USE OF GEOCODED FARS DATA TO ANALYZE FATAL MOTORCYCLE CRASHES

Kevin Majka
Alan Blatt
Marie Flanigan
CUBRC
United States

Saverio Pugliese
Calspan Corporation
United States

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ABSTRACT

Much work has been done recently to examine the trends, contributing factors and characteristics of the increasing number of fatal motorcycle crashes occurring in the United States. This paper explores two new resources, geocoded FARS data and roadway orthoimagery, to examine the geo-spatial characteristics of U.S. fatal motorcycle crashes.

Using 2001, 2002, 2003, and 2004 FARS crash data (that were previously geocoded by the National Highway Traffic Safety Administration's National Center for Statistics and Analysis), we have characterized the locations in the United States that have had fatal motorcycle crashes. Locations where crashes occurred were identified by using spatial and attribute queries of the NHTSA FARS database after the database was imported into a Geographic Information System. During the period from 2001 through 2004, FARS identifies 14,653 fatal motorcycle crashes. Approximately 91 percent of these crashes (13,329) were successfully geocoded and entered into the analyses. A majority (about 70%) of motorcycle fatalities occur on undivided roadways.

A valuable new approach to the analysis of fatal motorcycle crashes will be described. This approach involves use of high resolution orthoimagery which is now available for some, although not all, roadways. In addition, care must be taken to insure that available imagery displays roadway features at the time of the crash.

This paper provides the first geospatial analysis of fatal U.S. motorcycle crashes using *national geocoded* FARS data coupled with available roadway orthoimagery. Precise crash location, roadway imagery and FARS crash attributes provide unique opportunities to investigate crash trends, causation factors and potential crash mitigation techniques.

INTRODUCTION

A variety of studies have recently examined the trends, contributing factors and characteristics of the increasing number of fatal motorcycle crashes occurring in the United States [1,2,3]. In addition, geocoded motor vehicle crash data has specifically been used in some analyses to study the spatial and temporal distribution of crashes [4,5,6,7]. For the most part these geographic studies have been performed with relatively small sets of crashes on local, regional or state levels. In some cases, crash analyses were performed using highway segments distinguished by functional classification (freeway v. non-freeway) and location (urban v. non-urban) [8]. Studies have also been performed that show that design attributes such as number of lanes, curve characteristics, vertical grade, surface type, median type, turning lanes, shoulder width, and lane width, can be statistically related to crash activity [9]. Unfortunately, geocoded databases of roadway design attributes are not universally available, particularly for local roadways. This paper examines whether the analysis of orthoimages can help overcome the lack of availability of geocoded roadway design attributes. Orthoimages are geo-referenced images (prepared from a perspective photograph or other remotely-sensed data) in which displacement of objects due to sensor orientation or terrain relief has been removed. This results in an image with the geometric characteristics of a map and the image qualities of a photograph [10]. These characteristics suggest that orthoimages may provide a means of obtaining a quantitative view of some of the roadway features of interest to crash researchers.

The current study couples orthoimagery with Fatality Analysis Reporting System (FARS)[11] data which has been newly geocoded. FARS contains information on all fatal crashes that occur each year in the United States (where death occurred within 30 days of the crash). The objective of this study is to investigate the geospatial patterns of fatal motorcycle crashes to determine if newly available analysis tools can be used to gain additional insight into crash causation and potential crash mitigation strategies.

Statement of the Problem

In October 2001, NHTSA published a comprehensive report which indicated that during the 10 year period from 1990 to 1999, 24,495 people died in motorcycle crashes [1]. Of these, 45% (or 10,963 people) died in *single-vehicle* motorcycle crashes. Nearly half of these single vehicle fatalities (5347) occurred in crashes where the motorcycle had to negotiate a curve prior to the crash - and over 90% of these subsequently ended up 'off-roadway'. Of the single-vehicle motorcycle fatalities which occurred while negotiating a curve – over 60% involved speeding as an operator-contributing factor.

Since the decade of the 90s, the situation has not improved. According to a more recent NHTSA report [12], motorcycle fatalities increased by 89% between 1997 (when 2116 fatalities were recorded) and 2004 (when 4008 fatalities occurred). In 2004 motorcycle rider fatalities made up 9.4% of *all* motor vehicle crash fatalities in spite of the fact that motorcycles accounted for only 2% of all registered vehicles and only 0.3% of vehicle-miles-traveled in the U.S. that year. Likewise, NHTSA reported that in 2004, about 76,000 motorcyclists were injured in traffic crashes. This is 13% more than the 67,000 motorcyclists injured in 2003. NHTSA further noted that when comparing fatality rates per vehicle-miles-traveled in 2004, motorcyclists were about 34 times more likely than passenger car occupants to die in a traffic crash (compared to 15 times more likely in 1997).

Focus of This Paper

This paper will utilize the newly available geocoded FARS data from 2001 through 2004, coupled with orthoimages of selected fatal crash locations to assess whether orthoimages can expand our understanding of motorcycle crash causation.

Figure 1 displays a national map showing the 13,329 fatal motorcycle crash locations which occurred in the US during this four year period.

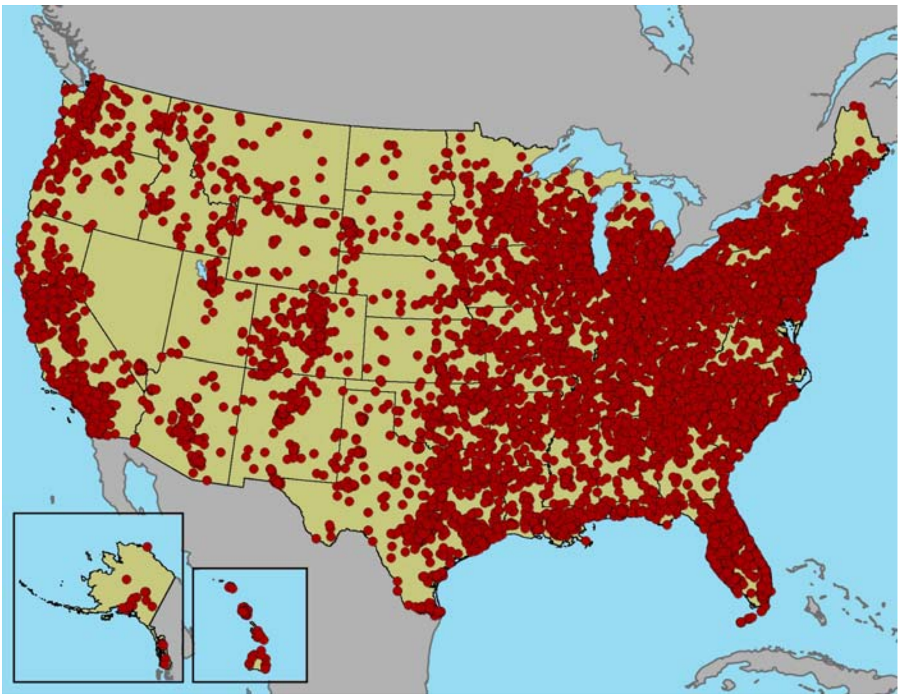

Figure 1. Fatal Motorcycle Crash Locations in U.S. from 2001 through 2004.

To identify a subset of these crashes for which orthoimages could be examined, some initial analyses of the FARS database were performed. First, single-vehicle motorcycle crashes were extracted from FARS and examined in the context of straight vs curved roadway alignment. Of the 6,448 single-vehicle motorcycle crashes in this four year period, roadway alignment was reported for 6415 crashes (or 99.5%) with 43% of these crashes occurring on straight roads and 57% (or 3655 crashes) occurring on curved roads. Moisture conditions were also reported in FARS for about 39% of the 6448 single vehicle motorcycle crashes. It was found that 40% of these crashes took place on straight dry roads while 57% took place on curved dry roads. The remainder (only 3%) indicates that relatively few crashes (with moisture conditions reported) occurred on straight or curved *wet* roads, possibly because fewer trips were made during inclement weather conditions. These combined results suggested that a focus on curved roads might be of particular interest.

Next, speed was considered. Of the 6,448 single-vehicle crashes, 2500 (or 39%) had estimated travel speeds reported in FARS. **Figure 2** shows the distribution of these single vehicle motorcycle crashes as a function of travel speed with the cumulative percentage (summed over those with reported speeds) also plotted. The estimated travel speed which saw the highest number of crashes over the four year period was 55 mph. It is also apparent that 50% of all of these crashes occurred at speeds in excess of 50 mph.

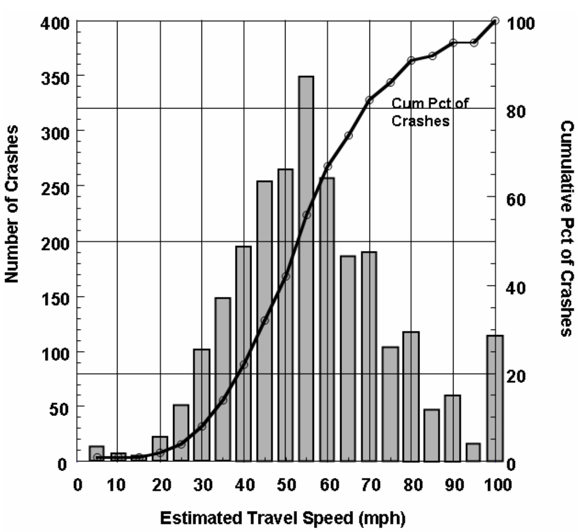

Figure 2. Distribution of Single Vehicle Fatal Motorcycle Crashes as a Function of Travel Speed

The ‘first harmful event’ for single-vehicle motorcycle crashes in FARS was examined next. After overturns (which may or may not be due to roadway characteristics), the greatest number of crashes (562) reported the first harmful event as hitting a guardrail. Of these 562 guardrail crashes, 431 occurred on curved roads during this 4 year period. A further examination of travel speed showed that 163 of the 431 crashes (or 38%) had estimated travel speeds reported in FARS. These speeds ranged from under 25 mph to over 90 mph.

Figure 3 shows a plot of posted speed limit vs the *average* travel speed reported for single-vehicle (motorcycle) guardrail crashes occurring on curved roadways with posted speed limits between 30 and 75 mph. The number of crashes included in each average is shown in parentheses next to each data point while the vertical lines show the minimum and maximum reported travel speeds included in the average. Note that the largest number of crashes (54) occurred on roadways with a posted speed of 55 mph. For these 54 crashes, the average travel (or crash) speed was 65 mph and the reported travel speeds ranged from 28 to 97 mph. These and the other analyses described above were used to define a manageable (and rational) subset of fatal motorcycle crash locations for which orthoimages were sought. The FARS case selection process is summarized in the Methodology section below.

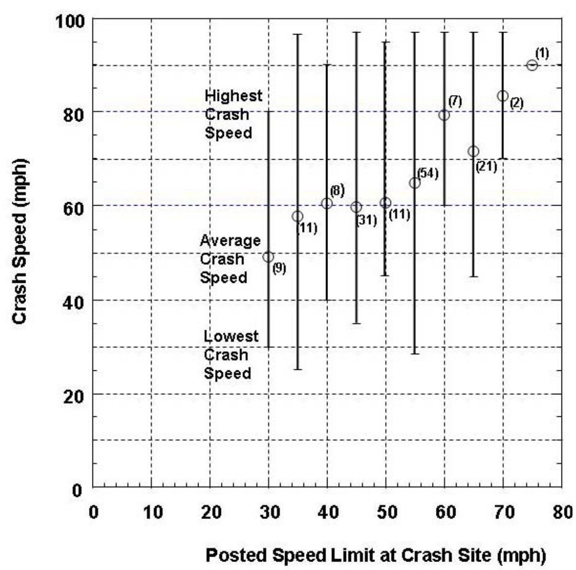

Figure 3. Reported Travel/Crash Speed vs Posted Speed Limits for Guardrail Collisions on Curved Roads

METHODOLOGY

Beginning in 2001 the National Highway Traffic Safety Administration (NHTSA), which is responsible for the compilation of FARS data, has made an effort to geocode (or give real world latitude and longitude coordinates to) each fatal crash. This geocoding task was undertaken by NHTSA's National Center for Statistical Analysis (NCSA). NCSA has several methods by which to accomplish this task. The first is to use, whenever present, the crash coordinates that are provided by the responding emergency vehicles (which may be contained in the police accident report). The second method is to geocode the locations, which is a process that takes a street address or intersection, matches it to a streets database and geographic file, and returns real world coordinates. The last method is an interactive process by which the crashes are manually digitized and placed in the correct location on a computer map.

FARS Case Selection

Using 2001, 2002, 2003, and 2004 FARS geocoded crash data for the 50 states and the District of Columbia, we identified 13,329 locations in the United States that had a fatal motorcycle crash in any one of the calendar years 2001, 2002, 2003, or 2004. Further classification of these crashes revealed that 6,448 of those crashes (48.4%) were single-vehicle (motorcycle) crashes. For 562 of these single vehicle crashes, the first harmful event was a collision with a guardrail, with 431 (of 562) characterized as having a curved roadway alignment. Of the 431 single-vehicle (motorcycle) crashes for which collision with a guard rail on a curved roadway was the first harmful event, 54 had a posted speed limit of 55 miles per hour and their actual (estimated) travel speeds were known. These 54 crashes represented the largest number of guardrail crashes on curved roadways at any single posted speed and subsequently became the set of crashes selected for this orthoimagery study. This selection process or 'drill-down method' is illustrated below in **Figure 4**.

In actual practice, these motorcycle crashes were identified by using spatial and attribute queries of the NHTSA FARS database after the database was imported into a Geographic Information System (i.e., ESRI's ArcGIS 9.1 software). The processing of the data included first, selecting those crashes that were defined as 'motorcycle' crashes, which include all makes and models of motorcycles, and exporting this subset of crashes as the population of crashes used in this study for the 2001 through 2004 time frame.

Analysis of Crashes Using Orthoimagery

The set of 54 crashes to be examined was exported and integrated within Google Earth Plus (4th edition) to find those crashes that had commonly available, medium to high resolution orthoimages available for measurement. By importing each crash's latitude and longitude coordinates into Google Earth Plus, a 'visit' of the 54 crash locations was conducted and a determination made as to whether a suitable image was available for each crash location. Of the 54 crashes, 25 images were found to have acceptable resolution so that the roadway radius of curvature could be measured.

For each curve, a nominal distance of 300 meters along the curved roadway was examined on either side of the crash site. A circle was constructed (on the orthoimage) which followed the road curvature over this distance and the circle's radius determined. **Figure 5** illustrates this process. Using the Google Earth measurement tool, the radius of curvature (r) was recorded for each crash location. The orthoimages were then introduced into the ArcGIS environment and the measured radii validated using the ArcGIS internal measurement system.

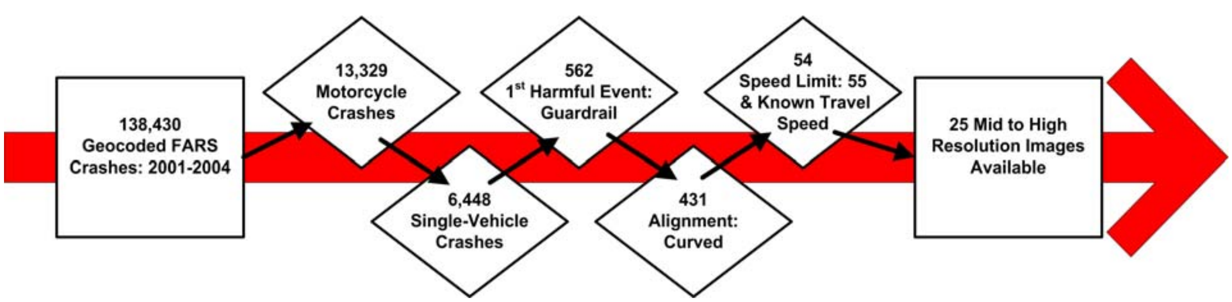

Figure 4. Flowchart Illustrating FARS Crash Case Selection

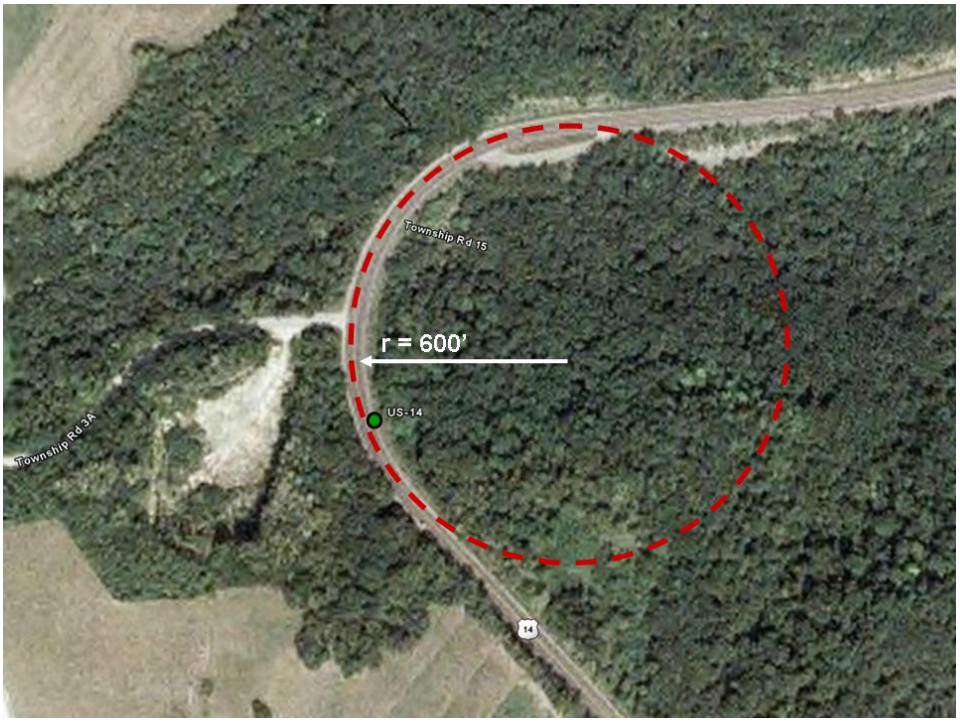

Figure 5. Orthoimage of Crash Site (on US-14) with Illustration of Approach for Measuring Radius of Curvature.

RESULTS

Table 1 provides a summary of selected attributes (from the FARS database) associated with each of the 25 crashes for which high resolution orthoimages were examined. **Figure 6** and **Figure 7** show representative orthoimages of four fatal, single-vehicle motorcycle crash locations where the rider collided with a guardrail on a curved roadway. **Table 2 s**ummarizes the roadway curvature data extracted from the orthoimages for each of the 25 crashes examined. Data on posted and reported travel speed from FARS is also tabulated. In addition, lateral accelerations were calculated for both the posted and crash reported speeds as follows:

$$\text{Posted Speed Lateral Acceleration} = S_p^2 / r$$

where S_p is the posted speed at the crash location and r is the roadway radius of curvature. Similarly,

$$\text{Crash Speed Lateral Acceleration} = S_c^2 / r$$

where S_c is the reported crash speed and r is the roadway radius of curvature.

The results of the lateral acceleration calculations are shown in Figures 8, 9 and 10. **Figure 8** illustrates the relationship between the roadway curvature and the crash lateral acceleration. As expected, the fatal crashes with the highest lateral accelerations tend to occur more frequently on roadways with small radii of curvature (i.e., sharper curves). **Figure 9** provides a crash case-by-case comparison of the crash lateral acceleration and posted speed lateral accelerations. Finally, **Figure 10** shows the number of fatal crashes in our study plotted against the difference between the crash and the posted speed lateral accelerations.

Table 1. Summary of (Selected) FARS Attribute Data for Crashes Examined in Study

Crashes sorted by ID#

ID	Roadway Label	Year	Light Conditions	Roadway Profile	Speed Limit	Travel Speed	PDOF	Alcohol	Age
001	908M	2002	Dark but Lighted	Level	55	97	12	No	32
002	Cole Grade	2004	Daylight	Grade	55	28	12	No	53
003	I-35W	2002	Daylight	Level	55	55	12	No	61
004	I-464	2002	Daylight	Grade	55	97	10	Yes	63
005	I-70	2004	Daylight	Grade	55	65	3	No	33
006	I-74	2002	Daylight	Grade	55	90	Unknown	Yes	27
007	I-75	2002	Daylight	Grade	55	70	2	Yes	35
008	I-95	2003	Daylight	Level	55	97	11	No	29
009	I-95	2003	Dark but Lighted	Level	55	55	12	Yes	30
010	Pala Temecula	2001	Daylight	Grade	55	35	5	No	53
011	Southern St	2003	Dark but Lighted	Level	55	97	9	No	31
012	SR-1	2001	Daylight	Level	55	70	12	Yes	32
013	SR-13	2001	Daylight	Grade	55	30	12	No	70
014	SR-166	2004	Dusk	Level	55	97	3	No	23
015	SR-18	2004	Dark	Grade	55	40	12	Yes	50
016	SR-74	2001	Daylight	Level	55	40	12	No	64
017	SR-89	2003	Daylight	Grade	55	73	3	Yes	54
018	SR-94	2001	Daylight	Grade	55	55	12	No	21
019	Trona Wildrose	2004	Daylight	Grade	55	40	12	No	82
020	US-101	2003	Dark	Grade	55	55	12	No	50
021	US-14	2004	Daylight	Grade	55	88	2	No	22
022	US-169	2003	Dark but Lighted	Grade	55	97	1	No	26
023	US-301	2003	Daylight	Level	55	65	12	No	53
024	US-36	2002	Dusk	Hill crest	55	70	12	Yes	20
025	Wantagh St	2002	Dark	Level	55	97	12	No	20

Note: No adverse weather conditions reported for any crash. Surface conditions for all crashes reported as ‘dry’ except for US-36 crash (ID=24) which reported surface conditions as ‘Other’.

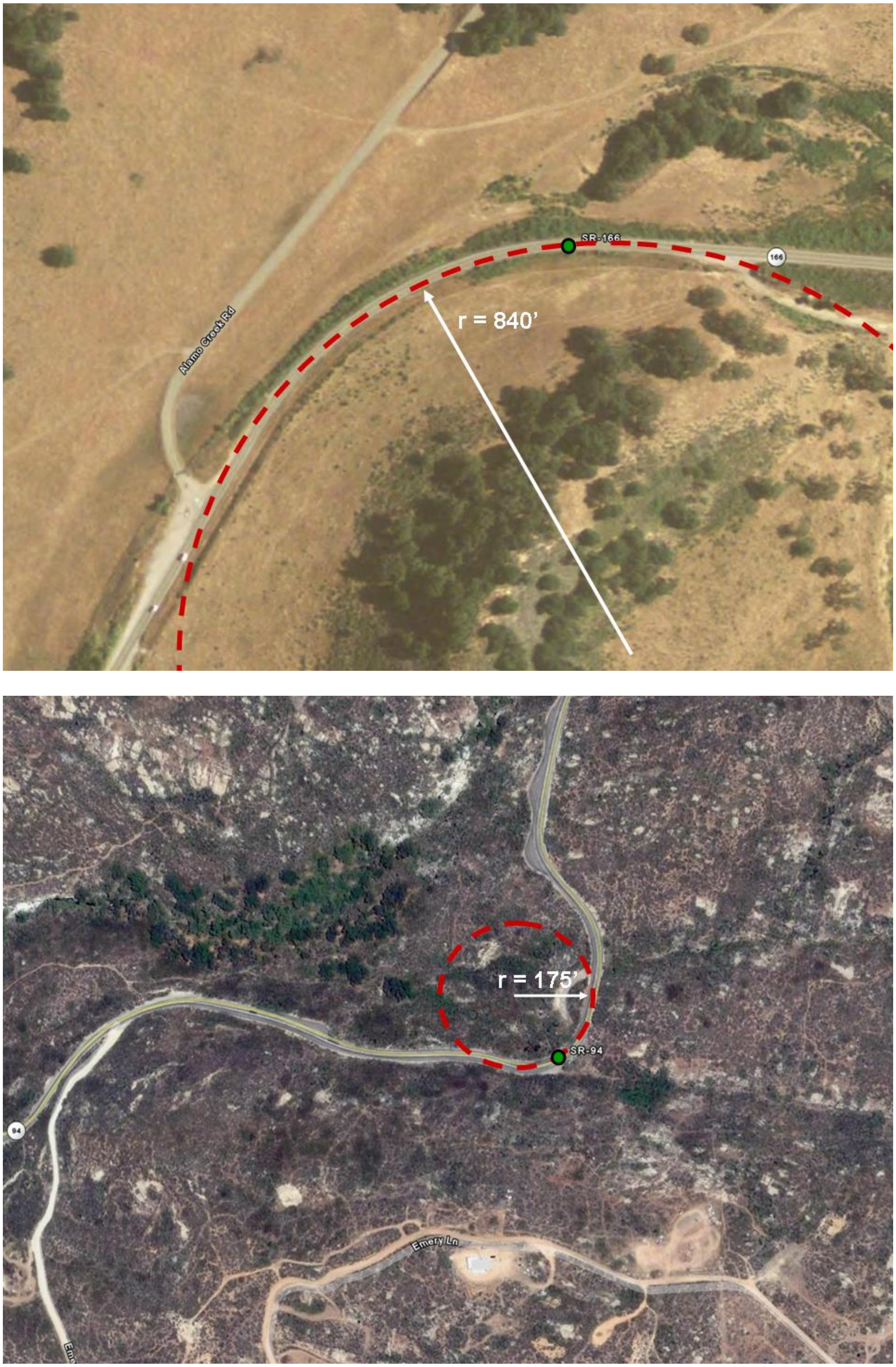

Figure 6 Orthoimages of Curves Where Fatal Crashes Occurred on SR-166 (top) and SR-94 (bottom)

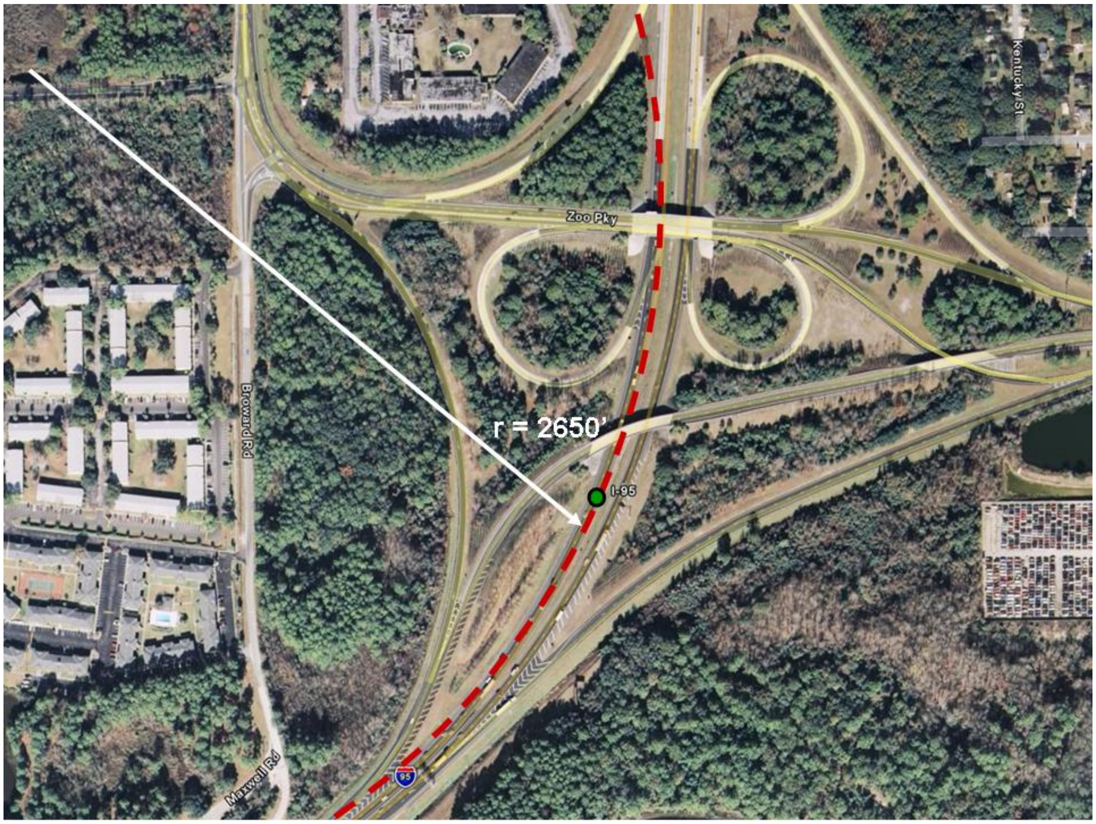

Figure 7 Orthoimages of Curves Where Fatal Crashes Occurred on I-95 (top) and I-464 (bottom)

Table 2 . Crash Characteristics Derived from Orthoimages

(Crashes Sorted on Last Column)

Crash ID	Posted speed (mph)	Travel speed (mph)	Travel speed (ft/sec)	Travel speed (m/sec)	Roadway Curve: Roadway Label	Roadway Curve: Radius (ft)	Roadway Curve: Radius (m)	Values for Crash: lat acc (ft/sec2)	Values for Crash: lat acc (m/sec2)	Values for Crash: lat acc (g's)	Values for Posted Speed: lat accel (ft/sec2)	Values for Posted Speed: lat accel (m/sec2)	Values for Posted Speed: lat acc (g's)	Delta lat accel (crash-posted) (m/sec2)
013	55	30	44	13	SR-13	295	89.9	6.56	2.00	0.20	22.06	6.72	0.69	-4.72
015	55	40	59	18	SR-18	240	73.2	14.34	4.37	0.45	27.11	8.26	0.84	-3.89
002	55	28	41	13	Cole Grade	615	187.5	2.74	0.84	0.09	10.58	3.22	0.33	-2.39
010	55	35	51	16	Pala Temecula	645	196.6	4.09	1.25	0.13	10.09	3.07	0.31	-1.83
016	55	40	59	18	SR-74	1210	368.8	2.84	0.87	0.09	5.38	1.64	0.17	-0.77
019	55	40	59	18	Trona Wildrose	1885	574.5	1.83	0.56	0.06	3.45	1.05	0.11	-0.50
003	55	55	81	25	I-35W	950	289.6	6.85	2.09	0.21	6.85	2.09	0.21	0.00
008	55	55	81	25	I-95	2650	807.7	2.46	0.75	0.08	2.46	0.75	0.08	0.00
018	55	55	81	25	SR-94	175	53.3	37.18	11.33	1.15	37.18	11.33	1.15	0.00
020	55	55	81	25	US-101	1360	414.5	4.78	1.46	0.15	4.78	1.46	0.15	0.00
023	55	65	95	29	US-301	2665	812.3	3.41	1.04	0.11	2.44	0.74	0.08	0.30
005	55	65	95	29	I-70	1690	515.1	5.38	1.64	0.17	3.85	1.17	0.12	0.47
007	55	70	103	31	I-75	1950	594.4	5.41	1.65	0.17	3.34	1.02	0.10	0.63
012	55	70	103	31	SR-1	1865	568.5	5.65	1.72	0.18	3.49	1.06	0.11	0.66
009	55	97	142	43	I-95	4400	1341.1	4.60	1.40	0.14	1.48	0.45	0.05	0.95
024	55	70	103	31	US-36	1120	341.4	9.41	2.87	0.29	5.81	1.77	0.18	1.10
001	55	97	142	43	908M	2400	731.5	8.43	2.57	0.26	2.71	0.83	0.08	1.74
025	55	97	142	43	Wantagh St	1995	608.1	10.15	3.09	0.32	3.26	0.99	0.10	2.10
017	55	73	107	33	SR-89	695	211.8	16.49	5.03	0.51	9.36	2.85	0.29	2.17
006	55	90	132	40	I-74	1450	442.0	12.02	3.66	0.37	4.49	1.37	0.14	2.29
011	55	97	142	43	Southern St	1200	365.8	16.87	5.14	0.52	5.42	1.65	0.17	3.49
022	55	97	142	43	US-169	890	271.3	22.74	6.93	0.71	7.31	2.23	0.23	4.70
014	55	97	142	43	SR-166	840	256.0	24.10	7.34	0.75	7.75	2.36	0.24	4.98
021	55	88	129	39	US-14	600	182.9	27.76	8.46	0.86	10.85	3.31	0.34	5.16
004	55	97	142	43	I-464	165	50.3	122.67	37.39	3.81	39.44	12.02	1.22	25.37

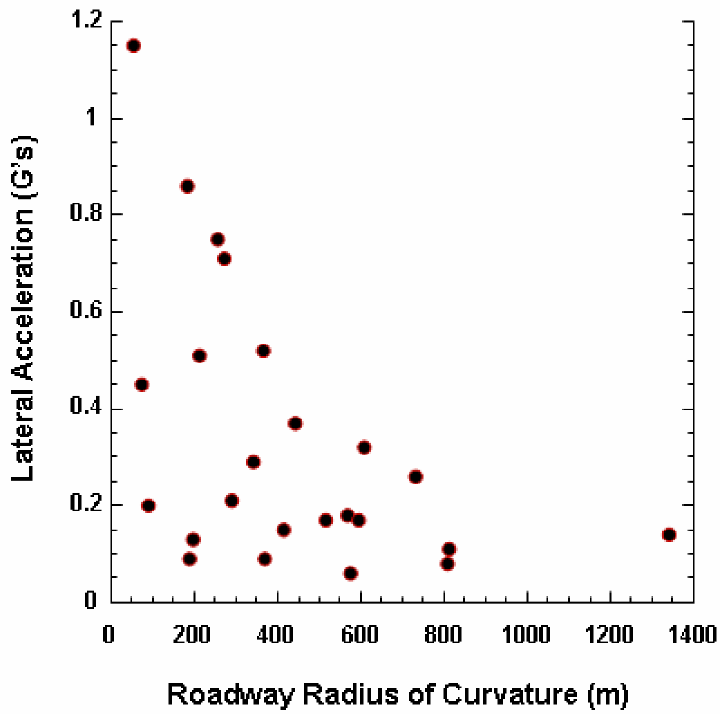

Figure 8. Lateral Acceleration vs Roadway Radius of Curvature

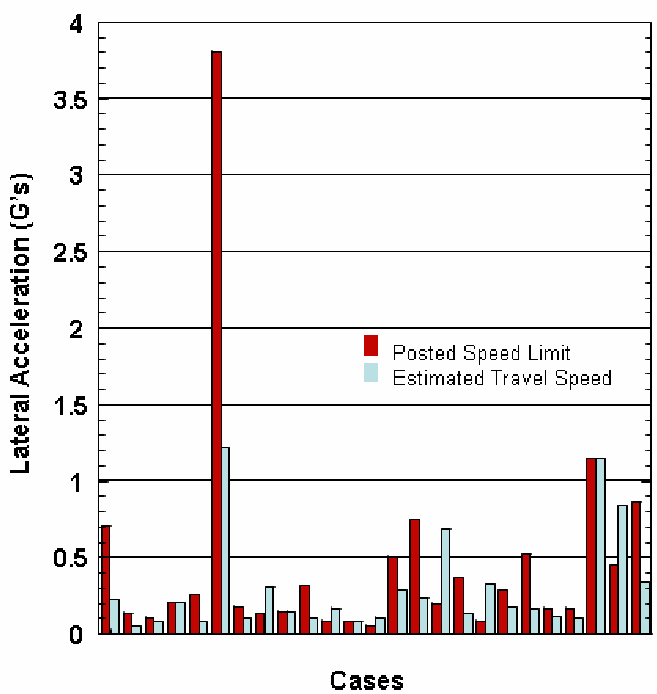

Figure 9. Case by Case Comparison of Posted Speed and Crash Speed Lateral Accelerations

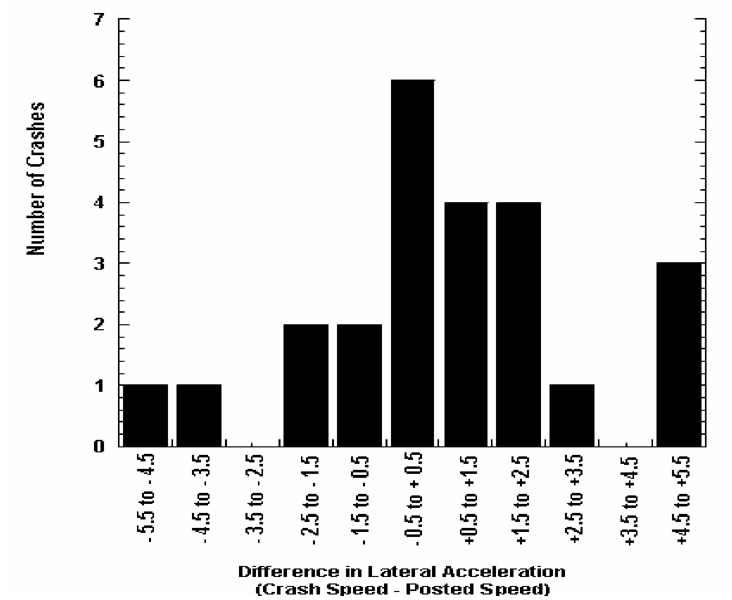

Figure 10. Bar Chart Showing Number of Crashes vs Difference in Lateral Acceleration (Crash Speed Minus Posted Speed in m/sec2)

Discussion

The use of orthoimagery to supplement the FARS database for motorcycle crashes has allowed us to determine the road curvature at the crash scene for 25 single vehicle crashes involving collision with a guardrail on a curved road. Lateral acceleration values based upon the posted speed limit and the estimated travel speed of the motorcycle prior to the collision event were calculated using the orthoimagery derived road curvatures.

Rider, vehicle and roadway characteristics, singly or in combination, are potential factors that can influence the maximum lateral acceleration values sustainable on these curves. Rider factors such as age, experience, training and drug use can clearly influence the driver's perception of risk and his understanding of the motorcycle's handling capabilities. Roadway factors include pavement type, surface condition, grade and elevation. Motorcycle type, weight, power and tire properties can also affect the lateral acceleration achievable by the rider without loss of control.

There is a dearth of data available on the lateral acceleration levels that average motorcycle riders are willing (or able) to achieve when negotiating a curve. For passenger vehicles, past research has indicated that the maximum lateral acceleration values drivers are willing to subject themselves to in crash type situations falls in the range of 0.3 to 0.5 g's even though the cornering capabilities of vehicles vastly exceed these levels [13].

Thus, it may be reasonable to assume that the average motorcycle rider would typically negotiate a curve at a lateral acceleration level less than 0.5 g's. If one uses this assumption, then some interesting observations can be gleaned from the data in Table 2 and Figures 9 and 10. In seven of the selected cases (highlighted in blue in Table 2), the estimated travel speed resulted in a lateral acceleration level in excess of 0.5g's. Five of these were in excess of 0.7g's. It is assumed that a primary causal factor for these fatalities may have been a direct result of the rider entering the curve at too high a rate of speed to successfully negotiate the curve.

It is also noted that for the vast majority of curved roadways examined, the lateral acceleration one would experience when traveling at the posted speed limit was well below 0.4g's. However, in four cases (highlighted in green in Table 2), the lateral acceleration derived for motorcycles traveling the *posted* speed limit was also in access of 0.5g's. The lateral acceleration values for these cases ranged from 0.69 to 1.22g's. Of particular note is the fact that in three of these four cases, the estimated travel speed of the motorcyclist was *at or below* the posted speed limit. This would lend some credence to the belief that 0.5g's may be too high a threshold for average motorcyclists to handle in curves.

For our study, only commonly available mid to high resolution orthoimagery was utilized in the analysis of crash locations, specifically those available through Google Earth. Google Earth is a dynamic service which continually updates the orthoimagery they provide. During our investigation, roughly 50% of all motorcycle crashes on curved roadways with the first harmful event being a collision with a guardrail, were covered by mid to high resolution imagery. Due to expanded orthoimagery collection services, national organization and technological advances in collection methods, it is reasonable to assume that high resolution coverage of areas should increase in the future.

CONCLUSIONS & RECOMMENDATIONS

This study illustrates the opportunity to increase our understanding of fatal motorcycle crashes by using geocoded crash data and orthoimages. Together these tools enable analysts to identify crash locations and visualize and measure crash scene roadway characteristics. Simple calculations of posted and crash lateral accelerations permit the identification of roadways with potential problems. For example, four curved roadways were identified in the analyses where the lateral accelerations calculated for the posted speed limits exceed the commonly accepted threshold of 0.5g's.

Further analyses could be strengthened if the accuracy of crash locations was improved. Currently, crash locations are approximate and include both recorded error and geocoded error. For example, the current accuracy is not sufficient to determine which side of the road the crash occurred on. Including direction of travel in FARS is recommended to overcome this hurdle.

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REFERENCES

[1] Shankar U (NHTSA NCSA), "Fatal Single Vehicle Motorcycle Crashes", Technical Report DOT HS 809 360, Oct 2001.

[2] Coben J., Steiner C, Owens P, 'Motorcycle-related hospitalizations in the United States, 2001'**.** American Journal of Preventive Medicine, Volume 27, Issue 5, Pages 355-362, 2004

[3] McGwin G, Whatley J, Metzger J, Valent F, Barbone F, Rue LW III, 'The Effect of State Motorcycle Licensing Laws on Motorcycle Driver Mortality Rates', The Journal of Trauma, Injury, Infection, and Critical Care, Volume 56, Number 2, February 2004

[4] Pierce JA, Ray LU, Wood S, Murrin P, 'Creating and Using a Geographic Information System for Motor Vehicle-Related Injury Surveillance in San Diego County.' Topics in Emergency Medicine. Emergency Medical Services. 21(1):26-31, March 1999.

[5] Flanigan M, Blatt A, Lombardo L, Mancuso M, Miller M, Wiles D, Pirson H, Hwang J, Thill JC, Majka K, 'Assessment of Air Medical Coverage Using the Atlas & Database of Air Medical Services (ADAMS); Correlations with Reduced Highway Fatality Rates'**,** Air Medical Journal, July / August 2005, p. 151

[6] Black, W. 1991. Highway accidents: A spatial and temporal analysis. Transportation Research Record 1318, 75-82.

[7] Thomas I, 'Spatial Data Aggregation: Exploratory Analysis of Road Accidents.' Accident Analysis and Prevention, 28:2, 251-264, 1996

[8] Preusser DF, Williams AF, Ulmer RG, 'Analysis of Fatal Motorcycle Crashes: Crash Typing', Accident Analysis and Prevention, Vol. 27, No. 6, pp. 845-851, 1995

[9] Strathman JG, Duecker KJ, Zhang J, Williams T, 'Analysis of Design Attributes and Crashes on the Oregon Highway System', Oregon Department of Transportation, Report FHWA-OR-RD-02-01, August 2001

[10] "Content Standards for Digital Orthoimagery", Subcommittee on Base Cartographic Data, Federal Geographic Data Committee, FGDC-STD-008-1999, Feb 1999.

[11] Fatality Analysis Reporting System (FARS), http://www-fars.nhtsa.dot.gov

[12] 2006 Motorcycle Safety Program Plan, NHTSA, DOT HS 810 615, June 2006.

[13]"An Assessment of the National Highway Traffic Safety Administration's Rating System for Rollover Resistance: Special Report 265" (2002), p. 34