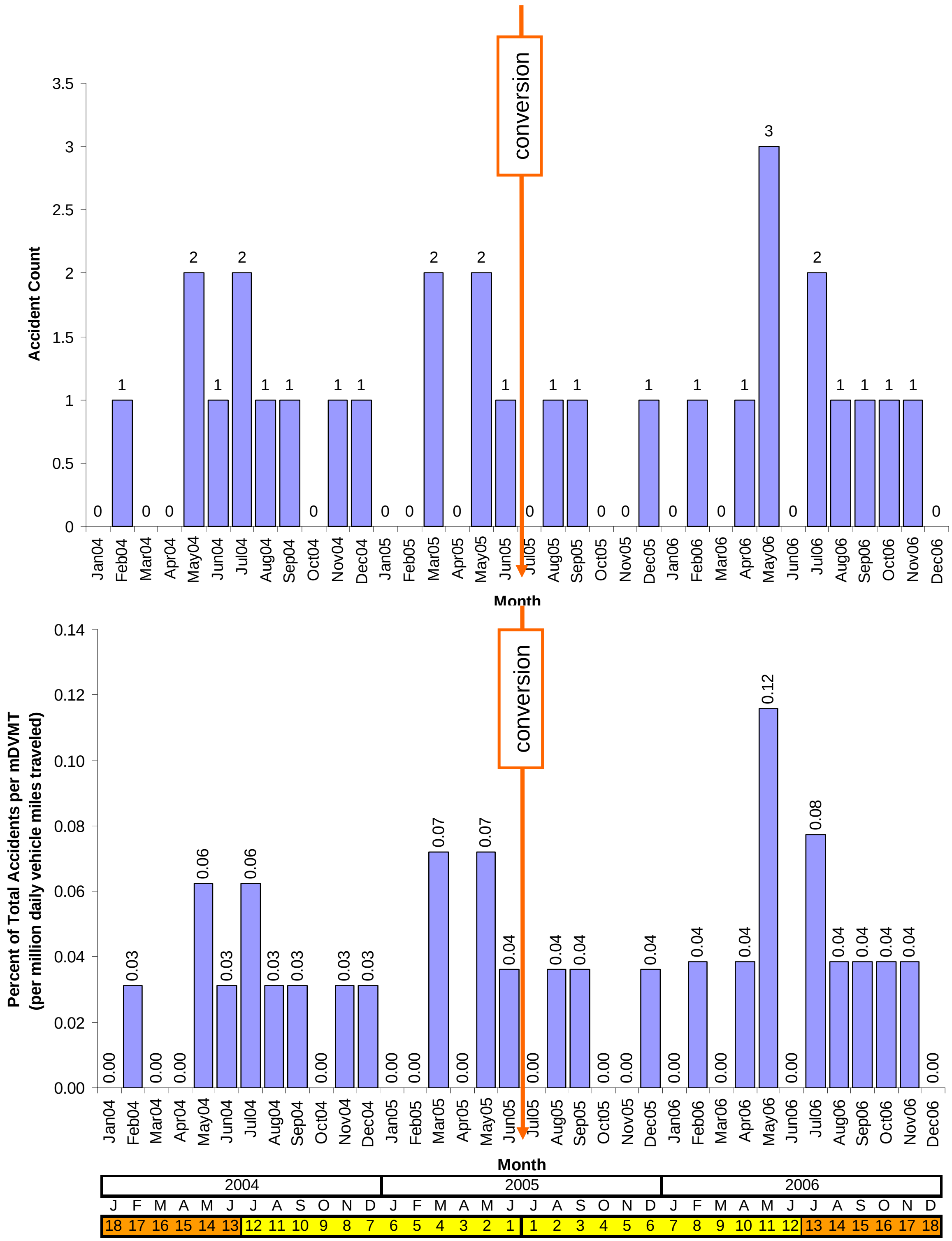


Figure 4-6. Number of Accidents within visible range of Digital Billboard 4 (upper); Percentage of Total Accidents per million daily vehicle mile traveled, DVMT (lower)

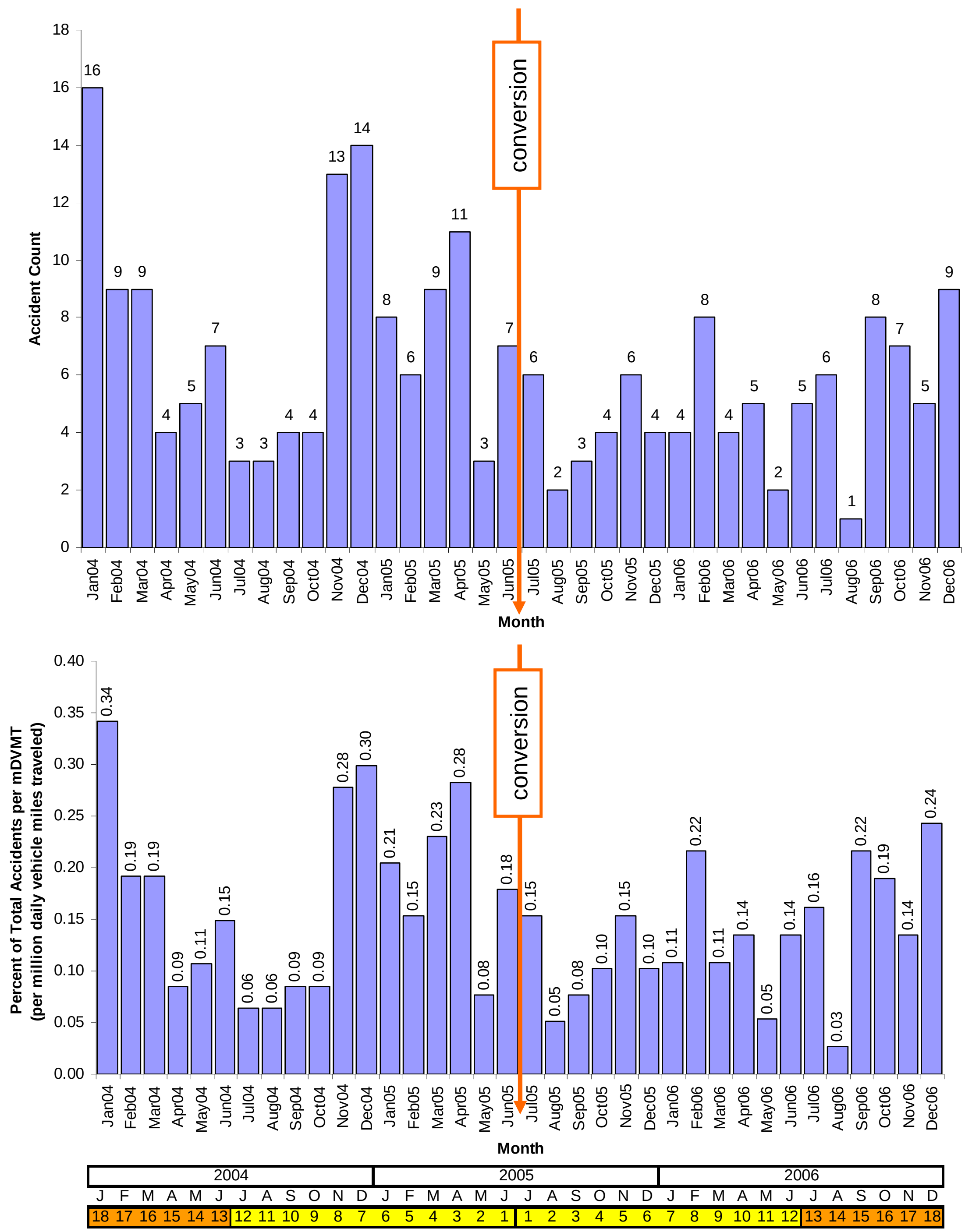


Figure 4-7. Number of Accidents within visible range of Digital Billboard 5 (upper); Percentage of Total Accidents per million daily vehicle mile traveled, DVMT (lower)

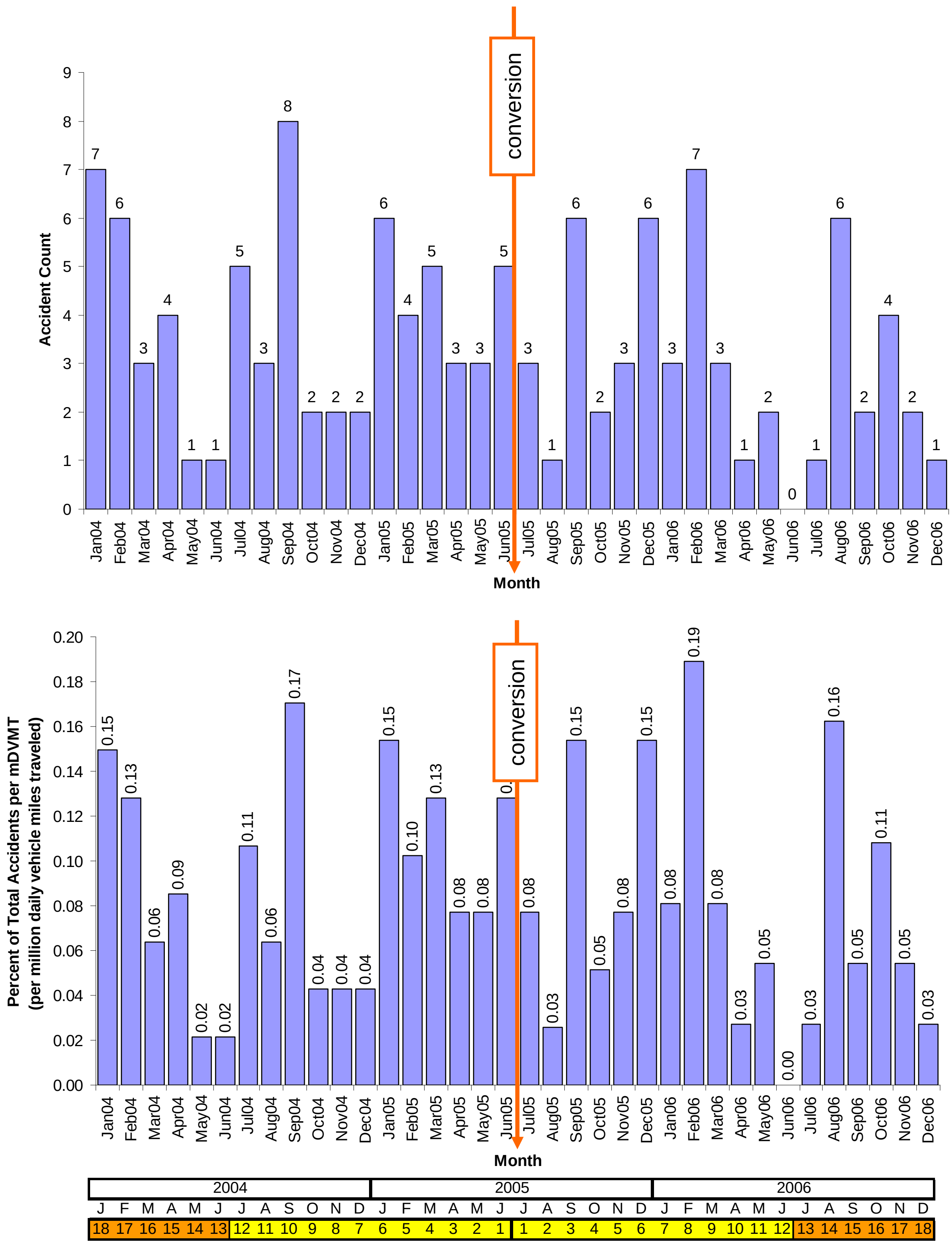


Figure 4-8. Number of Accidents within visible range of Digital Billboard 6 (upper); Percentage of Total Accidents per million daily vehicle mile traveled, DVMT (lower)

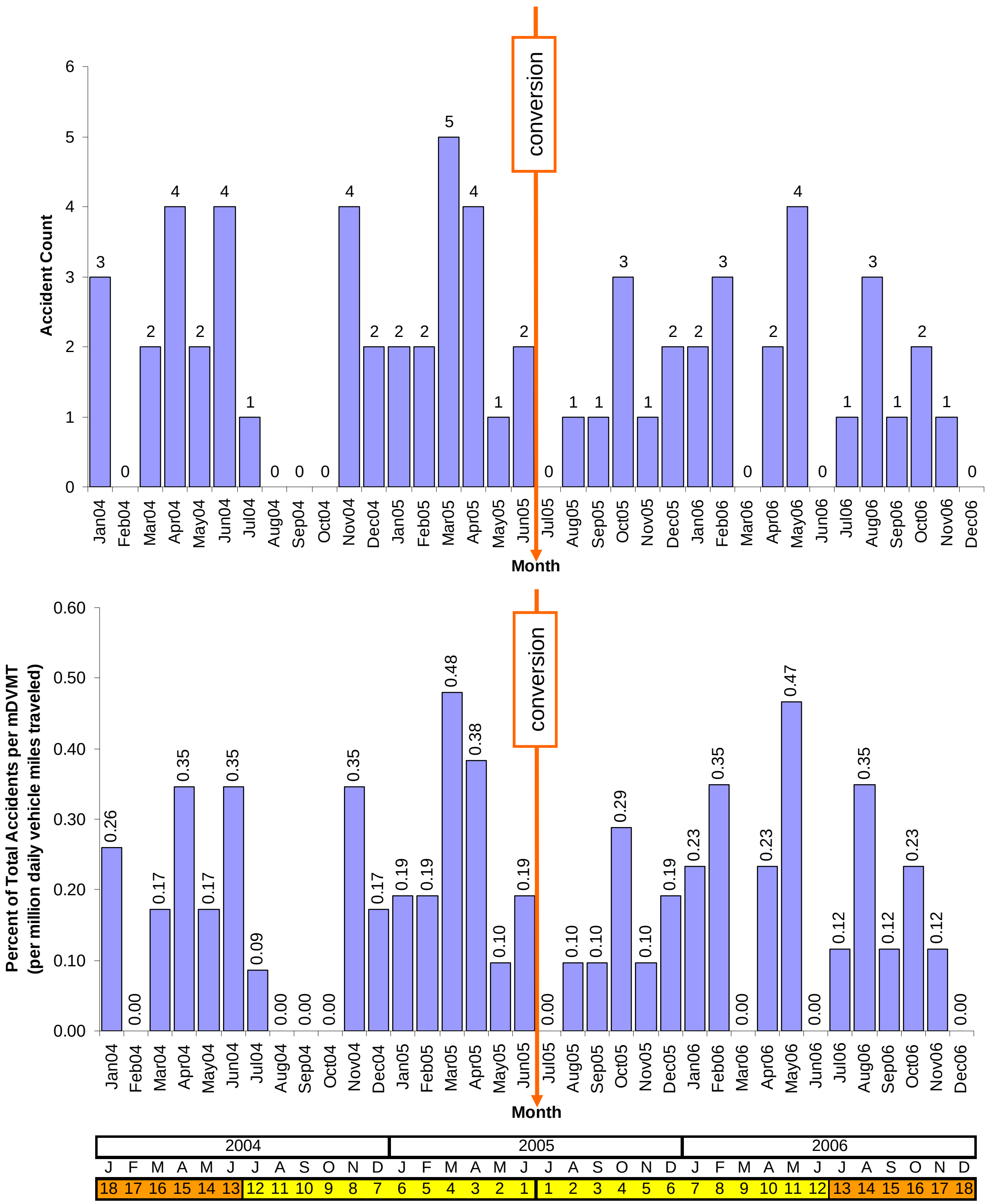


Figure 4-9. Number of Accidents within visible range of Digital Billboard 7 (upper); Percentage of Total Accidents per million daily vehicle mile traveled, DVMT (lower)

A more fair and unbiased comparison of accident data would exclude accidents from known causes, as recorded in police accident reports. Figure 4-10 shows the frequency of accidents on the Interstates in Cuyahoga County by contributing circumstance (driving under the influence, adverse weather, animal hits, etc). Table 4-6 summarizes the percentages of several of these circumstances for the accidents occurring near the digital billboards and within viewer reaction zones.

		Digital Billboard						
		1	2	3	4	5	6	7
Percentage of Recorded Contributory Factors Analysis	Alcohol	3.03%	1.59%	0.00%	1.52%	1.91%	6.85%	1.48%
	Drugs	1.52%	1.59%	0.00%	0.00%	0.24%	0.91%	0.74%
	Animal Related	21.21%	0.00%	10.71%	0.00%	5.57%	0.46%	0.74%
	Speeding	27.27%	7.14%	41.96%	7.58%	17.90%	9.59%	8.15%
	Senior Related	3.03%	5.56%	9.82%	6.06%	5.73%	7.76%	5.93%

Table 4-6. Percentage of Accidents within Viewer Reaction Zones near Digital Billboards as recorded with known contributor causes

Tables 4-7 through 4-10 and Figures 4-11 through 4-17 show the number of accidents with statistical bias events excluded within the visible range at all seven digital billboards by count and by rate by daily-vehicle mile traveled. These figures represent both the 24 month and 36 months sets of data centered around the conversion in July 2005. Tables 4-9 and 4-10 summarize the same data for 36 and 24 month windows and also account for seasonal trends in the County and account for vehicle-miles traveled during the specific months at the specific sign locations.

Exclude bias accidents, a comparison of the histograms of accidents (on either a monthly basis) at the location 18 months before the digital conversion and 18 months after the digital conversion indicates no substantial change in accident patterns. Comparing a year before and after, the peak number of accidents on any given month decreased from 62 to 53, after the introduction of the digital billboard at the location; the peak number of accidents on any given month decreased from 5 to 4. Similar results were obtained for the larger 18-month windows. The data and analysis indicates no significant change in accident occurrences that can be attributed to the conversion of these billboards to digital format.

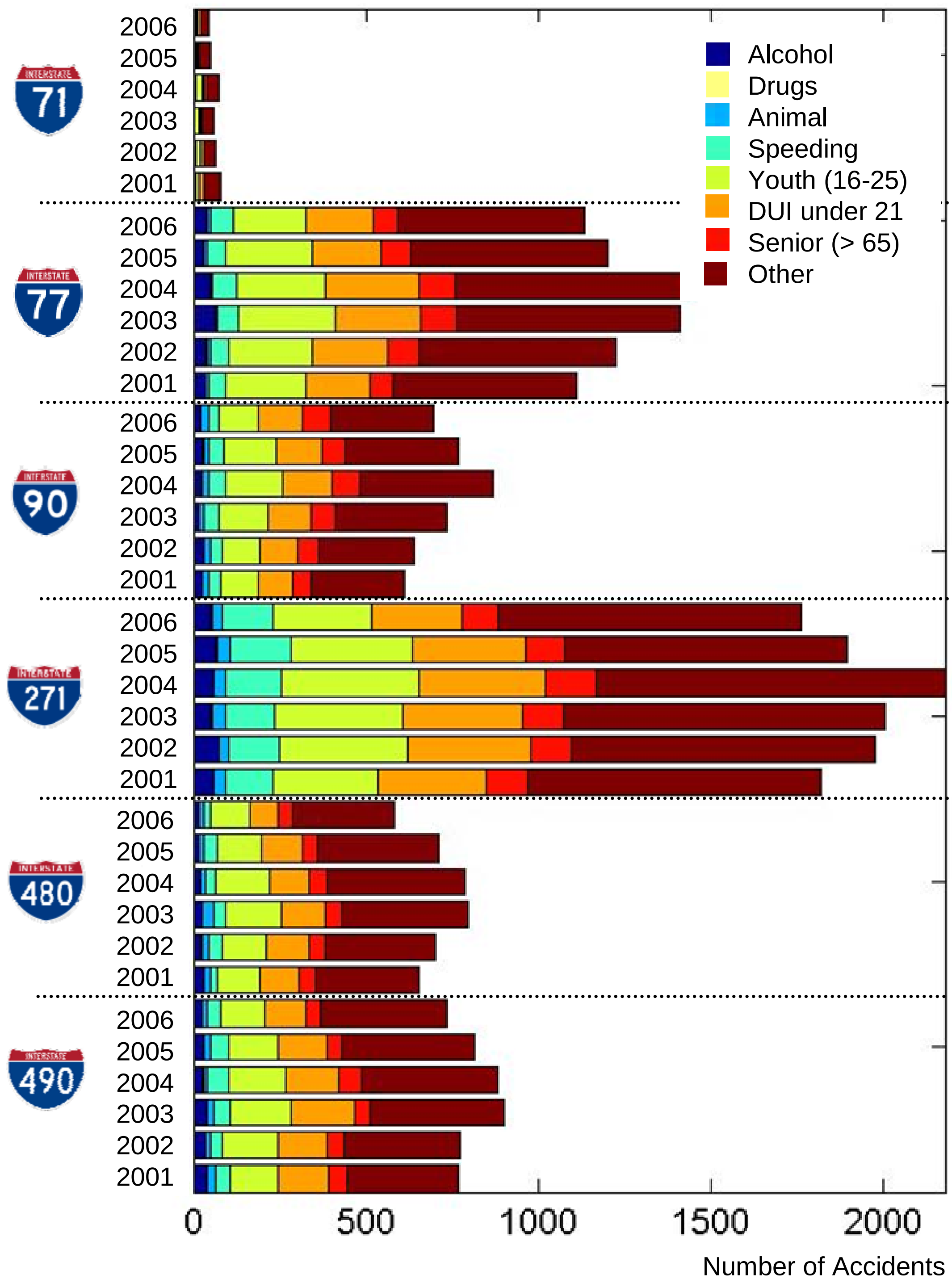


Figure 4-10. Summary Statistics of Accidents by Interstate by Year in Cuyahoga County and Color Stacked by Police Recorded Contributing Circumstances

		Digital Billboard 1	2	3	4	5	6	7	All
Conventional Billboard (18 months prior to conversion)	Total Accidents as Conventional Billboard	13	4	8	2	41	20	8	96
	Average Number of Accidents in a Month	0.7	0.2	0.4	0.1	2.3	1.1	0.4	0.8
	Standard Deviation	0.8	0.5	0.7	0.3	2.4	1.3	0.7	1.3
	Peak Number of Accidents in Any Given Month	2	2	2	1	9	4	2	9
	Minimum Number of Accidents in Any Given Month	0	0	0	0	0	0	0	0
Digital Billboard (18 months after conversion)	Total Accidents as Digital Billboard	11	4	7	2	21	15	5	65
	Average Number of Accidents in a Month	0.6	0.2	0.4	0.1	1.2	0.8	0.3	0.5
	Standard Deviation	0.5	0.4	0.7	0.3	1.2	1.3	0.6	0.9
	Peak Number of Accidents in Any Given Month	1	1	2	1	4	4	2	4
	Minimum Number of Accidents in Any Given Month	0	0	0	0	0	0	0	0
Difference (prior to and after conversion)	Number of Accidents	-2	0	-1	0	-20	-5	-3	-31
	percent difference	-15.4%	0.0%	-12.5%	0.0%	-48.8%	-25.0%	-37.5%	-32.3%
	Average Per Month	-0.1	0.0	-0.1	0.0	-1.1	-0.3	-0.2	-0.2
	Peak Number of Accidents in Any Given Month	-1	-1	0	0	-5	0	0	-5
	Minimum Number of Accidents in Any Given Month	0	0	0	0	0	0	0	0

Table 4-7. Bias Adjusted Accident Count Data for a 36-Month Window (±18 months prior to and after conversion to digital billboard) of Accidents in the Viewer Reaction Zone of Digital Billboards on Interstate Route Sections

		Digital Billboard 1	2	3	4	5	6	7	All
Conventional Billboard (12 months prior to conversion)	Total Accidents as Conventional Billboard	9	1	6	2	26	14	4	62
	Average Number of Accidents in a Month	0.7	0.1	0.5	0.2	2.0	1.1	0.3	0.7
	Standard Deviation	0.6	0.3	0.8	0.4	1.9	1.3	0.5	1.1
	Peak Number of Accidents in Any Given Month	2	1	2	1	5	4	1	5
	Minimum Number of Accidents in Any Given Month	0	0	0	0	0	0	0	0
Digital Billboard (12 months after conversion)	Total Accidents as Digital Billboard	7	3	6	2	17	14	4	53
	Average Number of Accidents in a Month	0.6	0.3	0.5	0.2	1.4	1.2	0.3	0.6
	Standard Deviation	0.5	0.5	0.8	0.4	1.2	1.5	0.7	1.0
	Peak Number of Accidents in Any Given Month	1	1	2	1	4	4	2	4
	Minimum Number of Accidents in Any Given Month	0	0	0	0	0	0	0	0
Difference (prior to and after conversion)	Number of Accidents	-2	2	0	0	-9	0	0	-9
	percent difference	-22.2%	200.0%	0.0%	0.0%	-34.6%	0.0%	0.0%	-14.5%
	Average Per Month	-0.1	0.2	0.0	0.0	-0.6	0.1	0.0	-0.1
	Peak Number of Accidents in Any Given Month	-1	0	0	0	-1	0	1	-1
	Minimum Number of Accidents in Any Given Month	0	0	0	0	0	0	0	0

Table 4-8. Bias-Adjusted Accident Count Data for a 24-Month Window (±12 months prior to and after conversion to digital billboard) of Accidents in the Viewer Reaction Zone of Digital Billboards on Interstate Route Sections

		Digital Billboard 1	2	3	4	5	6	7
Conventional Billboard (18 months prior to conversion)	Percentage of Accidents on Interstate per million DVMT (PMDVMT)	0.042	0.020	0.004	0.052	0.052	0.027	0.059
	Standard Deviation	0.043	0.048	0.011	0.054	0.054	0.032	0.092
	Peak PMDVMT in Any Given Month	0.113	0.173	0.036	0.192	0.192	0.103	0.254
	Minimum PMDVMT in Any Given Month	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Digital Billboard (18 months after conversion)	Percentage of Accidents on Interstate per million DVMT (PMDVMT)	0.040	0.025	0.004	0.031	0.031	0.022	0.046
	Standard Deviation	0.033	0.048	0.012	0.033	0.033	0.034	0.096
	Peak PMDVMT in Any Given Month	0.068	0.116	0.036	0.108	0.108	0.108	0.342
	Minimum PMDVMT in Any Given Month	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Difference (prior to and after conversion)	Percentage of Accidents on Interstate per million DVMT (PMDVMT)	-0.002	0.005	0.000	-0.021	-0.021	-0.005	-0.014
	Peak PMDVMT in Any Given Month	-0.010	0.000	0.001	-0.021	-0.021	0.002	0.004
	Minimum PMDVMT in Any Given Month	-0.045	-0.057	0.000	-0.084	-0.084	0.006	0.088

Table 4-9. Bias-Adjusted Percentage of Interstate Accidents per million Vehicle-Mile Travel Data for a 36-Month Window (±18 months prior to and after conversion to digital billboard) of Accidents in the Viewer Reaction Zone of Digital Billboards on Interstate Route Sections

		Digital Billboard						
		1	2	3	4	5	6	7
Conventional Billboard (12 months prior to conversion)	Percentage of Accidents on Interstate per million DVMT (PMDVMT)	0.041	0.007	0.005	0.048	0.048	0.027	0.043
	Standard Deviation	0.036	0.027	0.013	0.044	0.044	0.034	0.067
	Peak PMDVMT in Any Given Month	0.113	0.096	0.036	0.128	0.128	0.103	0.140
	Minimum PMDVMT in Any Given Month	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Digital Billboard (12 months after conversion)	Percentage of Accidents on Interstate per million DVMT (PMDVMT)	0.037	0.027	0.006	0.037	0.037	0.031	0.055
	Standard Deviation	0.033	0.050	0.014	0.033	0.033	0.039	0.109
	Peak PMDVMT in Any Given Month	0.068	0.116	0.036	0.108	0.108	0.108	0.342
	Minimum PMDVMT in Any Given Month	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Difference (prior to and after conversion)	Percentage of Accidents on Interstate per million DVMT (PMDVMT)	-0.003	0.020	0.001	-0.010	-0.010	0.004	0.011
	Peak PMDVMT in Any Given Month	-0.003	0.023	0.001	-0.011	-0.011	0.005	0.042
	Minimum PMDVMT in Any Given Month	-0.045	0.021	0.000	-0.020	-0.020	0.006	0.202

Table 4-10. Bias-Adjusted Percentage of Interstate Accidents per million Vehicle-Mile Travel Data for a 24-Month Window (±12 months prior to and after conversion to digital billboard) of Accidents in the Viewer Reaction Zone of Digital Billboards on Interstate Route Sections

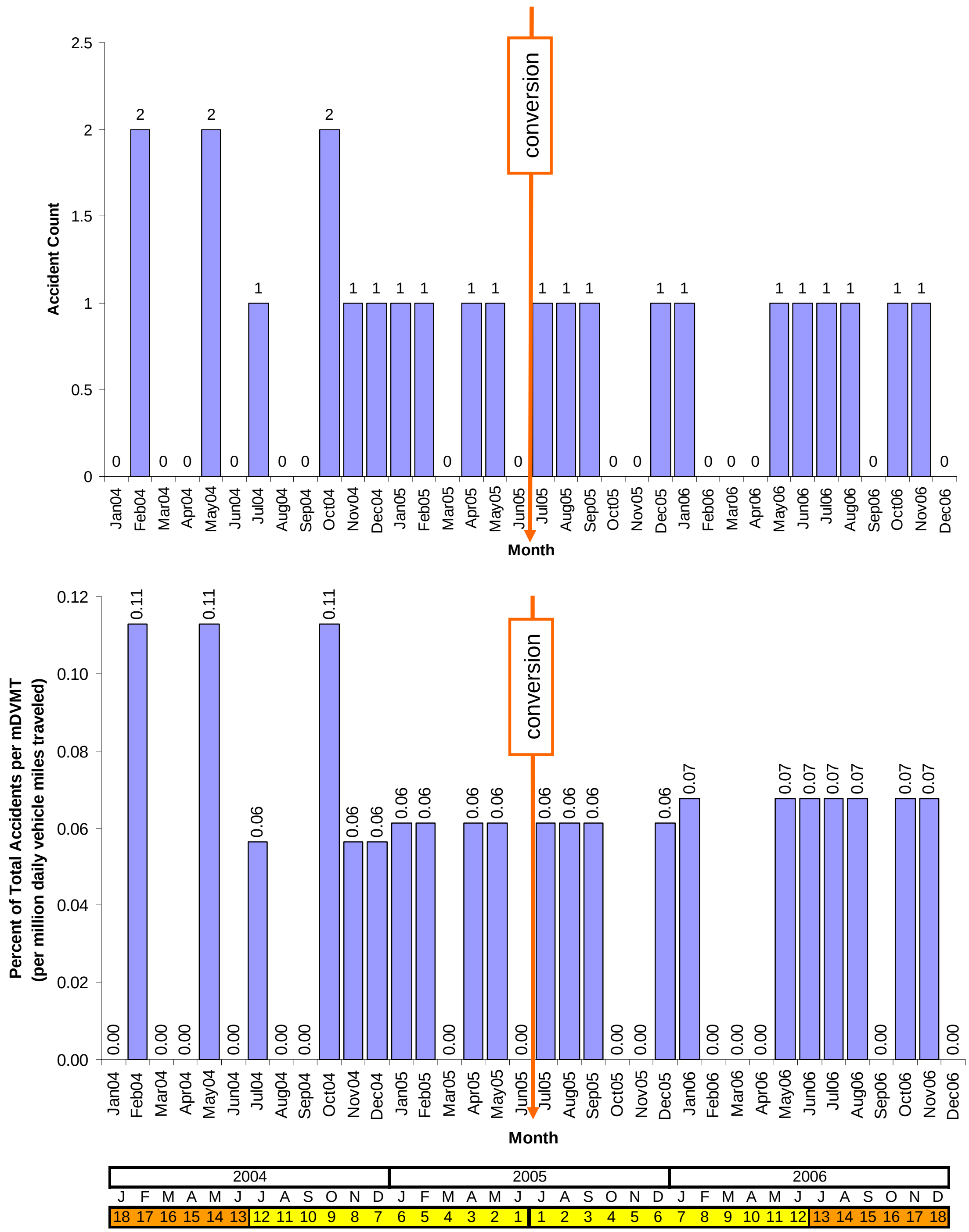


Figure 4-11. Bias-Adjusted Number of Accidents within visible range of Digital Billboard 1 (upper); Percentage of Total Accidents per million daily vehicle miles traveled, DVMT (lower)

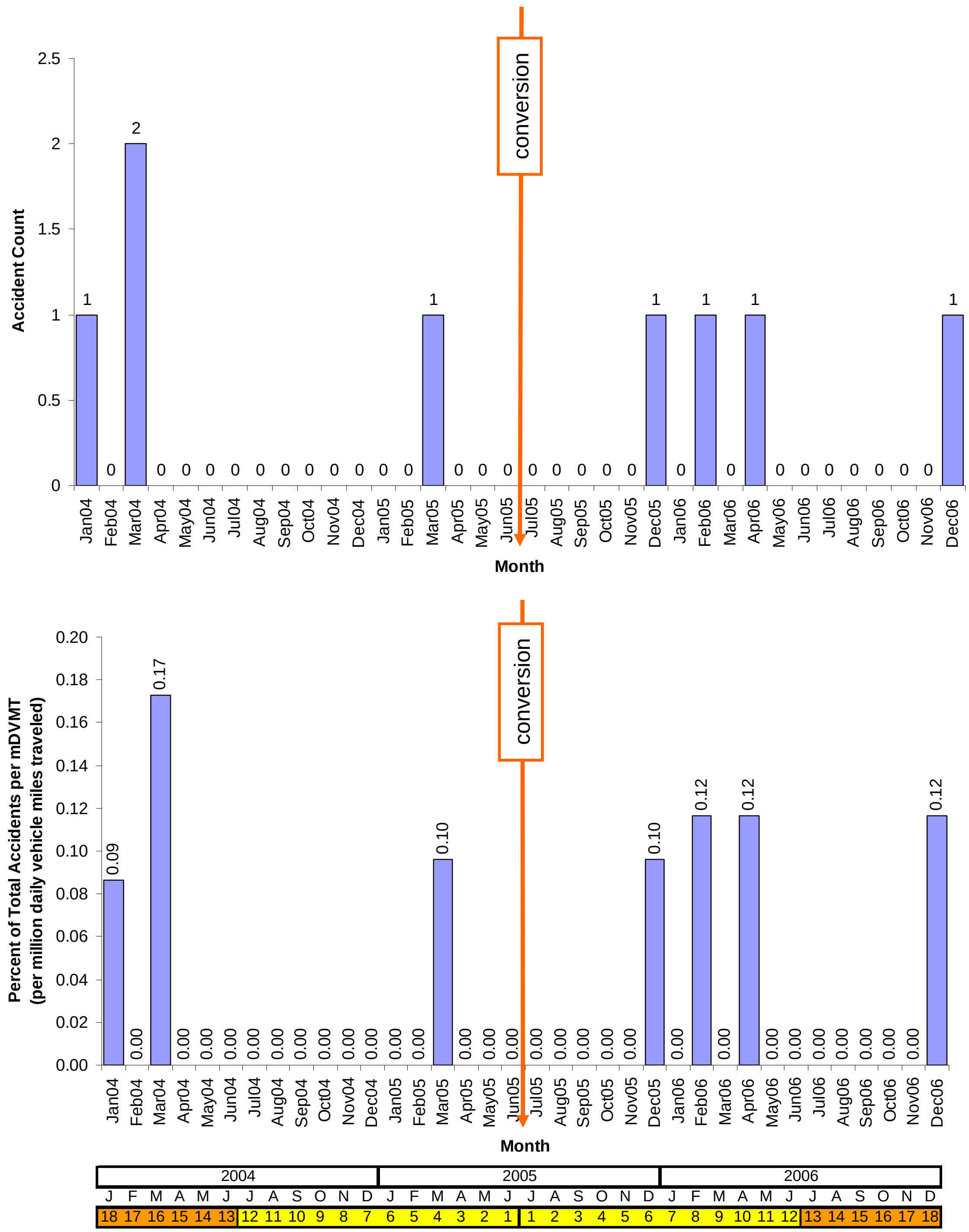


Figure 4-12. Bias-Adjusted Number of Accidents within visible range of Digital Billboard 2 (upper); Percentage of Total Accidents per million daily vehicle miles traveled, DVMT (lower)

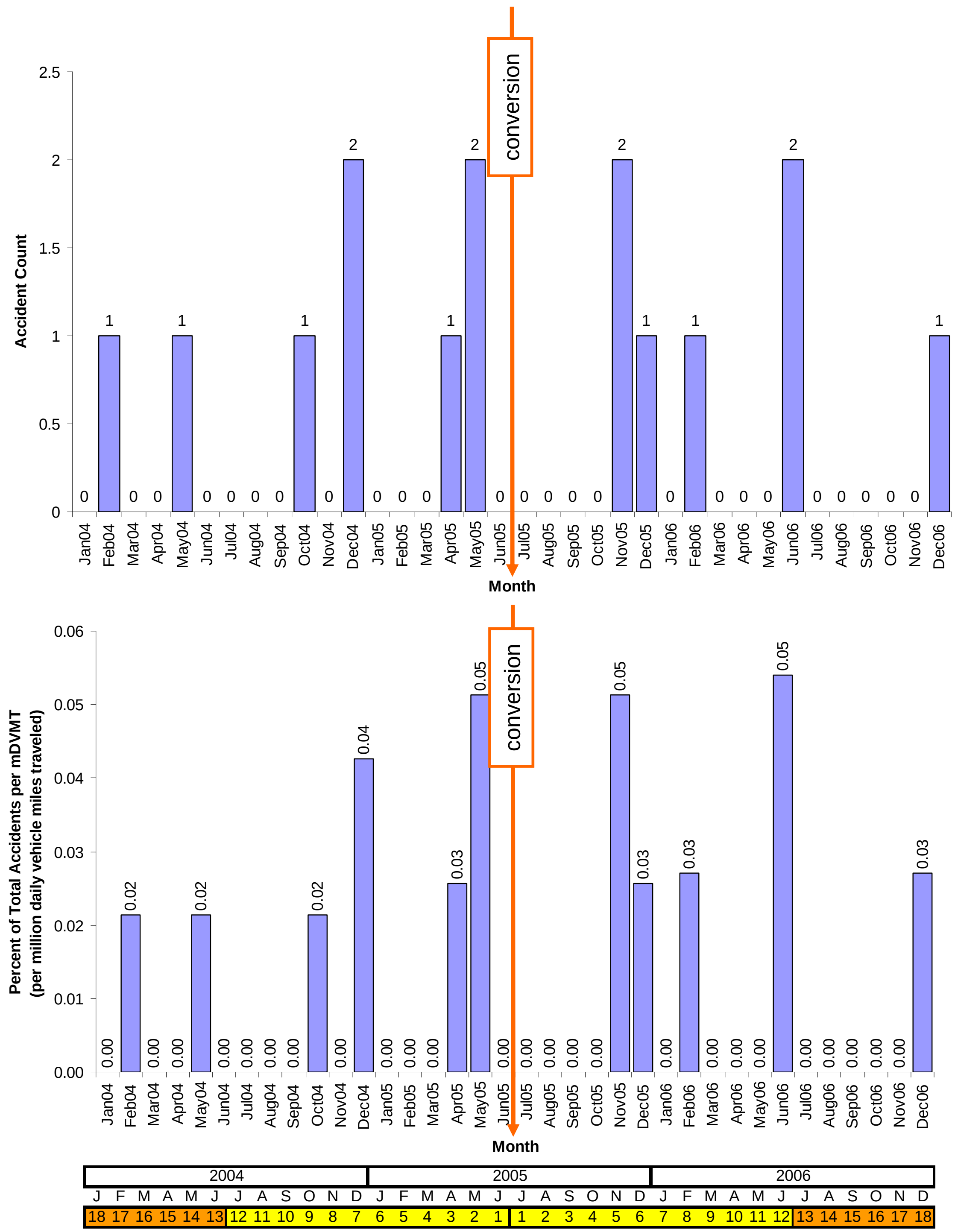


Figure 4-13. Bias-Adjusted Number of Accidents within visible range of Digital Billboard 3 (upper); Percentage of Total Accidents per million daily vehicle miles traveled, DVMT (lower)

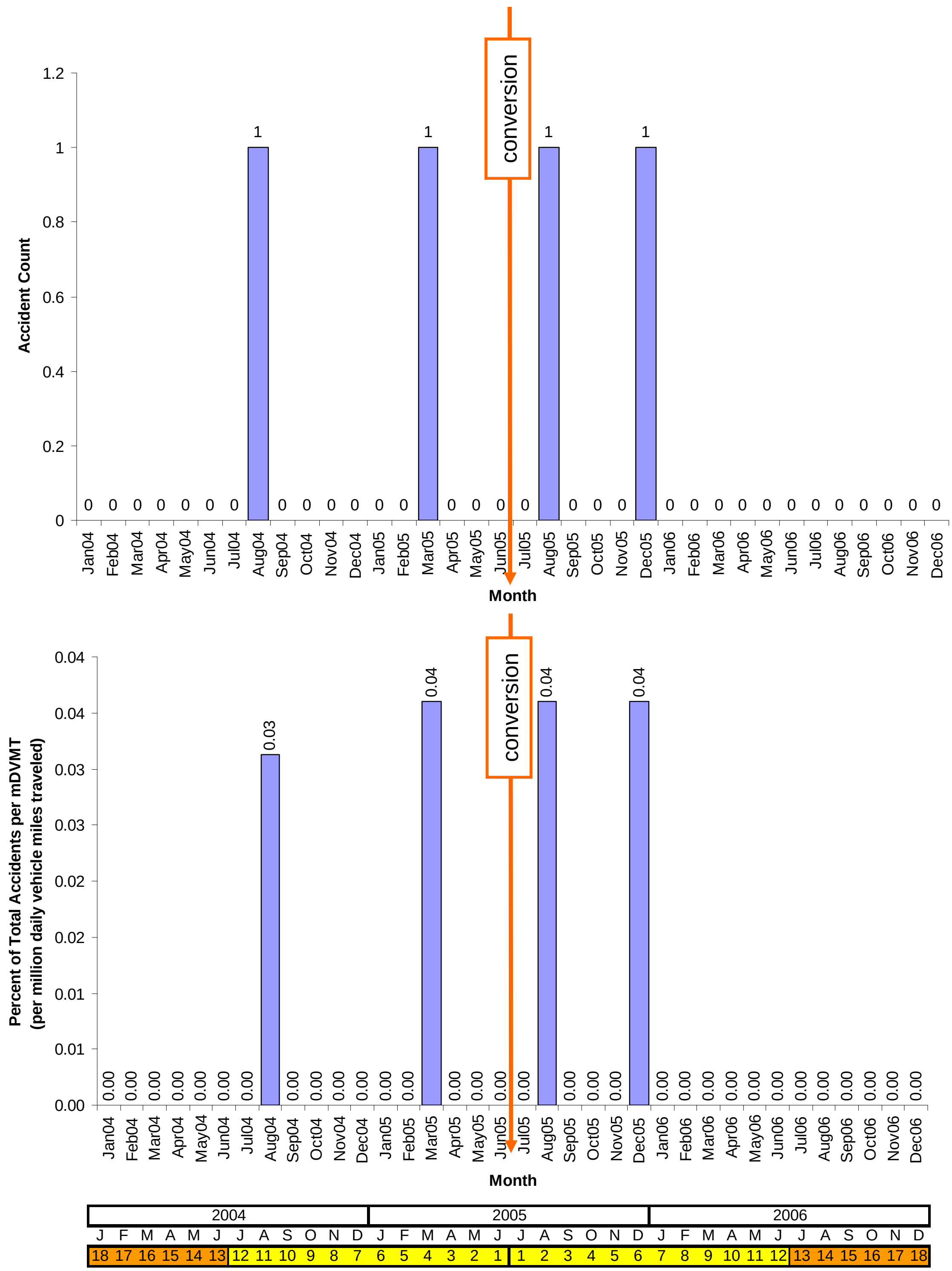


Figure 4-14. Bias-Adjusted Number of Accidents within visible range of Digital Billboard 4 (upper); Percentage of Total Accidents per million daily vehicle miles traveled, DVMT (lower)

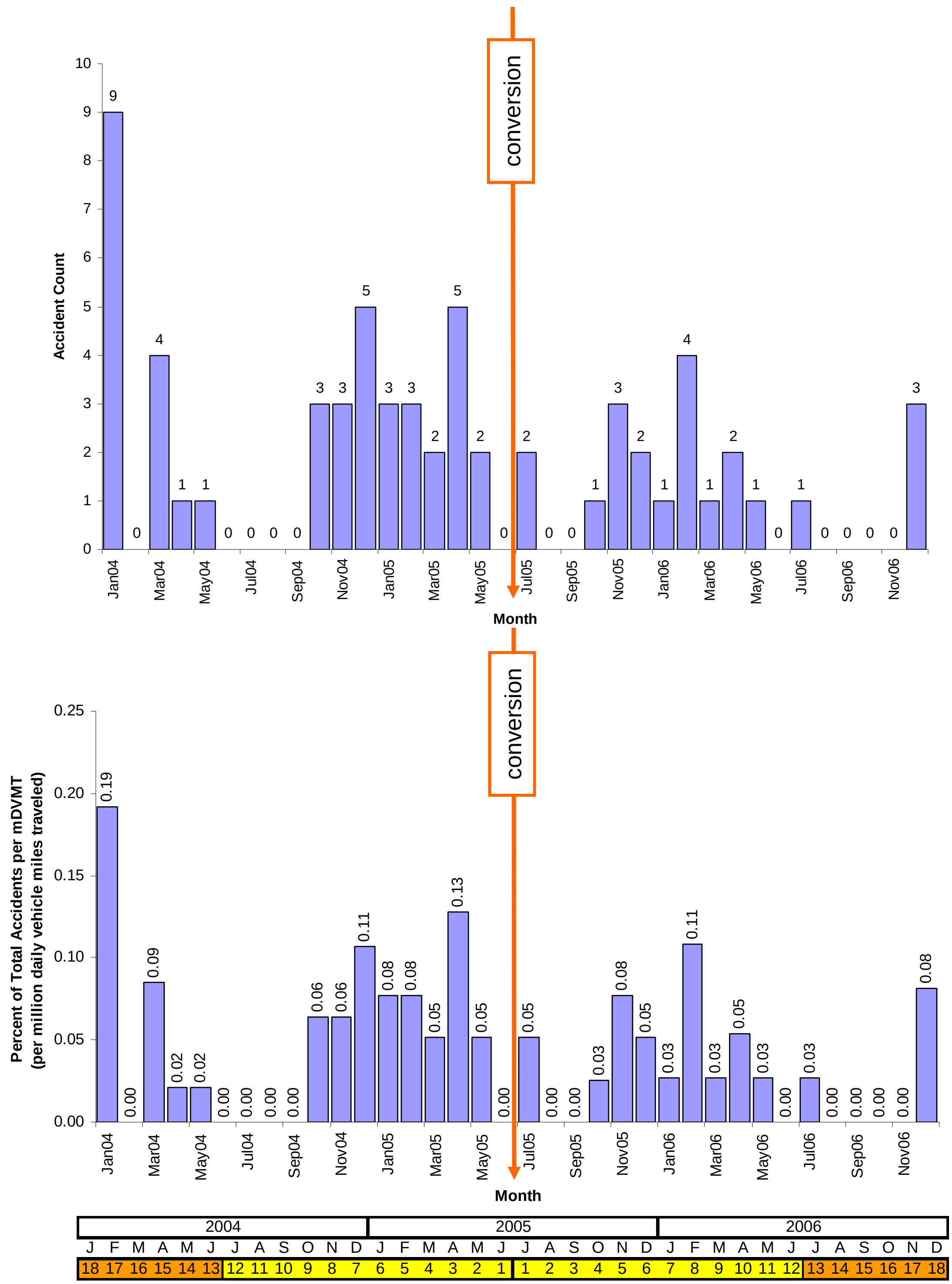


Figure 4-15. Bias-Adjusted Number of Accidents within visible range of Digital Billboard 5 (upper); Percentage of Total Accidents per million daily vehicle miles traveled, DVMT (lower)

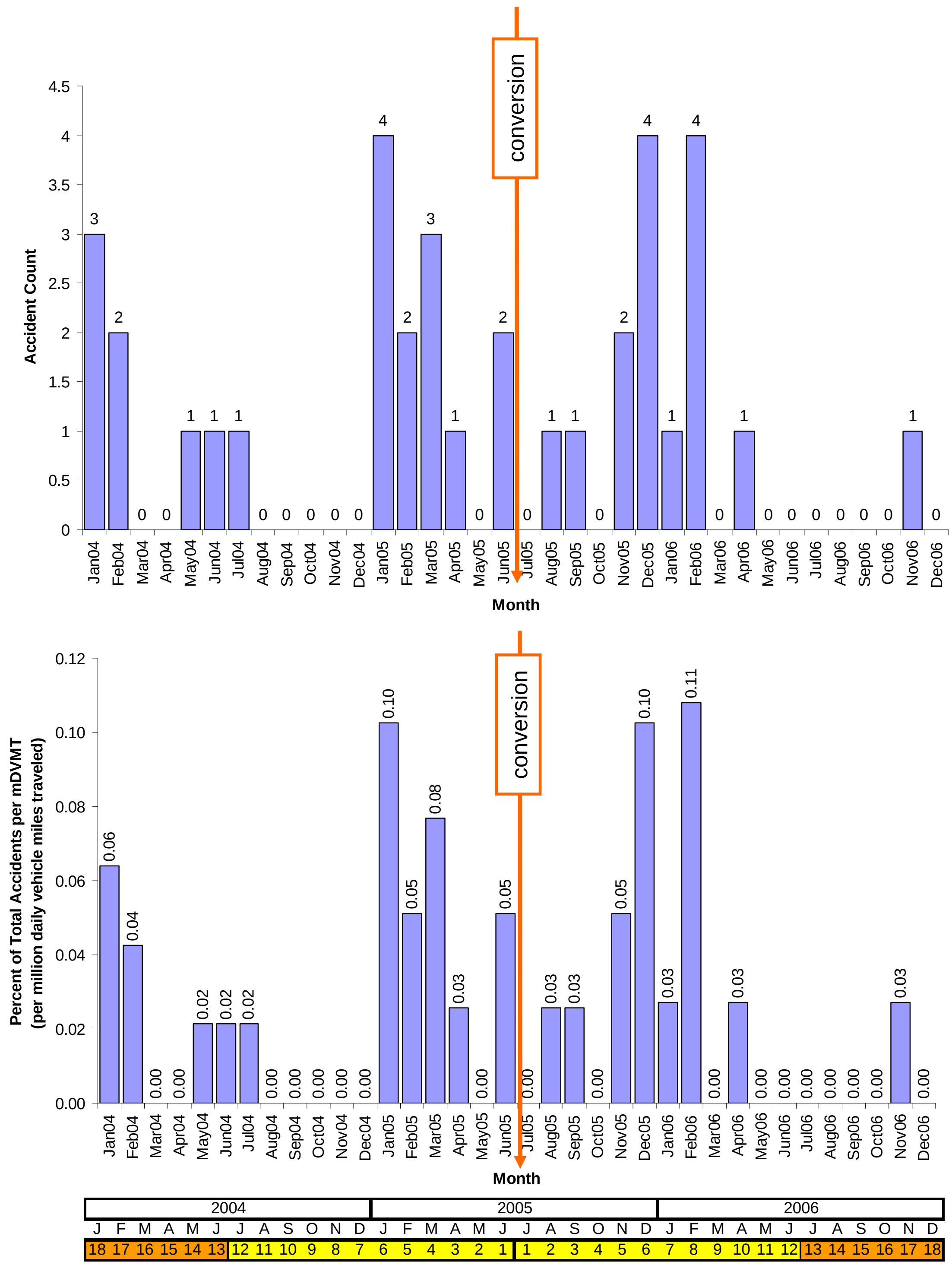


Figure 4-16. Bias-Adjusted Number of Accidents within visible range of Digital Billboard 6 (upper); Percentage of Total Accidents per million daily vehicle miles traveled, DVMT (lower)

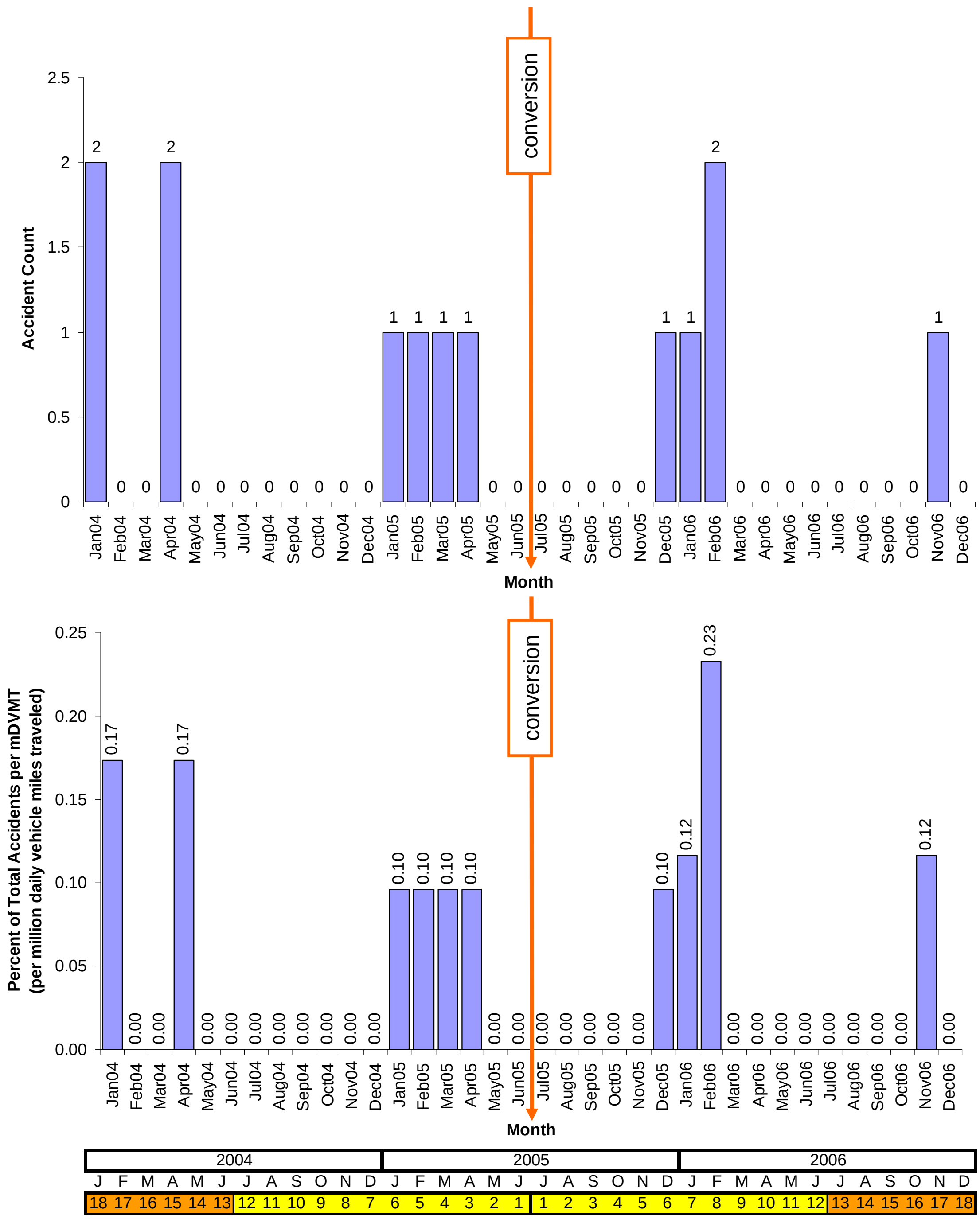


Figure 4-17. Bias-Adjusted Number of Accidents within visible range of Digital Billboard 7 (upper); Percentage of Total Accidents per million daily vehicle miles traveled, DVMT (lower)

4.4 Methodology: Spatial Analysis.

The objective of the spatial analysis is to study the correlation between traffic accidents and the digital billboards based on their route; that is, to examine whether traffic accidents occur more frequently at or near digital billboards on specific routes. These spatial sets of data are quantitatively compared using correlation coefficients. The procedure employed in this spatial study involves collecting accident information for a given route, analyzing and assembling the information into a useful format, identifying where digital and conventional billboards are located along the route, statistically analyzing the data by comparing the billboard locations and the accident locations, and calculating correlation coefficients for these sets of data.

Both the accident data and the billboard locations are assembled, or listed, by mile marker, so as to form a basis of comparison. Three comparisons of these variables are completed, including a comparison of

- Accident-Density and Billboard Density,
- Accident-Density and Viewer Reaction Distance, and
- Accident-Density and Proximity to the Billboards.

The above three comparisons are made for each of the six years examined in their aggregate, and for the specific cases 12 months before and 12 months after digital format. A quantitative measure of how well the data compared is obtained by using a statistical correlation coefficient. The results of the correlation coefficient analysis, and a discussion of correlation coefficients are in this section.

This study also examines a subset of traffic-accident data to assess its relationship to digital billboards. Once again, accident data was analyzed using all recorded Interstate accidents; the same analysis was additionally conducted by also excluded data with known bias. A fair and unbiased comparison of accident data would exclude accidents from known causes, as recorded in police accident reports. In this subset analysis of unbiased data, the excluded accidents were those recorded (1) with drivers under the influence of alcohol or drugs, (2) animal-related accidents (typically drivers hitting deer), (3) drivers in accidents located at on-ramps and off-ramps (drivers undertaking additional operations for lane-changes, decelerating), and (4) accidents during adverse weather conditions (specifically only accidents recorded during snowfall or with icy roads). These bias-exclusion criteria were used in bias-data subset analyses in this study. Correlation coefficients are calculated with the same accident data, however excluding known causes (adverse weather, DUIs, etc) and those accidents and billboards on interchanges (entrances/exits) within one mile (1/4 mile on each side of an interchange). Accident data near interchanges have the potential to statistically bias the results, because drivers undertake additional tasks such as lane changes, accelerating/decelerating, negotiating directions, and attention to others undertaking these additional tasks. These added factors could statistically bias and dilute a study of accident data when compared to typical conditions of "straight" driving.

A. Accident Density and Billboard Density.

This study defines accident density as the number of accidents per mile marker (every tenth of a mile). The billboard density, S_m^D, is defined as the number of billboards per mile, and is determined using a moving average of the number of billboards at each mile marker with a "window size" of one mile, and may be expressed by:

$$\left\{ S_m^D \ = \ \sum_{i=1}^{Q} \left[s_i \,\middle|\, m - 0.5 \le s_i \le m + 0.5 \right], \ m \ = \ 0, \ 0.1, \cdots, \ M \right\}$$

where s_i is the *ith* billboard's mile-marker location, and Q is the number of billboards observed along M, which is the total length of the particular Interstate route in miles.

Billboard density, that is, the average number of billboards (conventional and digital) per mile, varies along the length of the Interstates. If a noticeable correlation between billboards and accidents exists, then one would expect a significantly larger number of accidents in areas with relatively high billboard densities. The basis for evaluating the relationship between billboard locations and accident locations is the correlation coefficient. The correlation coefficient (ρ) between billboard density, S^D, and accident density, A^D, may be calculated using:

$$\rho \ = \ \frac{\sum_m (A_m^D - \bar{A}^D)(S_m^D - \bar{S}^D)}{\sqrt{\sum_m (A_m^D - \bar{A}^D)^2 \sum_m (S_m^D - \bar{S}^D)^2}}, \ m \ = \ 0, \ 0.1, \cdots, \ M$$

Table 4-11 shows the correlation coefficients with their corresponding data for the individual and aggregate years between 2001 and 2006. Figure 4-18 shows commonly accepted interpretations of correlation coefficients and visual scatter plots to emphasis what various correlation coefficients might represent.

B. Accident Density and Viewer Reaction Distance (VRD).

Accident density, A_m^D, was previously defined as the number of accidents per mile marker (every tenth of a mile). Viewer Reaction Distance (VRD) is a measure of the distance in which a driver has time to "notice" or react to a billboard which is in the driver's field of vision. The VRD is the distance to a billboard in which the driver is potentially within the "influence" of a billboard. Analogously, Viewer Reaction Time (VRT) is the time a driver is within the "influence" of a billboard. Reasonable values for VRD were determined as a function of the driver's speed. The posted speed limit on the Interstates is 65 mph; this approximately corresponds with a VRD of approximately 0.2 miles and a VRT of 10 seconds. This study uses a binary index, V_m^{VRD}, to represent if a given mile marker is within the VRD, and is represented as

$$\left\{ V_m^{VRD} = \begin{cases} 1, & d_m \le VRD \\ 0 \text{ otherwise} \end{cases}, \; m = 0, \; 0.1, \cdots, \; M \right\}$$

where d_m is the distance to the nearest billboard location for m*th* mile marker, VRD is 0.2 (the viewer reaction distance corresponding to a 10 second VRT at the 65 mph on the Interstate routes), and M is the total length of the particular Interstate route in miles. The index d_m is defined as

$$\left\{ d_m = \min\left(\left\{ |s_i - m|, i = 0, 1, \cdots, Q \right\}\right), \; m = 0, \; 0.1, \cdots, \; M \right\}$$

where s_i is the ith billboard's mile marker location and Q is the number of billboards observed.

The correlation coefficient between accident density, A^D, and viewer reaction distance, V^{VRD}, is calculated similar to that which was previously defined. Correlation coefficients are determined for data that are within 0.2 miles of the nearest billboard, based on the previous discussion of Viewer Reaction Distance. If a noticeable correlation between digital billboards and accidents exists, then one would expect significant increases in the number of accidents occurring 0.0 to 0.2 miles from the digital billboard.

C. Number of Accidents and Proximity to Billboards.

Accident density, A_m^D, was previously defined as the number of accidents per mile marker (one tenth of a mile). An index, P_m, is used to represent proximity to a billboard, and is simply the distance from an individual mile marker to the nearest billboard. P_m may be expressed by:

$$\left\{ P_m = \left| d_m - m \right|,\ m = 0,\ 0.1,\ \cdots,\ M \right\}$$

where d_m is the distance to the nearest billboard location for mth mile marker and M is the total length of the Interstate route in miles. The correlation coefficients between billboard proximity indices, A^D, and accident density, V^{VRD}, are similar to that previously defined.

Correlation coefficients are determined for data that are within 0.4 miles of the nearest billboard. Based on the previous discussion of Viewer Reaction Distance (VRD), 0.4 miles is twice the 0.2 mile VRD value. If a noticeable correlation exists between digital billboards and vehicle accidents, then one would expect significant increases in the number of accidents between the 0.0 and 0.2 mile range and between the 0.2 and 0.4 mile range; the correlation coefficient would be large (close to $\pm$ 0.7 or greater). However, these correlation coefficients are actually close to zero, indicating almost statistical independence; that is no statistical relationship between digital billboards and traffic accidents. Further, when known-cause statistical bias is excluded, these correlation coefficients move closer to zero, suggesting no causal relationship.

4.5 Results: Spatial Analysis.

This study seeks to evaluate whether the digital billboards had an influence on the occurrence of traffic accidents. As discussed, a useful measure of compliance ("association") between two sets of data (billboards and traffic accidents) is the correlation coefficient. If the variables "tend" to go up and down together, then the correlation coefficient will be positive. If the variables "tend" to go up and down in opposition with each other, than the correlation coefficient will be negative. By definition, a correlation coefficient can be no larger than +1, and no smaller than -1. Values at, or very near to, +1 indicate a perfect one-to-one correlation, and values at, or very near to, -1 indicating perfect inverse correlation. Values at or near zero indicate statistical independence of one set of data with respect to the other. Statistically, a correlation coefficient of 0.7 or smaller is considered to indicate "weak" correlations, at best, and does not indicate much difference from correlation coefficients of zero. It is important to note that correlation is not necessarily causation, even though it may be an indicator.

Table 4-11 lists the correlation coefficients obtained for the relationships examined in this study, namely:

- Accident Density and Billboard Density,
- Accident Density and Viewer Reaction Distance, and
- Accident Density and Proximity to Billboard.

Figures 4-19 through 4-22 show the correlation coefficient results mapped on a scale of "association" for each Interstate. All correlation coefficients are close to zero and within the "no association" range.

As seen in Table 4-11 and in Figures 4-19 through 4-22, the correlation coefficients for accident density and billboard density are all statistically low, with coefficients ranging between -0.217 to +0.270. Similar low-value, "no association" correlation values are calculated when accident density and viewer reaction distances are compared; value range from -0.102 to +0.014. Comparisons between accident density values and their distances to the nearest billboard, digital or conventional, yield coefficients ranging between -0.208 to +0.005.

Table 4-11 also shows the correlation coefficients for number of accidents by milemarker for Interstates for 12 months before and after digital conversion. These correlation coefficients compare accident location before and after with no account for billboards and are high, close to one and suggest a "strong association". This association, as shown in Figures 4-30 through 4-33, supports the observation that, with or without digital billboards, accident milemarker locations are strongly correlated, and that a location with many accidents is likely to have many accidents from year to year; or conversely, few accidents from year to year. Generally, when billboards and accidents from bias data are excluded, almost all the coefficients are closer to zero.

Also of note is the fact that the correlation coefficients are relatively consistent from digital billboard to digital billboard within each category on each Interstate. We note that there are no large increases or decreases of the coefficients exist from one year to another. This consistency positively influences the confidence in the study results. Additionally, preliminary calculations were performed to account for variations in traffic volume along the Interstate routes. When the discrete values for accident density are weighted by average yearly Interstate volume rates, the resultant correlation coefficients move closer to zero in all cases.

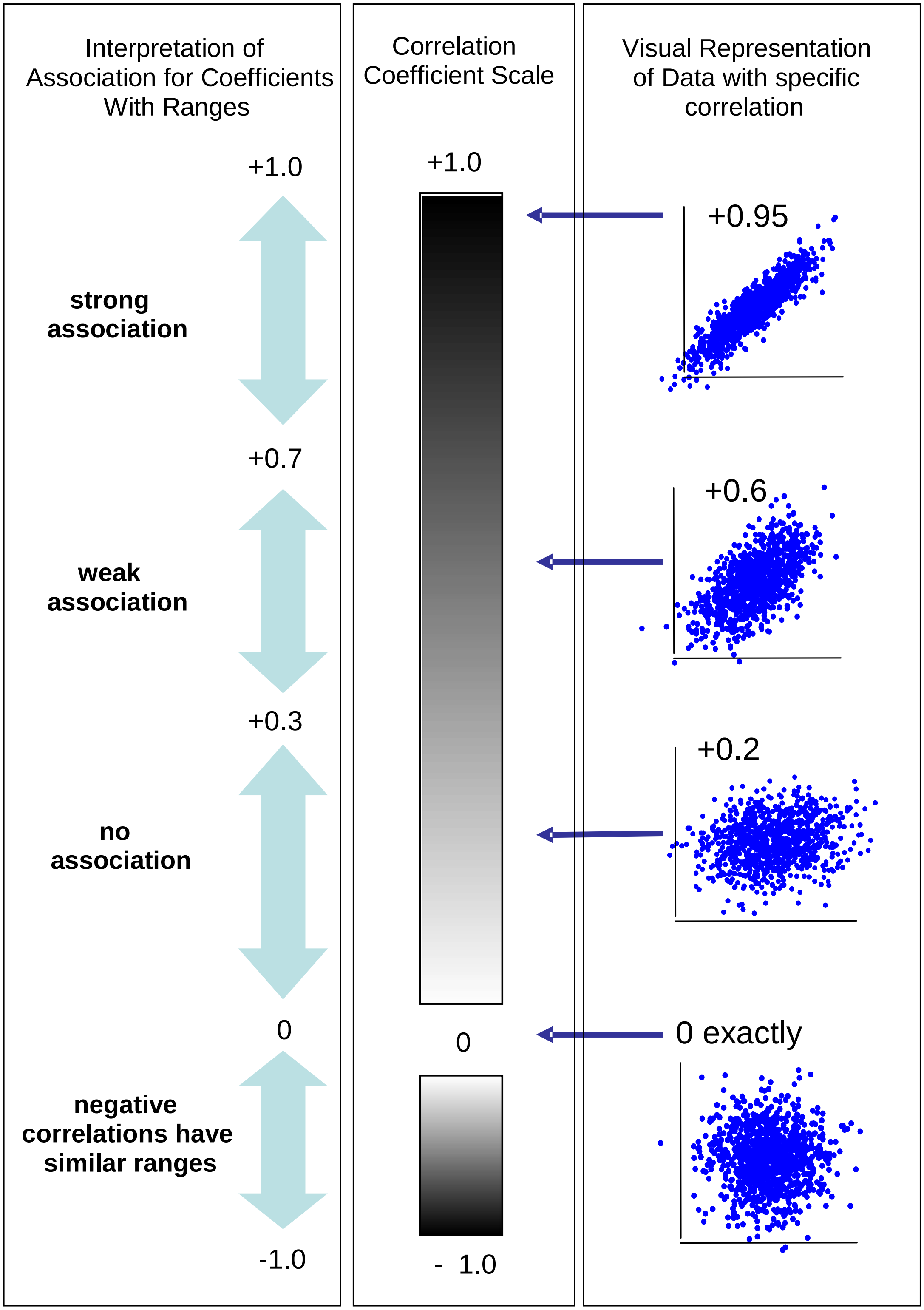


Figure 4-18. Conceptual Representation of Correlation Coefficient Scale Depicting Ranges with Strong, Weak and no Association.

Correlation Variables	Time Range of Data	Interstate I-77	Interstate I-90	Interstate I-271	Interstate I-480	Largest Correlation Coefficient (+ or -)
Accident Density vs. Billboard Density	All years (2001-2006)	-0.042	0.270	-0.217	0.096	-0.270
	12 months prior to conversion	-0.024	0.263	-0.052	0.117	0.263
	12 months after conversion	0.047	0.215	-0.157	0.058	0.215
Accident Density vs. VRD	All years (2001-2006)	-0.095	-0.062	-0.075	-0.002	-0.095
	12 months prior to conversion	-0.102	-0.069	-0.050	0.014	-0.102
	12 months after conversion	-0.088	-0.071	-0.065	-0.020	-0.088
Accident Density vs. Proximity to Billboard	All years (2001-2006)	-0.091	-0.170	0.011	-0.111	-0.170
	12 months prior to conversion	-0.084	-0.208	-0.016	-0.108	-0.208
	12 months after conversion	-0.103	-0.172	0.005	-0.127	-0.172
Accident Density in 12 months after vs. 12 months prior		0.873	0.961	0.963	0.902	0.963

Table 4-11. Correlation Coefficients of Various Comparisons for Interstates

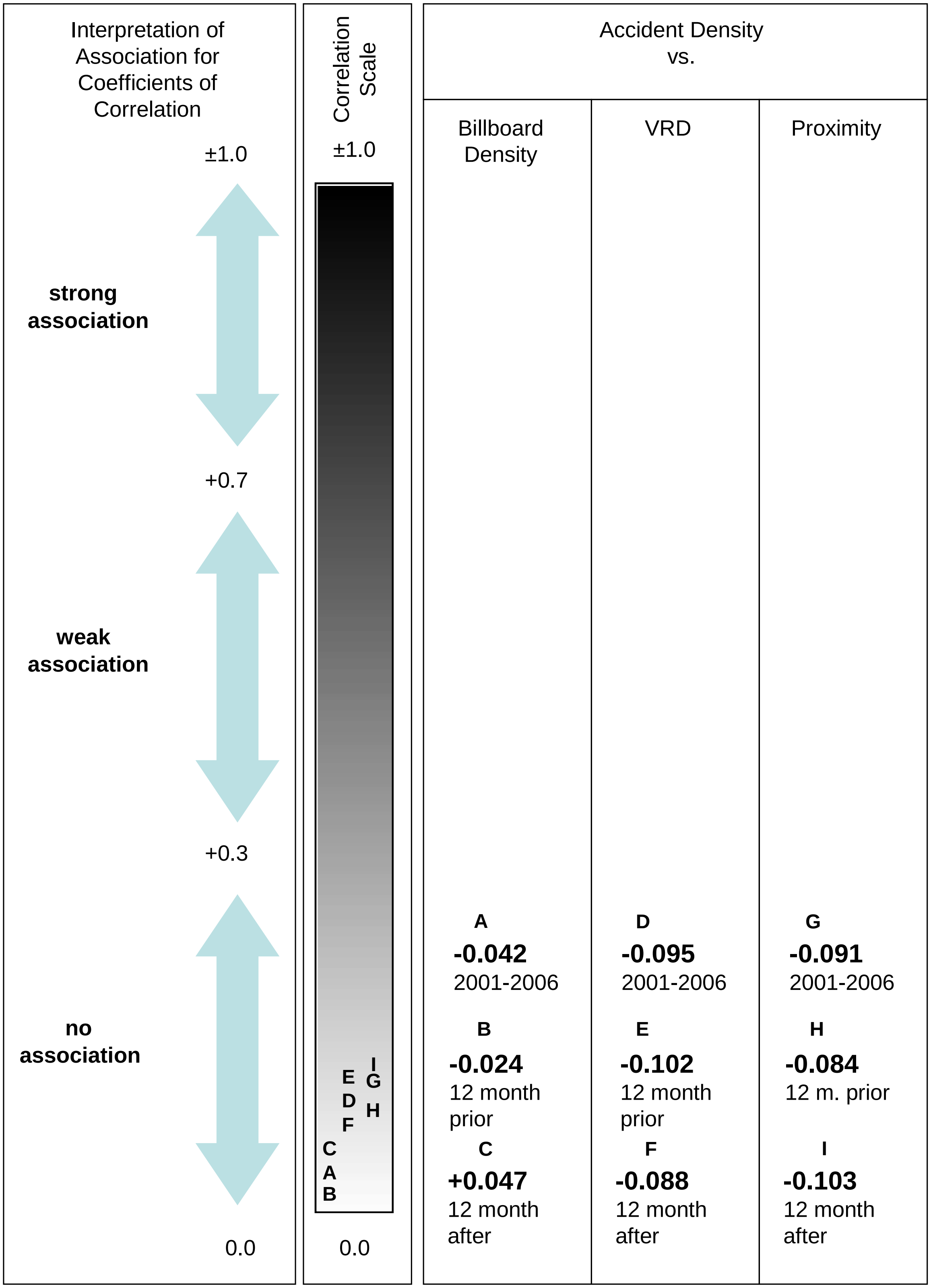


Figure 4-19. Correlation Coefficients on Association Scale for I-77

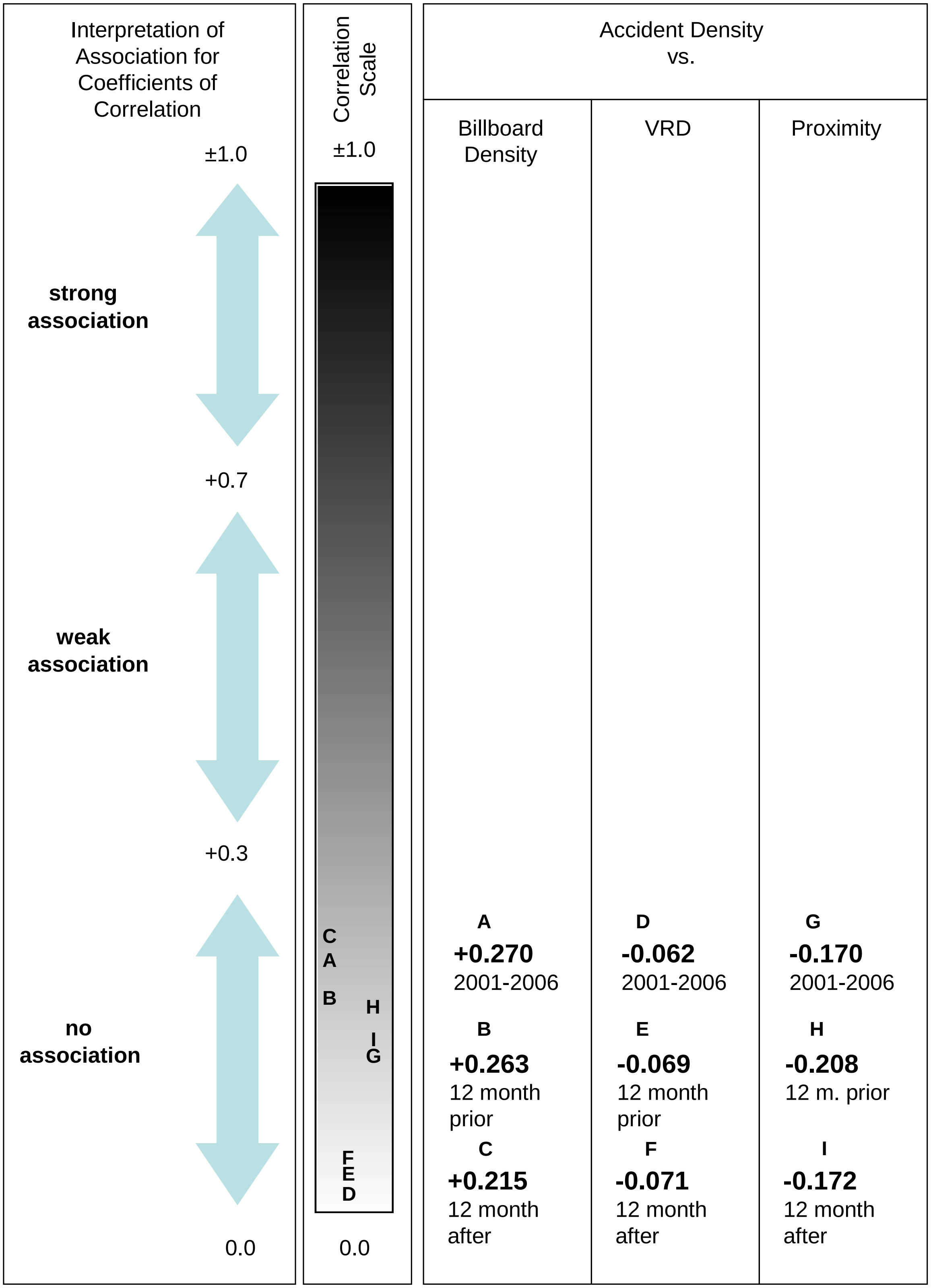


Figure 4-20. Correlation Coefficients on Association Scale for I-90

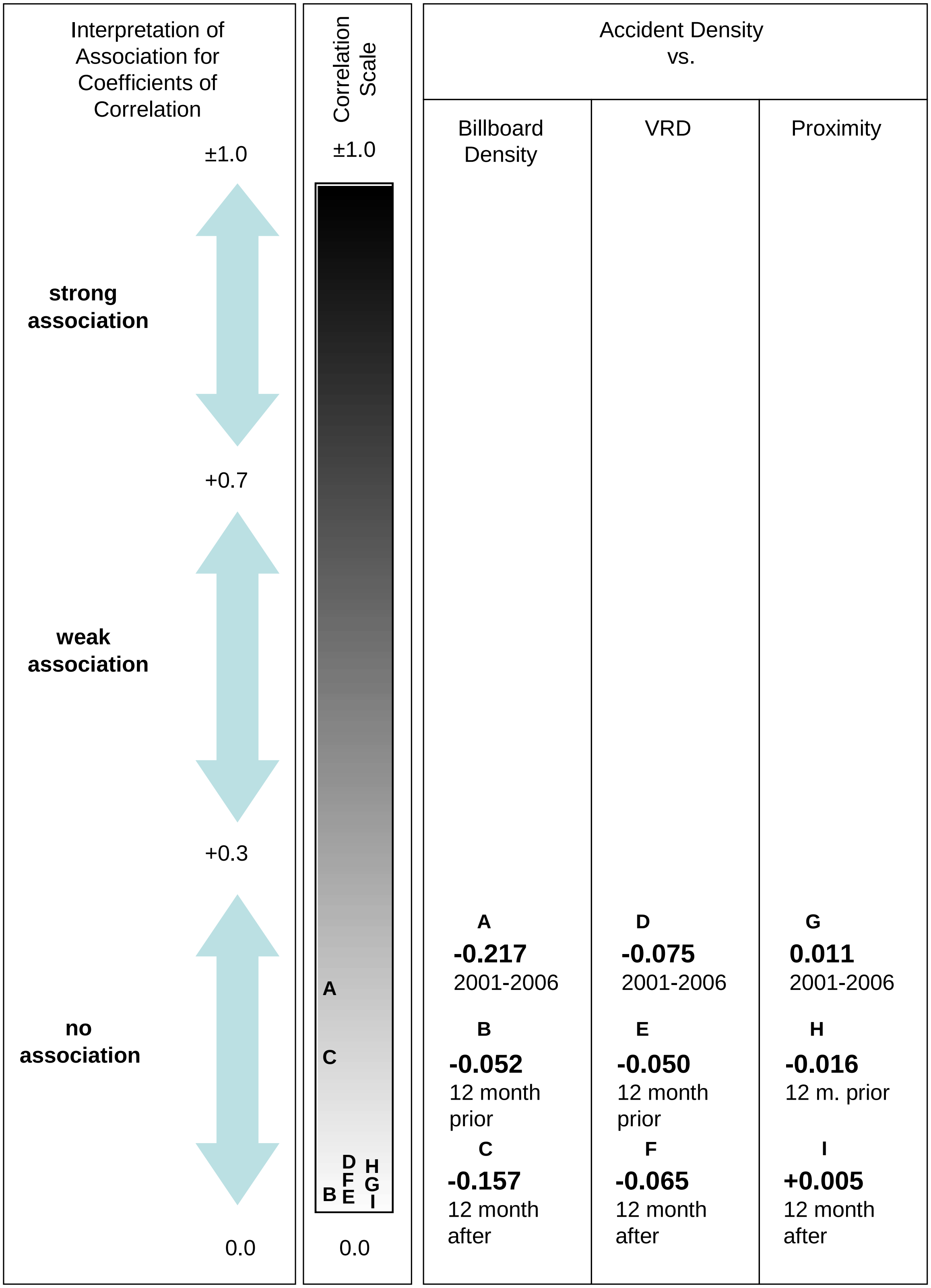


Figure 4-21. Correlation Coefficients on Association Scale for I-271

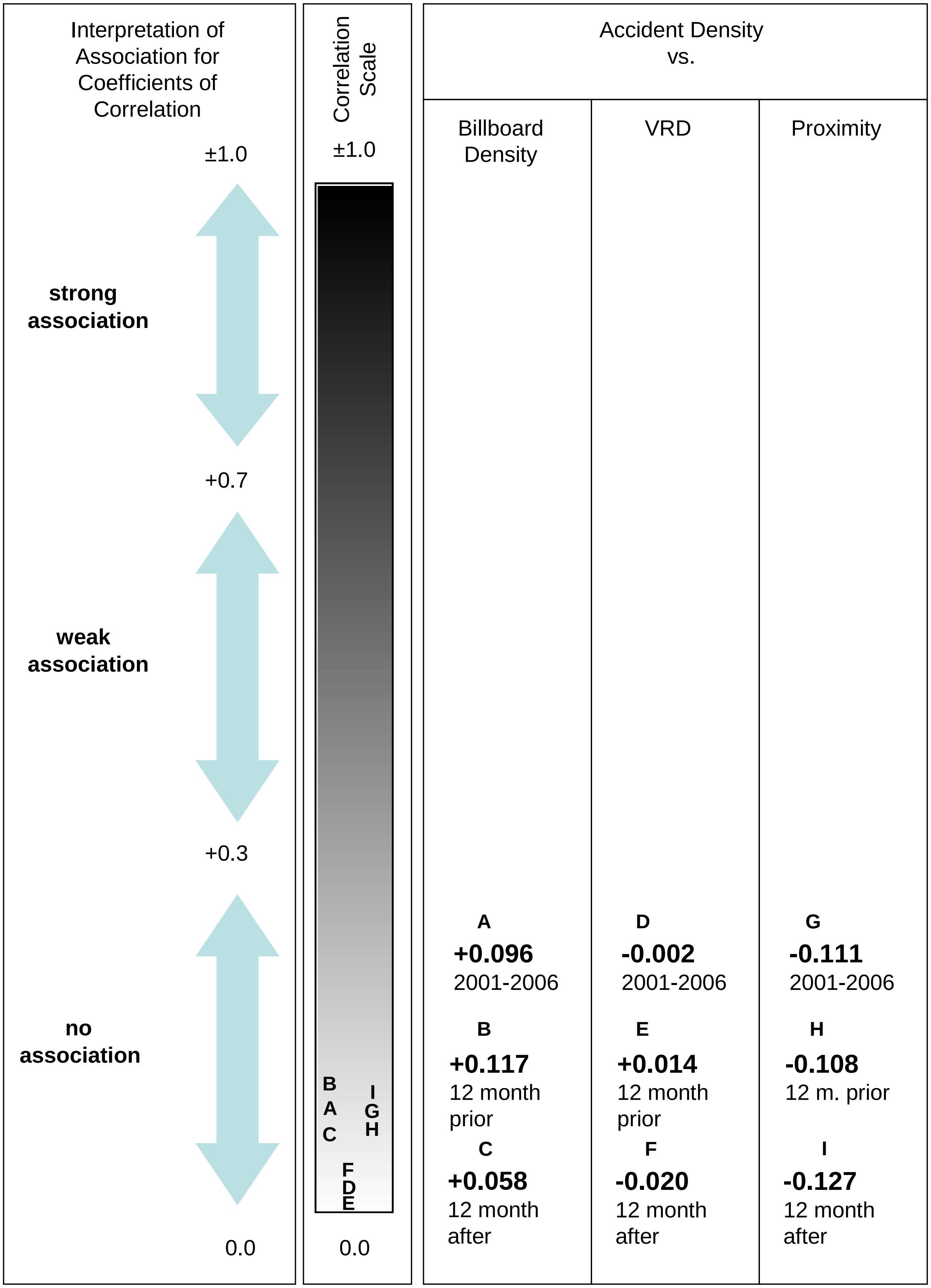


Figure 4-22. Correlation Coefficients on Association Scale for I-480

Figure 4-23 shows the geocoded locations of accidents between 2001 and 2006 on Interstates routes. Figures 4-24 and 4-25 show the relative spatial distribution of accidents per volume (APV) along the Interstates; the sign locations and approximate VRD zones (yellow boxes) are shown. In additional to digital billboards, these figures also show the locations of conventional ones. Lengths of interstate with digital or conventional have statistically comparable APV ratios at locations near segments without any billboards. Accidents occur on interstates with or without billboards. This observation is further reinforced by the correlation coefficients that were calculated between accident milemarker locations from year-to-year as shown in Figures 4-30 through 4-33. These values are evaluated independently of any billboard information (the last row shown in Table 4-11). The values are well-correlated and in the "strong association" range. Figure 4-26 through 4-29 show hotspots of the number of accidents along interstates. In these figures, the accident counts are not adjusted for traffic volumes.

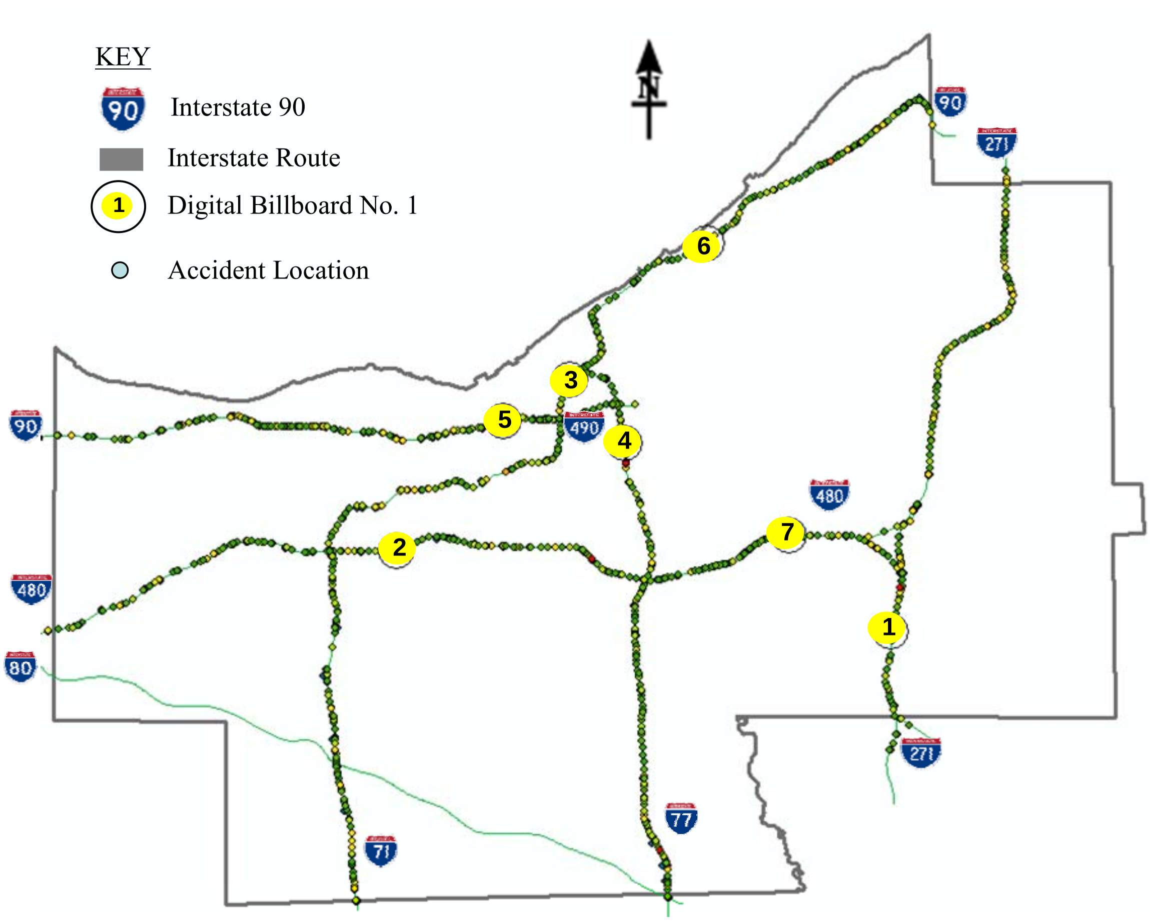


Figure 4-23. Geocoded Accidents between 2001 and 2006 on Cuyahoga County Interstates

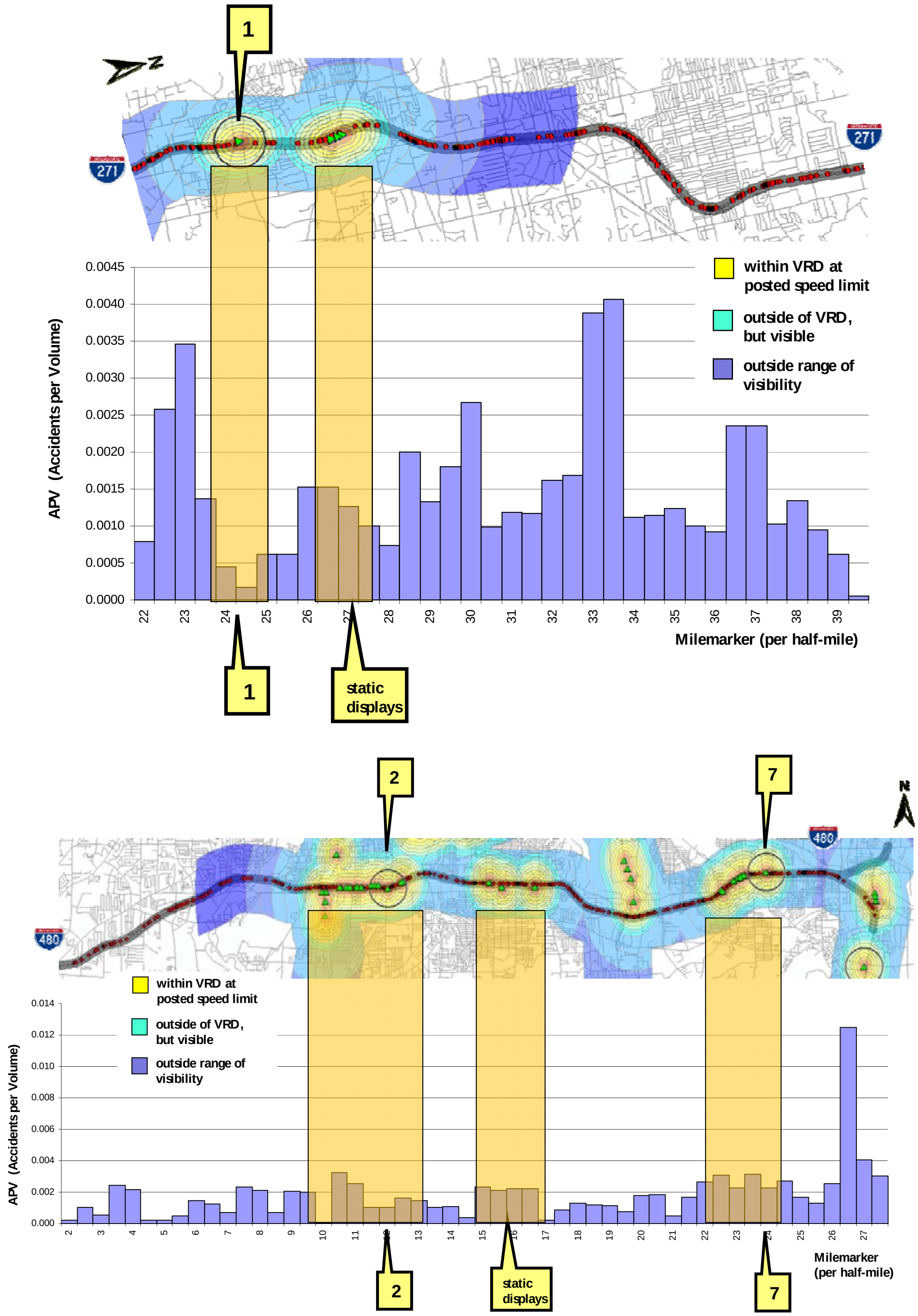


Figure 4-24. Summary Statistics of Accidents per Volume within Viewer Reaction Zone of Digital Billboards 1, 2, and 7 for Interstate 271 (upper) and Interstate 480 (lower) [conventional billboards also shown]

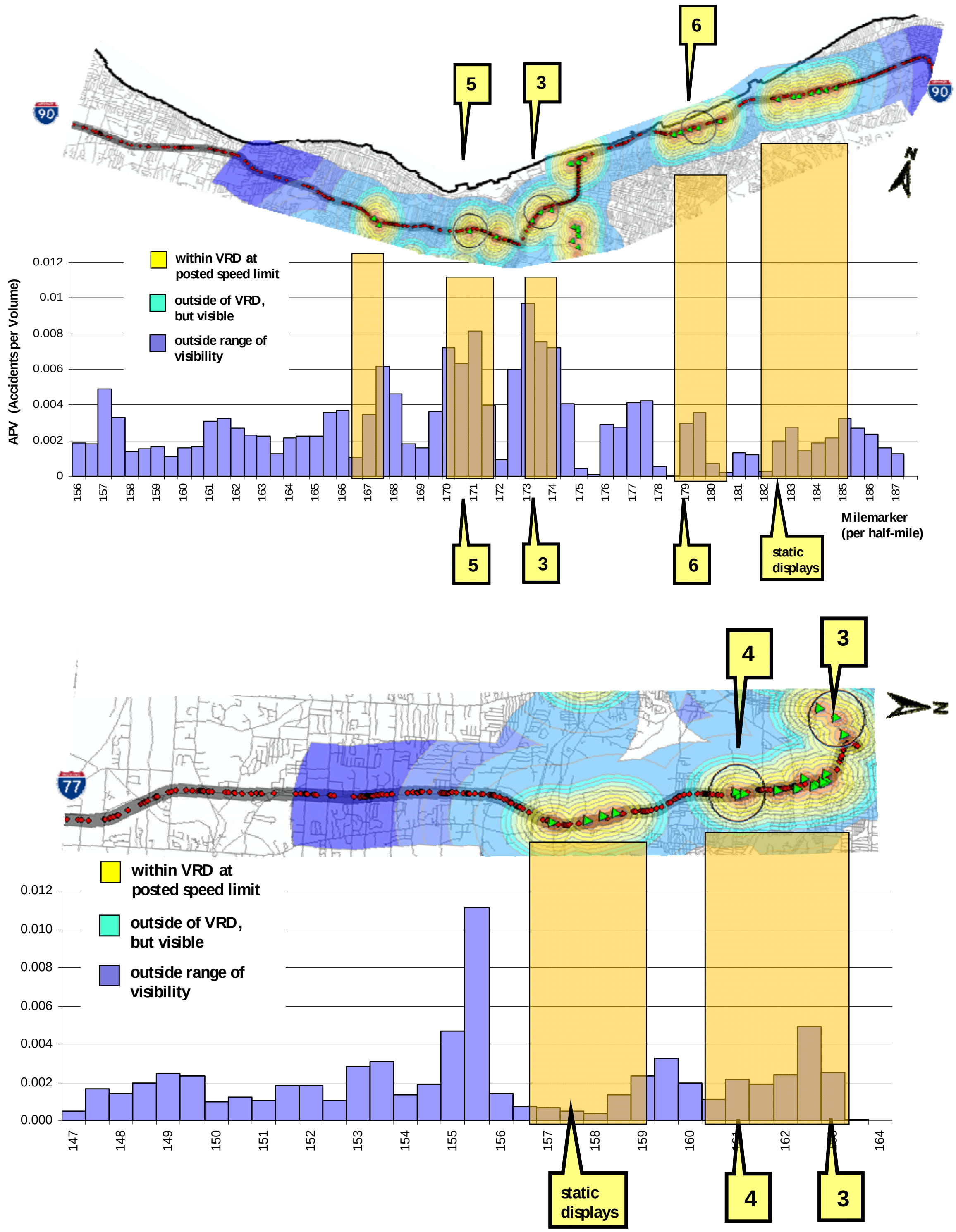


Figure 4-25. Summary Statistics of Accidents per Volume within Viewer Reaction Zone of Digital Billboards 3, 4, 5, and 6 for Interstate 90 (upper) and Interstate 77 (lower) [conventional billboards also shown]

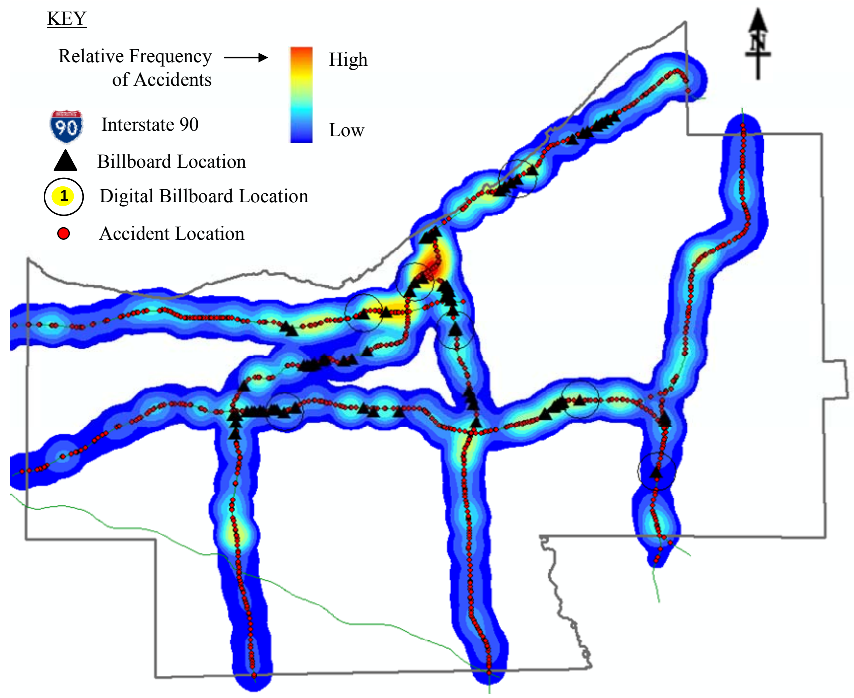


Figure 4-26. Accident Density Hotspots showing locations of conventional and digital billboards and locations of accidents between 2001 and 2006

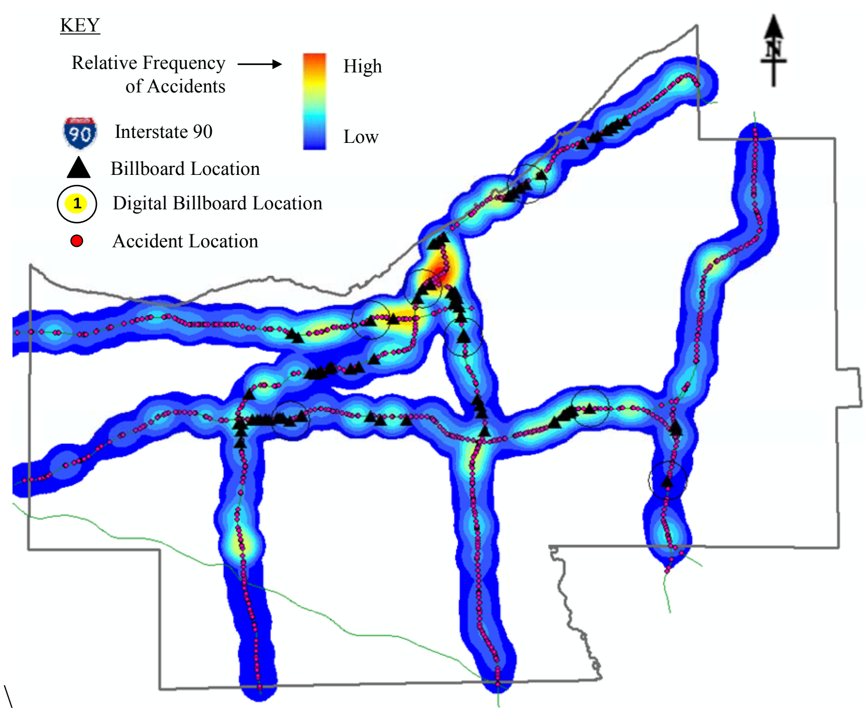


Figure 4-27. Accident Density Hotspots showing locations of conventional and digital billboards and locations of bias-excluded accidents between 2001 and 2006

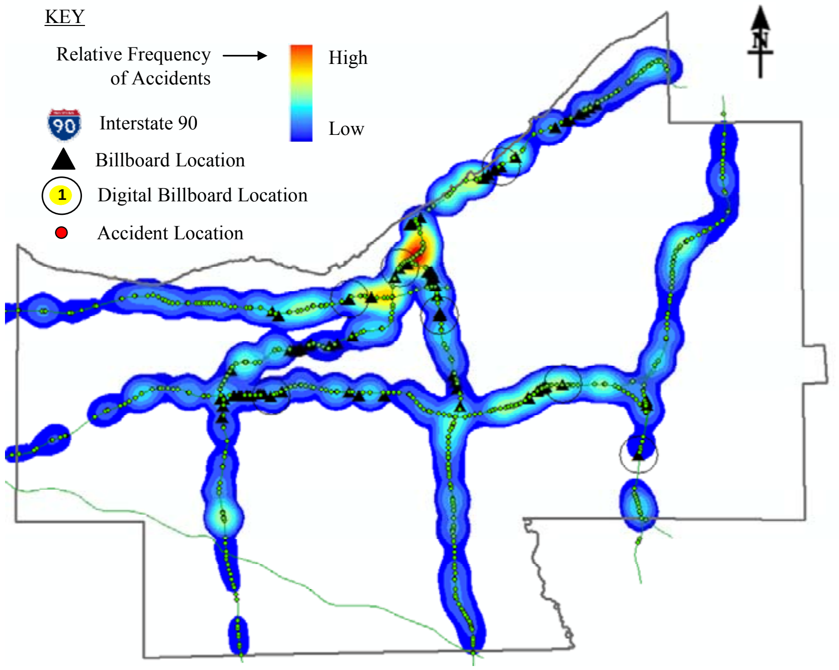


Figure 4-28. Accident Density Hotspots showing locations of conventional and digital billboards and locations of bias-excluded accidents in one year prior to digital sign conversion

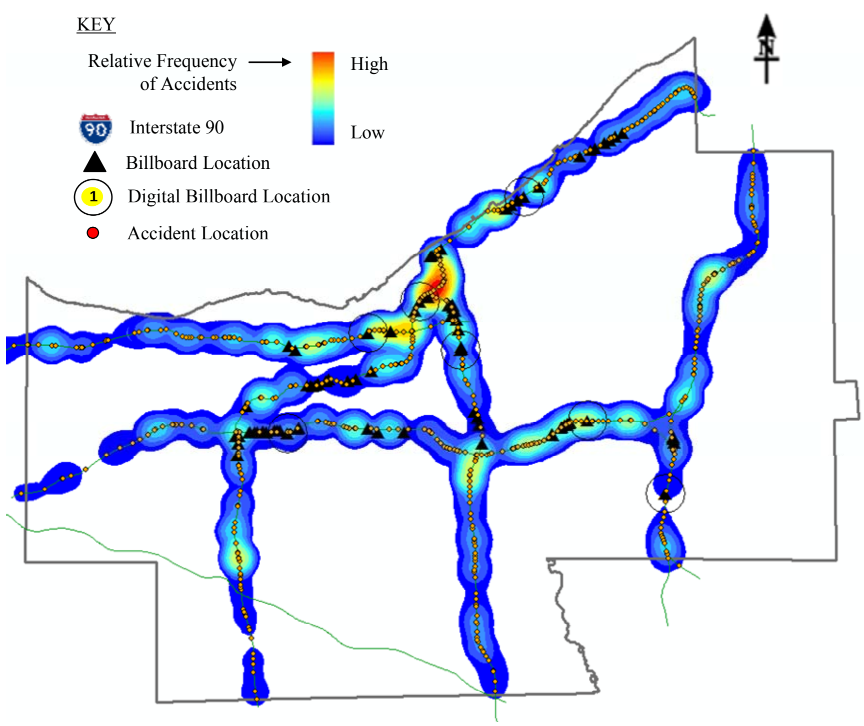
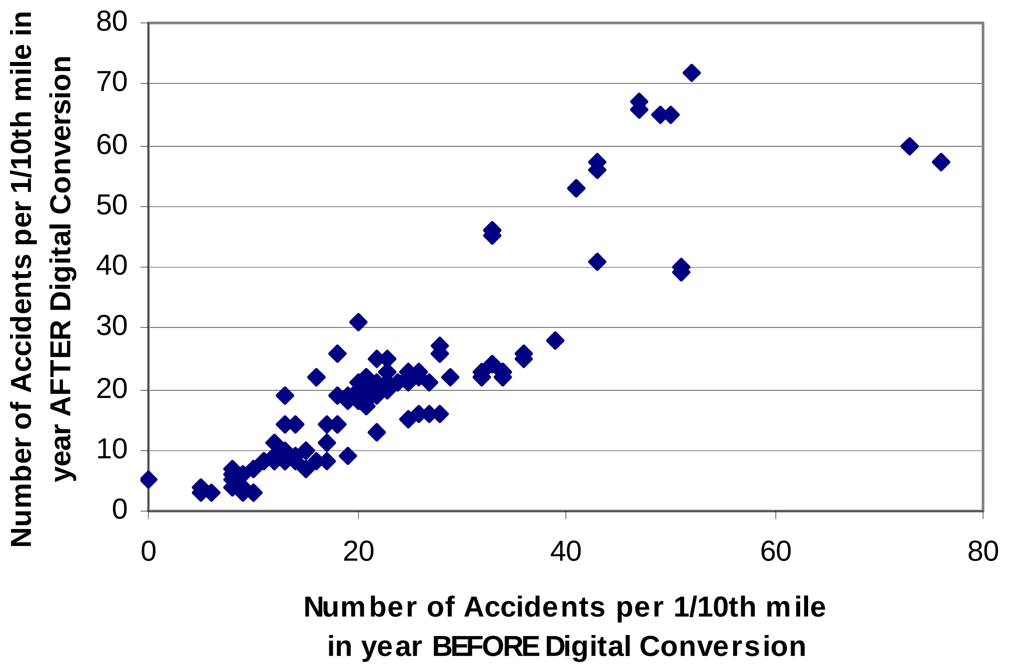


Figure 4-29. Accident Density Hotspots showing locations of conventional and digital billboards and locations of bias-excluded accidents in one year after digital sign conversion



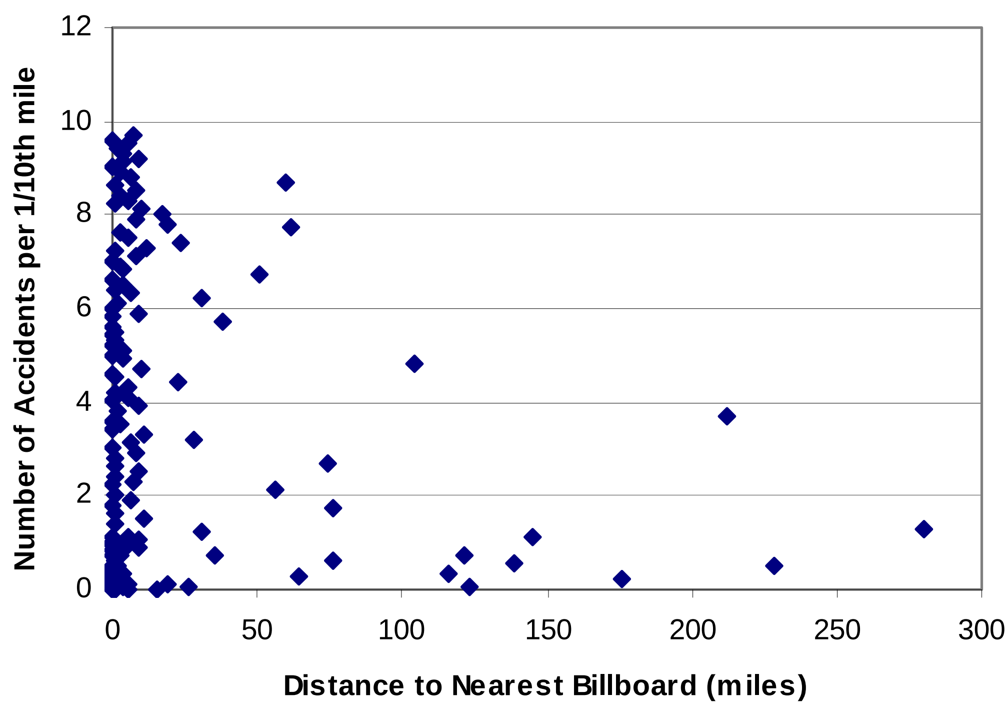
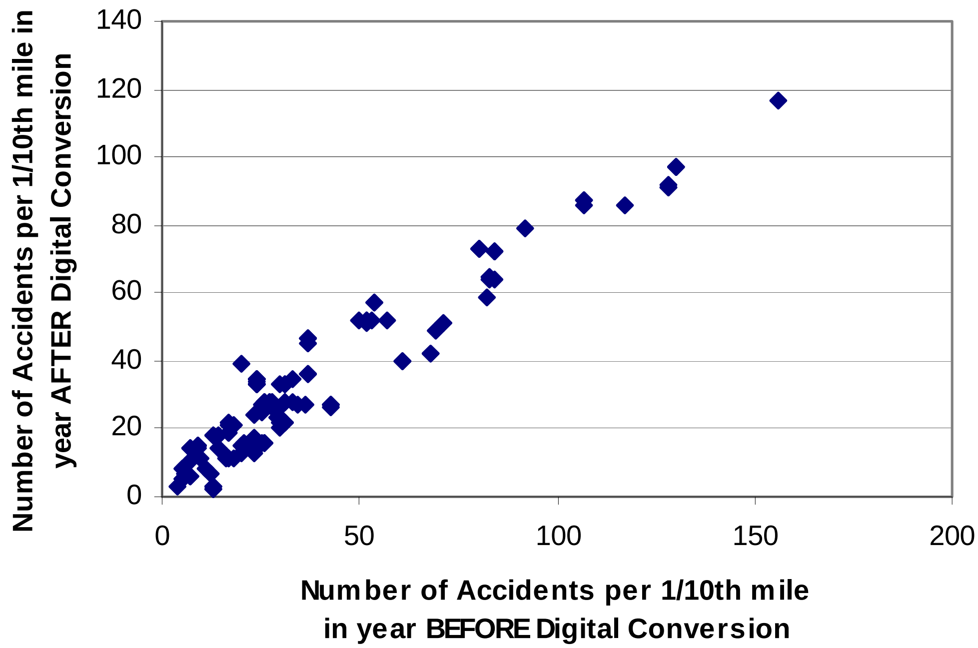


Figure 4-30. Interstate I-77 Comparisons
Relation of Number of Accident in year before digital to year after (top) and
Relation of Number of Accidents to Distance to Nearest Billboard (bottom)



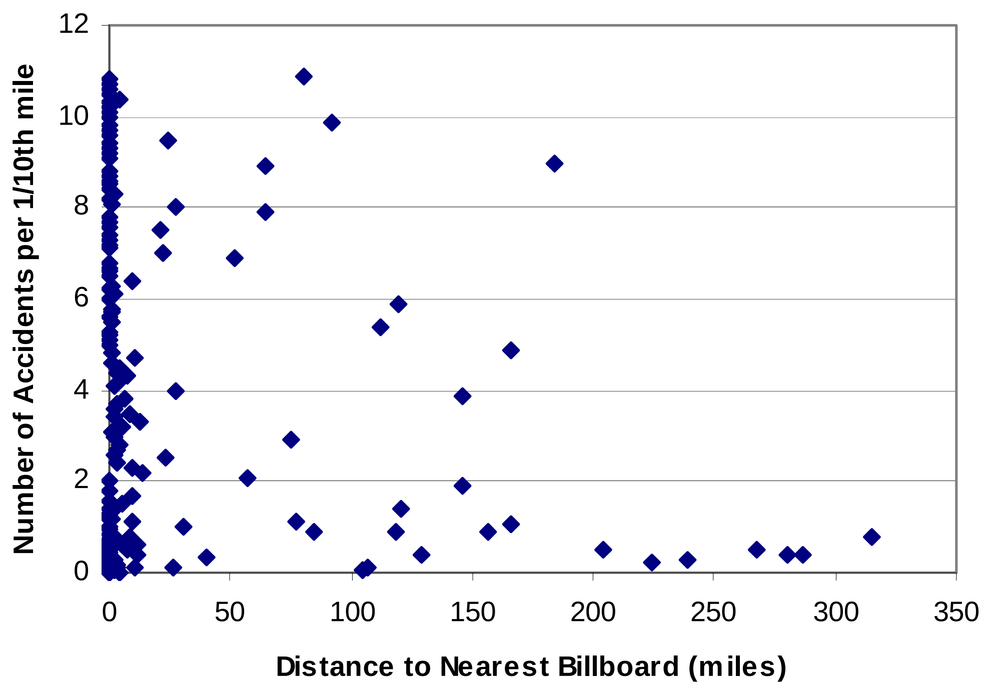
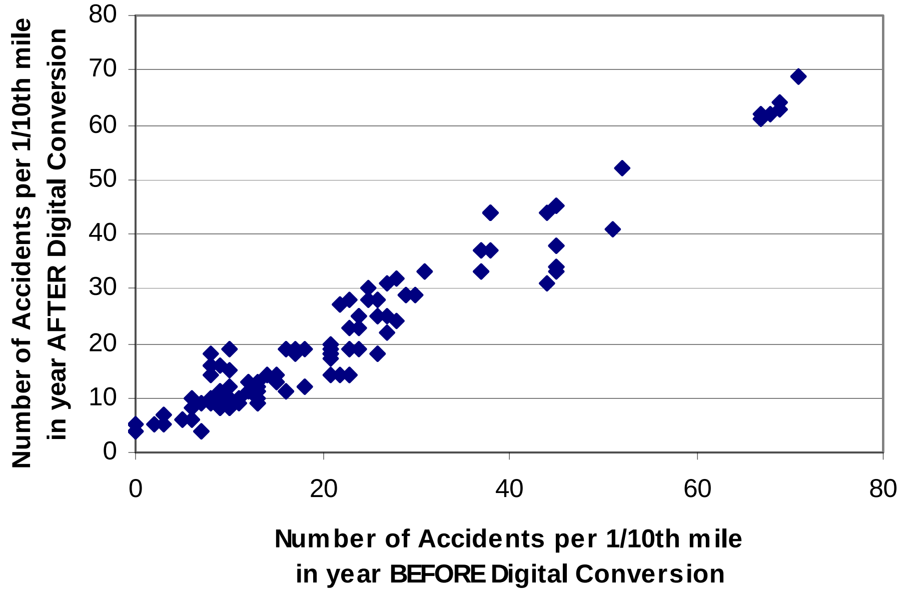


Figure 4-31. Interstate I-90 Comparisons
Relation of Number of Accident in year before digital to year after (top) and
Relation of Number of Accidents to Distance to Nearest Billboard (bottom)



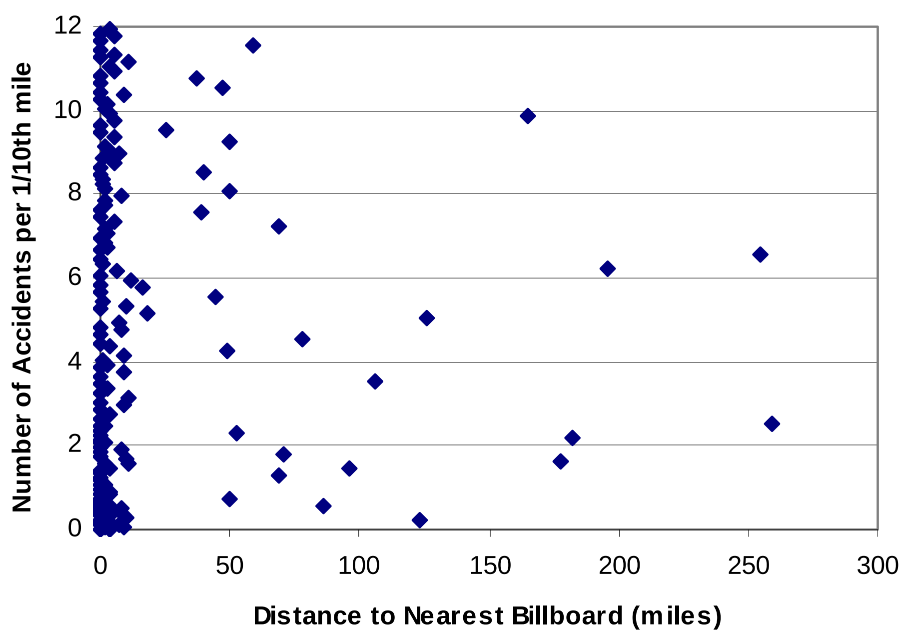
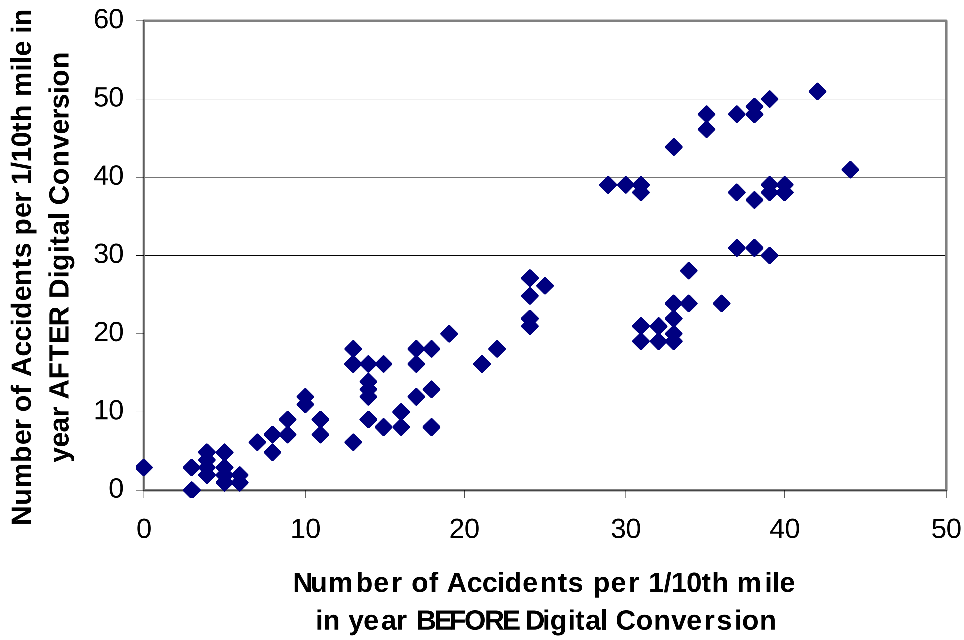


Figure 4-32. Interstate I-271 Comparisons
Relation of Number of Accident in year before digital to year after (top) and
Relation of Number of Accidents to Distance to Nearest Billboard (bottom)



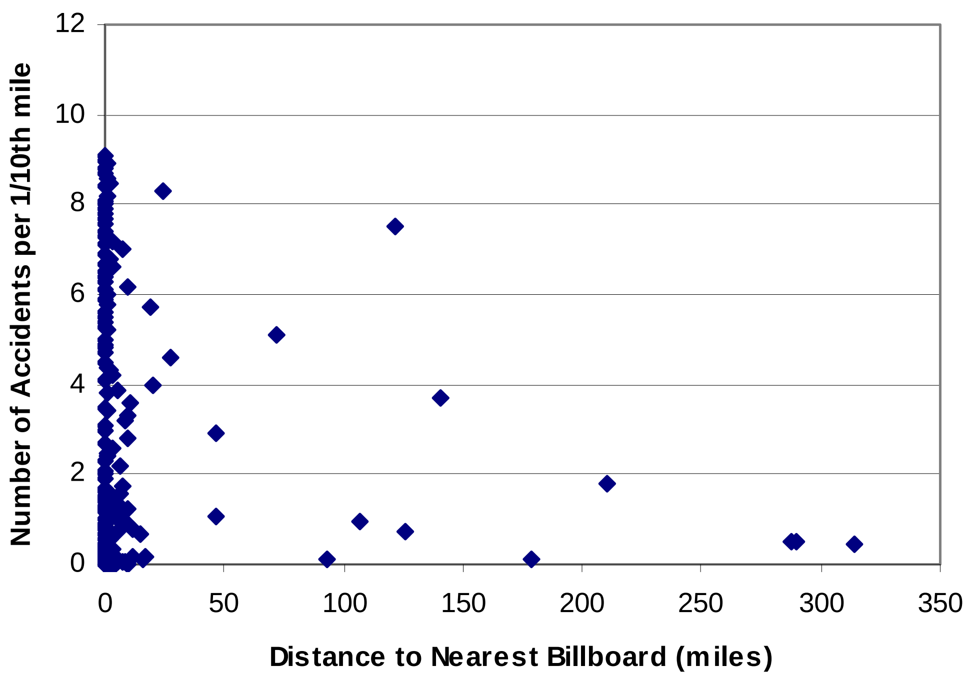


Figure 4-33. Interstate I-480 Comparisons
Relation of Number of Accident in year before digital to year after (top) and Relation of Number of Accidents to Distance to Nearest Billboard (bottom)

5.0 CONCLUSIONS

The conclusion of this study is that digital billboards have no statistical relationship with the occurrence of accidents. The analysis and statistics in Cuyahoga County demonstrate that accidents are no more likely to occur along sections of Interstate routes near digital billboards than those sections without them.

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

1. The accident statistics and metrics remain consistent, exhibiting statistically insignificant variations, for periods of 12 months before and after the conversion (a total of 24 months) at each of the billboards. The same conclusion also applies for periods of 18 months before and after the conversion (a total of 36 months). Metrics include the total number of accidents in any given month, the average number of accidents over the 12- and 18-month periods, the peak number of accidents in any given month, and the number of accident-free months. These conclusions account for variations of traffic-volume and vehicle-miles traveled.

2. The correlation coefficients demonstrate no statistical relationship between vehicular accidents and billboards (including conventional and the seven, digital billboards). Also, these correlation coefficients strongly suggest no causal relationship between the billboards and vehicular accidents.

3. When data-bias is excluded, the results further reinforce the conclusion that no statistical relationship exists between the digital billboards and accidents. Data bias includes known accident causes (deer hits, DUIs, etc), and interchange-bias, where drivers undertake additional tasks, such as lane changes, accelerating/decelerating, and negotiating directions.

4. Accidents occur with or without billboards (digital or conventional). The accident statistics on sections of Interstate routes near billboards are comparable to the accident statistics on similar sections that have no billboards.

The overall conclusion of this study is that digital billboards have no statistical relationship with the occurrence of accidents. The frequency of traffic accidents may be much more likely attributable to, and correlated with other factors, such as DUIs, deer hits, adverse weather conditions, excessive speeding, *inter alia*.

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APPENDIX

Firm Profile of Tantala Associates

Profile of Albert M. Tantala, Sr., P.E.

Profile of Michael W. Tantala, P.E.

About TANTALA ASSOCIATES

TANTALA ASSOCIATES is a multi-disciplined, professional, consulting-engineering firm with an established practice for more than 40 years. The firm provides a unique union of research, consulting and design solutions, offering expertise in numerous practice areas encompassing civil engineering, transportation and risk management. The firm provides research and engineering to a diverse clientele spanning government, industry and academe. Our technical expertise includes industry-standard research and consulting specifically on outdoor advertising and safety. Tantala Associates has previously published safety technical reports and guidelines for the United States Sign Council (USSC) and published with the United States Transportation Research Board (TRB).

Albert M. Tantala, Sr., P.E., President/Principal

- More than 40 years experience in engineering and design
- Has a specialty in design and analysis of wind-loaded structures
- Licensed Engineer in NY, NJ, PA, DE, RI and VA
- BSE ('60) University of Pennsylvania; BA ('61), University of Pennsylvania; MSE ('65) Villanova University
- Co-authored "Traffic Safety Study: Research, Perspectives and Correlations" for United States Sign Council (USSC), 2003
- Current Board Member, and Past President of, the Pennsylvania State Registration Board for Professional Engineers, Land Surveyors and Geologists
- Personally designed, sited, inspected and provided engineering, planning and safety services concerning thousands of signs

Michael W. Tantala, P.E., Project Engineer

- More than 8 years experience in engineering, research and design
- Licensed Engineer in OH and PA; NCEES National Model Law Engineer Designee
- BSE ('98) University of Pennsylvania; MSE ('00), Princeton University; MA ('00), Princeton University; PhD candidate, Princeton University
- Has a specialty in Engineering Risk Assessment and Traffic Safety Analysis
- Co-authored "Traffic Safety Study: Research, Perspectives and Correlations" for United States Sign Council (USSC), 2003
- Co-authored "An Examination of the Relationship between Advertising Signs and Traffic Safety" for the 84th Transportation Research Board (TRB) Annual Conference Proceedings, Washington, D.C., 2005
- Visiting Fellow, Princeton University, School of Architecture, 2005-2006; Appointment, for several research projects; three projects include flooding of New York harbor's rivers, bays, and tidal estuaries, consequences of NY-NJ-CT metropolitan earthquakes and sustainability in campus-wide master planning activities.
- Consultant to Federal Emergency Management Agency; New Jersey State Police, Office of Emergency Management; inter alia

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