Evaluation of the 1st Automated Speed Enforcement Program on a US Freeway: The Scottsdale Arizona Experience

Institute for Transport and Logistics Studies

April 3rd, 2007

By Simon Washington

Visiting Professor

Institute for Transport and Logistics Studies,

University of Sydney

and

Professor

Department of Civil & Environmental Engineering

Arizona State University

Co-conspirators……

Kangwon Shin
Ida Van Schalkwyk

Department of Civil & Environmental Engineering
Arizona State University

1/30/2007

Arizona Freeway Cameras Return Next Month
Scottsdale, Arizona city council will vote to turn the cameras back on as of February 22.

Scottsdale, Arizona's lucrative freeway cameras will return February 22 after a city council vote today. The program had used a set of six cameras on a 6.5 mile stretch of the Loop 101 freeway to issue 90,344 citations worth a minimum of $14,184,008 last year. Scottsdale turned off the cameras on October 23 while it paid $75,000 to Arizona State University Professor Simon Washington to produce a report showing benefits to the system.

The study documented a 54 percent increase in rear-end collisions and a 9 percent increase in injuries from rear-end collisions. But the study's author dismissed the effect saying, "Increases in rear-end crashes are traded for reductions in other crash types." Washington estimated the program created a net $11 million benefit from those claimed reductions.

The substantial profit from the program was split between the state, Australian camera operator Redflex and Scottsdale.The financial results were enough for Governor Janet Napolitano (D) last week to embrace the freeway camera concept. She announced an effort was underway to install the devices statewide.

In 2004, before the freeway project, Scottsdale cleared $1,265,000 in profit from its side-street speed cameras. Scottsdale had issued a total of 36,021 photo radar citations since January 1997, according to the city's financial statements. Just two years later, with the freeway program active, that profit more than doubled to $3,116,000.

The re-activated Loop 101 program is expected to issue an estimated 60,500 tickets by June 30. This would generate between $9 and $12 million in revenue.

Source: Scottsdale gears up possible return of cameras (East Valley Tribune (AZ), 1/30/2007)

Permanent Link for this item
Return to Front Page

Presentation Outline

- Background
- Crash impact expectations (from international experience)
- Scottsdale program description
- Summary of preliminary findings
  - Effect of the Demonstration Program on detection Frequencies
  - Effect of the Demonstration Program on Mean Speeds
  - Effect of the Demonstration Program on Traffic Safety
- Conclusions
- Unanswered questions and future work

Background

Photo speed enforcement

- Photo radar technologies are used in 75 countries throughout the world to enforce speed limits
- In the US, however, photo enforcement has only been used at intersections (red light running) and expressways and major arterials
- Until 2006, the US had not seen an application of photo enforcement on limited access freeways
- Driving behavior differs across countries and so the impact of PE in the US is unknown

Published papers on freeway photo enforcement

Reference	Country	Camera type	Enforcement sites	Posted speed limits
(Lamm and Kloeckner, 1984)	Germany	Fixed	2 sites on Autobahn	62 mph (100kph)
(Waard and Rooijers, 1994)	Netherlands	Mobile	6 sites on motorways	75 mph (120kph)
(Sisiopiku and Patel, 1999)	US	Mobile	29-mile segment on I 96, Michigan.	70mph (113kph)
(Chen *et al*., 2002)	Canada	Mobile	12 sites on Highway 17	56mph (90kph)
(Ha *et al*., 2003)	South Korea	Fixed	1 site on urban highway	50mph (80kph)
(Champness and Folkman, 2005)	Australia	Mobile	1 site Highway section, Queensland	62 mph (100kph)

Crash Impact Expectations

Program Impact Expectations

What do the literature, past research experience, and crash theory tell us will happen as a result of automated speed enforcement?

Experiences in Europe, Asia, and Australia give insight as to how photo enforcement will influence driving behavior on freeways.

Program Impact Expectations

- Speeds will be reduced through disincentives
- Reduction in speeds will:
  - decrease the distance traveled per unit time of drivers

(i.e. shorter stopping and sight distances)

  - reduce speeds on impact (impact forces proportional to square of speed)
  - Diminish vehicle handling requirements
  - Diminish performance gap between conservative and 'aggressive' drivers

Program Impact Expectations (cntd.)

- Increased rear-end crashes
- Reduced crash severities (by proportion)
- Decreased injury crashes (by proportion)
- Decreased crash frequencies
- Peak-period crashes unaffected
- Spill-over effects minimal (time and space)

Background

The city of Scottsdale began a speed enforcement camera demonstration program on the Loop 101 freeway on January 22, 2006.

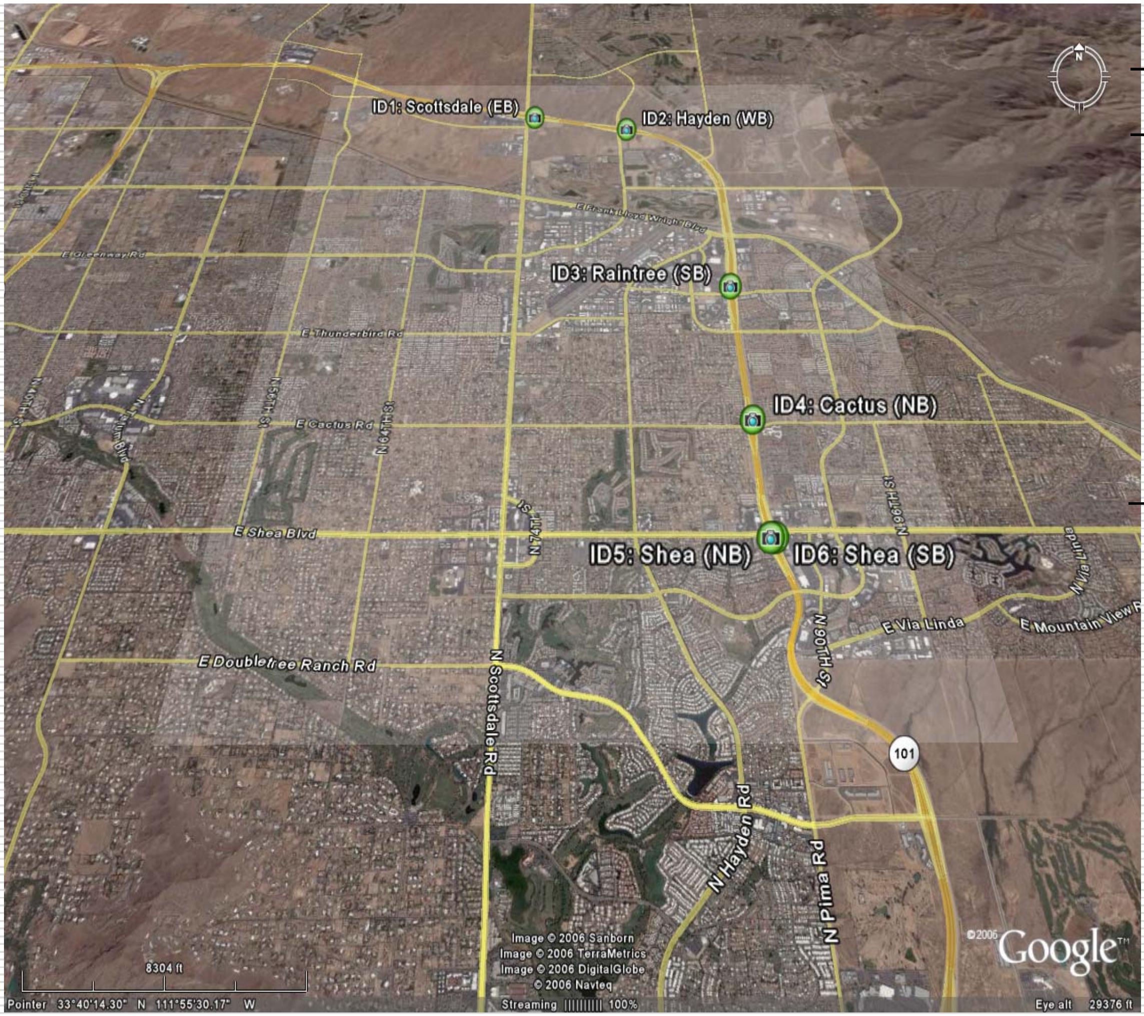
Camera Sites	6 sites on Loop 101 in Scottsdale (double cameras and loops)
Operation Characteristics	Speed limit: 65mph Enforcement limit: 76mph or higher
Speed determination	Using time measured by 2 Piezzo strips at each site

Equipment set-up

Background

- Vehicle’s registered owner receives a mailed speeding citation (per camera violated) within 60 days of violation.
- Citation includes picture of license tag, photo of driver, and calculated speed.
- Citation cost dependent upon speed ($10/mph over limit): Going 85mph = $200 ticket
- Criminal speeding occurs at speeds > 85mph
- Points assigned to driver’s license (towards suspension)
- Insurance rates may increase
- Traffic school possible every 2 years (to ‘wipe’ record clean)

Location of 6 Demonstration Sites



Site ID	Site	Direction
1	Scottsdale Rd. and Hayden Rd.	EB
2	Hayden Rd. and Princess Dr.	WB
3	Frank Lloyd Wright Blvd. and Raintree Dr.	SB
4	Raintree Dr. and Cactus Rd.	NB
5	Shea Blvd. and Mountain View Rd.	NB
6	Shea Blvd. and Mountain View Rd.	SB

Total length: Approximately 6.5 miles

(from MP 34.51 to MP 41.06)

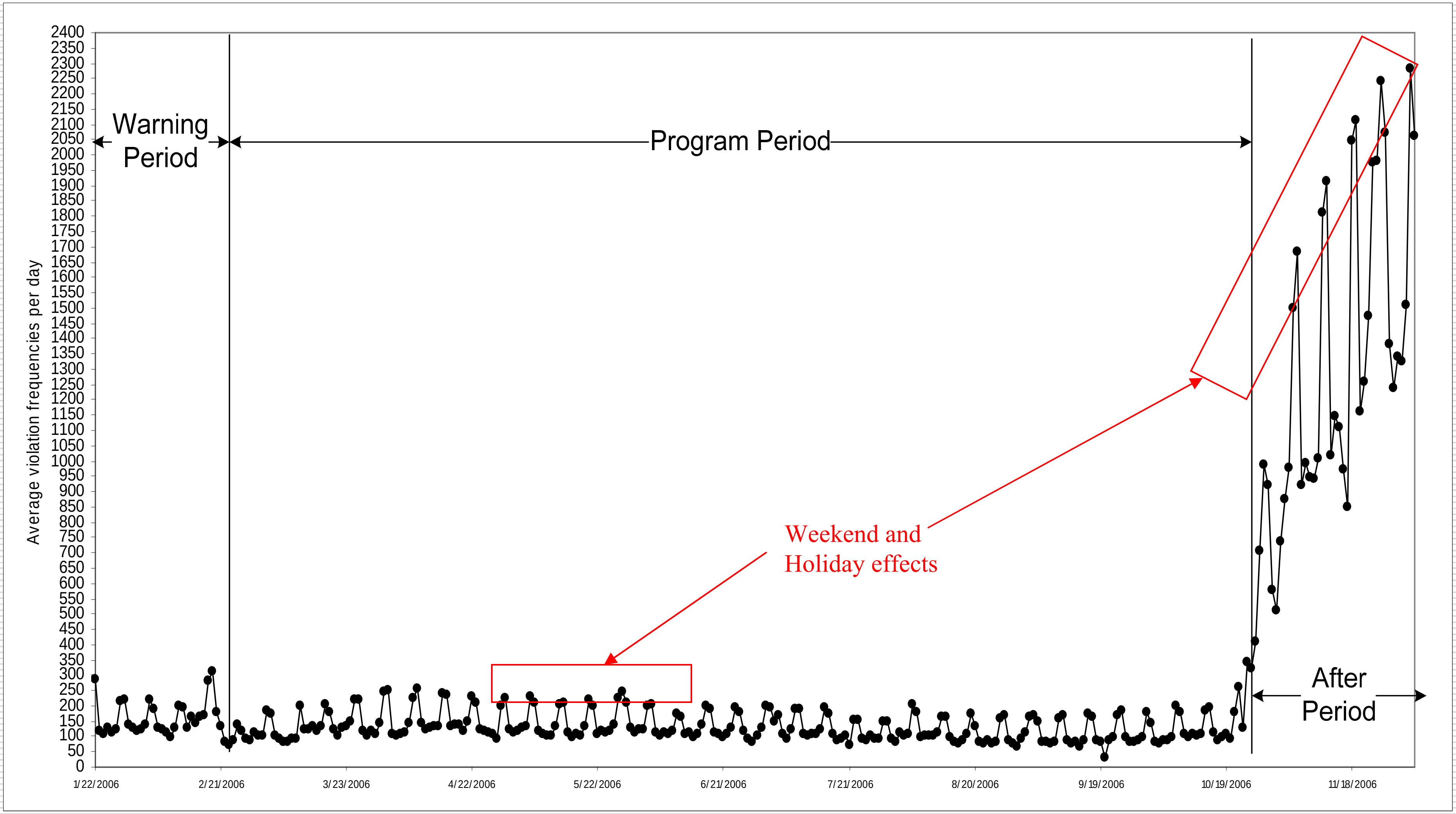
Analysis Preliminaries:

- Periods of observation:
  - *Before* (2001 – 2005 various periods)
  - *Warning* (January 22, 2006 – February 21, 2006)
  - *Program* (February 22, 2006 – October 23, 2006)
  - *After* (October 24^{th} – December 3^{rd})

- Data quality. There is a lag between crash occurrence and data input: some additional crashes are expected in the *Program* period.

Photo Enforcement Effect on detection Frequencies

Detection frequencies across periods (speed > 75mph)



Effects of the demonstration program on detection frequencies

- Average per-day per camera detection frequency differences (detections per camera per day)

Day of week	Pair	Difference	Significant	95% CIs	
				Lower	Upper
Weekday	"Warning"–"Program"	25.51	NO	-9.15	60.17
	"Warning"–"After"	-833.59	YES	-877.54	-789.64
	"Program"–"After"	-859.10	YES	-890.65	-827.54
Weekend and holiday	"Warning"–"Program"	43.27	No	-27.26	113.79
	"Warning"–"After"	-1543.06	YES	-1628.58	-1457.53
	"Program"–"After"	-1586.32	YES	-1645.57	-1527.07

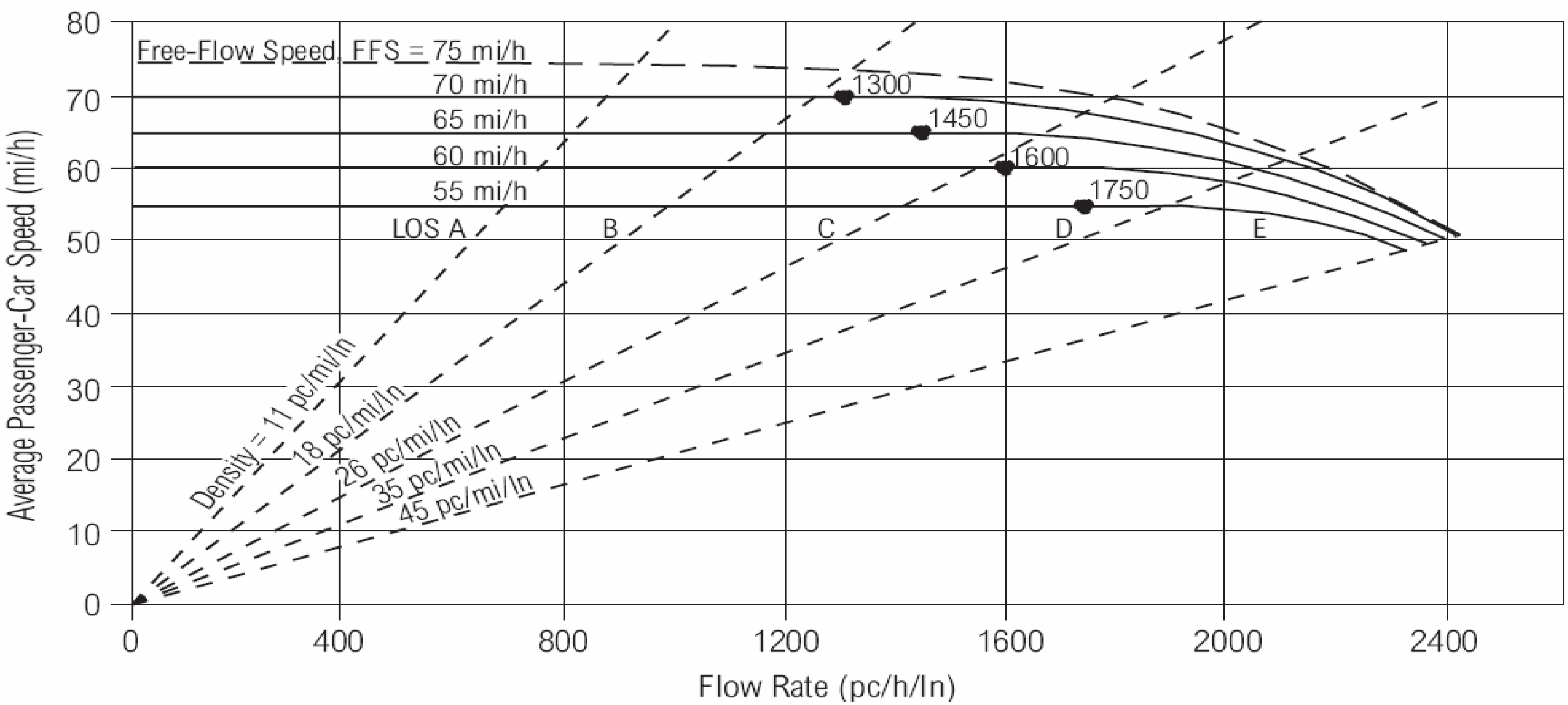
Photo Enforcement Effect on Mean Speeds

Traffic flow analysis considerations

- Mean speeds are highly sensitive to traffic flow (congestion), and so changes in traffic flow need to be factored in the calculations.
- Traffic flows and speeds are not available for all *Before* periods, so relationships between time of day and flow were developed.
- We believe that photo enforcement does not influence speeds appreciably during peak travel periods

Speed-Flow Relationship

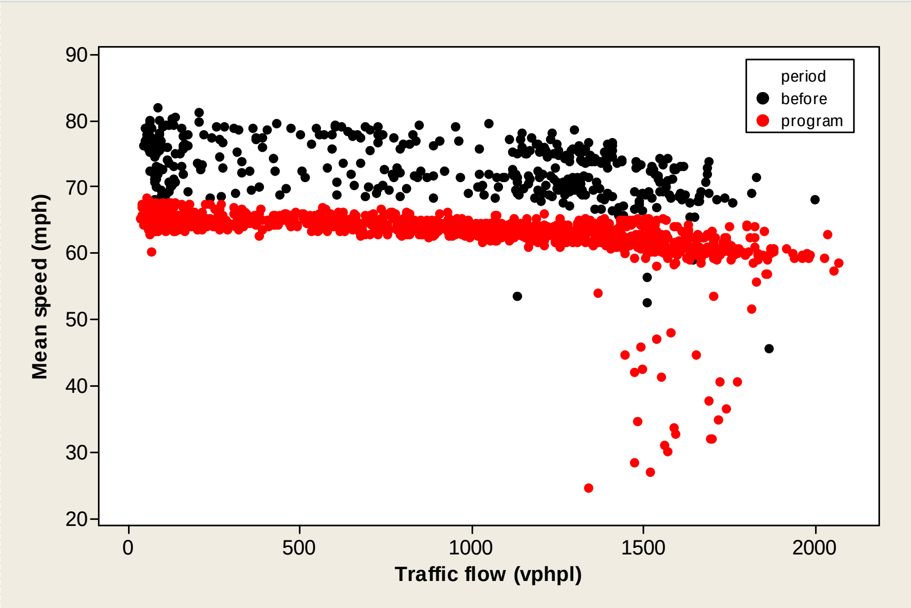
- We extracted the mean speeds in LOS A-C by using approximate level of service (LOS).



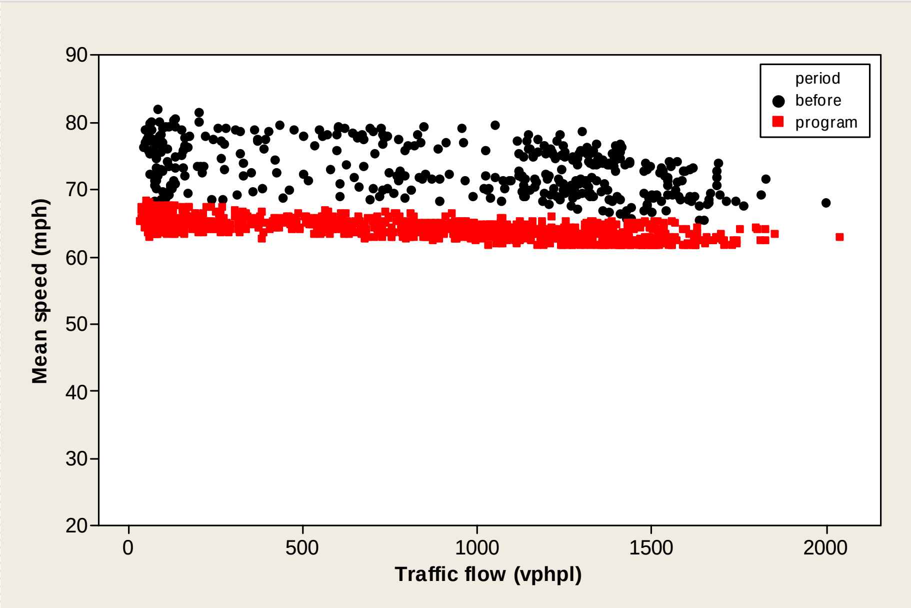
Source: Highway Capacity Manual 2000 (TRB, 2000)

Speed-Flow Relationship (Real Data)

All regimes (Regime 1, 2, and 3)



Regime 1 only



- Speeds serve as surrogates for LOS
- Time of day related to speeds

Effect of the demonstration program on mean speeds

- A differences of – 9.407 mph is the estimated difference in mean speeds DUE TO THE Demonstration Program.
- This difference accounts for the difference in mean speeds caused by changes in traffic volumes.

Period	Estimated Mean Speeds	Std. err	95% CIs	
			Lower	Upper
Before period (1)	73.57	0.0995	73.377	73.767
Program period (2)	64.17	0.0611	64.045	64.285
Difference (1 – 2)	**–9.407**	**0.1168**	**–9.636**	**–9.178**

Effect of Photo Enforcement on Traffic Safety

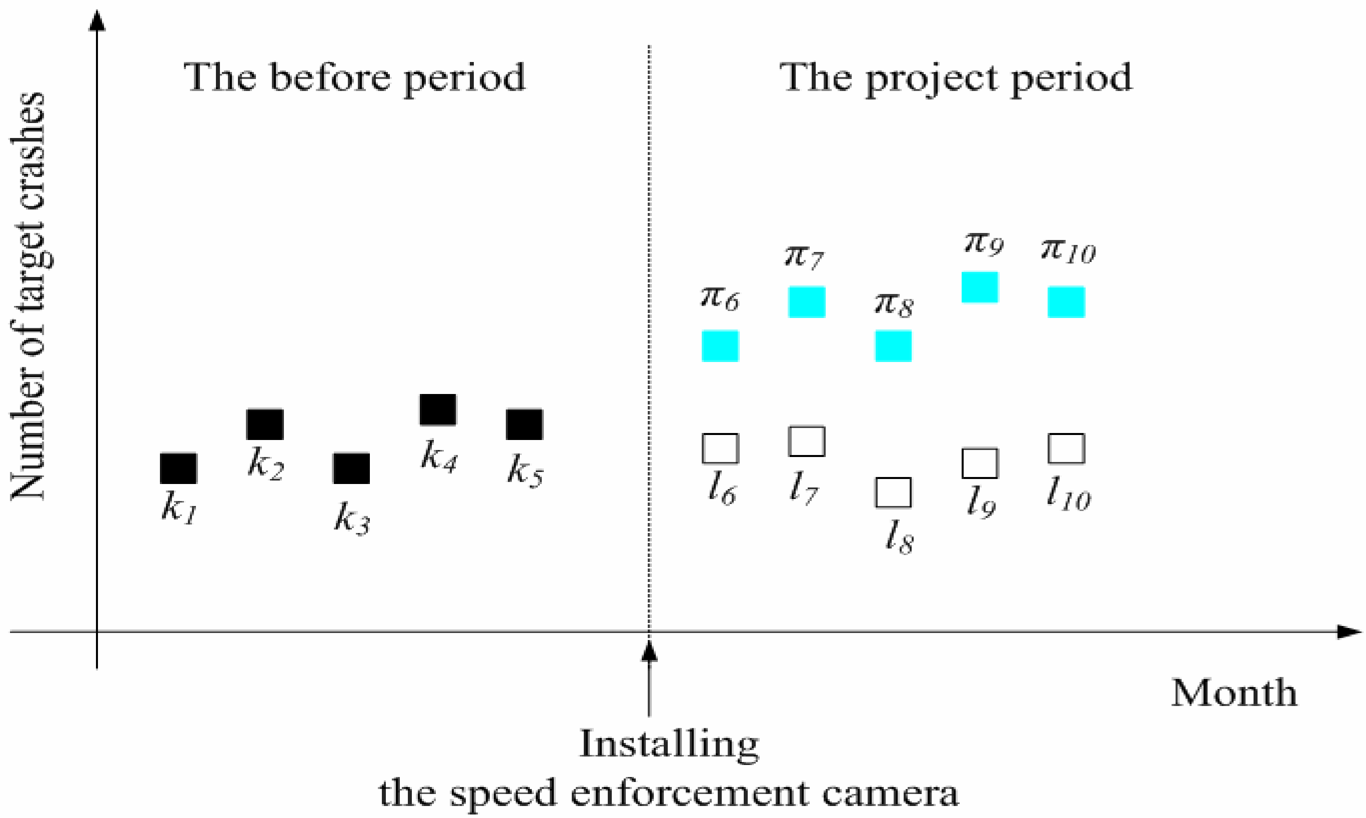
Determining Target Crashes

- Before estimating the impacts, it is necessary to define which crashes are *materially affected* by the speed enforcement cameras—referred to as "target" crashes.
- Since the crashes during the peak period are unlikely to be significantly affected by the photo enforcement cameras (speeds are constrained), *target crashes are crashes that occurred during the non-peak periods*
- Three different crash analysis assumptions are applied.
- Relationship between Time of Day (TOD) and flows is used (flows not available for all *Before* periods)

Crash Data Used in Analysis

- **Crash Data during the *Before* Period**
  - Duration: 02/22 – 8/31 (2001 through 2005)
  - Location: SR 101
- **Crash Data during the *Program* Period**
  - Duration: 02/22/2006 –8/31/2005 (191 days)
  - Location: Enforcement and comparison zones on the SR 101
    - Enforcement site: MP 34.51— MP 41.06 (6.5 miles)
    - Comparison site: MP 3.5 – MP 10 (6.5 miles)
- All crash data used in the analysis are "mainline" crashes classified by the ADOT (ramp and frontage road crashes removed).

Before and After Study in Traffic Safety Studies



k_i : The observed target crash frequency during the before period

l_j : The observed target crash frequency during the project period

π_j: The expected number of target crash frequency during the project period if the treatment had not been installed

Safety Analysis Assumptions (3-different approaches applied)

- Simple Before-After Study (naïve)

  Uses 'before' crash data corrected for traffic volumes (exposure to risk)

- Before-After with Comparison Group

  Uses ratio of crashes 'before' to 'program' at comparison site

- Empirical Bayes' accounting for Regression-to- th e-mean

  Uses multivariate models of reference sites and corrects for possible regression-to-the-mean effects

Estimates for simple before-after study

Step	Goals	Formulas for simple before-and-after study
Step 1	Estimate λ and predict π	$\hat{\lambda} = L$ $\hat{\pi} = K$
Step 2	Estimate $\hat{\sigma}^2[\hat{\lambda}]$ and $\hat{\sigma}^2[\hat{\pi}]$	$\hat{\sigma}^2[\hat{\lambda}] = \hat{\lambda}$ $\hat{\sigma}^2[\hat{\pi}] = \hat{\pi}$
Step 3	Estimate δ and θ	$\hat{\delta} = \hat{\pi} - \hat{\lambda} = K - L$ $\hat{\theta} \cong \dfrac{\left(\dfrac{\hat{\lambda}}{\hat{\pi}}\right)}{\left(1 + \dfrac{\hat{VAR}[\hat{\pi}]}{\hat{\pi}^2}\right)} = \dfrac{\left(\dfrac{L}{K}\right)}{\left(1 + \dfrac{K}{K^2}\right)}$
Step 4	Estimate $\hat{\sigma}^2[\hat{\delta}]$ and $\hat{\sigma}^2[\hat{\theta}]$	$\hat{\sigma}^2[\hat{\delta}] = \hat{\pi} + \hat{\lambda} = K + L$ $\hat{\sigma}^2[\hat{\theta}] \cong \dfrac{\hat{\theta}^2 \cdot \left[\dfrac{\hat{VAR}(\hat{\lambda})}{\hat{\lambda}^2} + \dfrac{\hat{VAR}(\hat{\pi})}{\hat{\pi}^2}\right]}{\left[1 + \dfrac{\hat{VAR}(\hat{\pi})}{\hat{\pi}^2}\right]^2} = \dfrac{\hat{\theta}^2 \cdot \left[\dfrac{L}{L^2} + \dfrac{K}{K^2}\right]}{\left[1 + \dfrac{K}{K^2}\right]^2}$

Analysis I: Simple Before and After Study

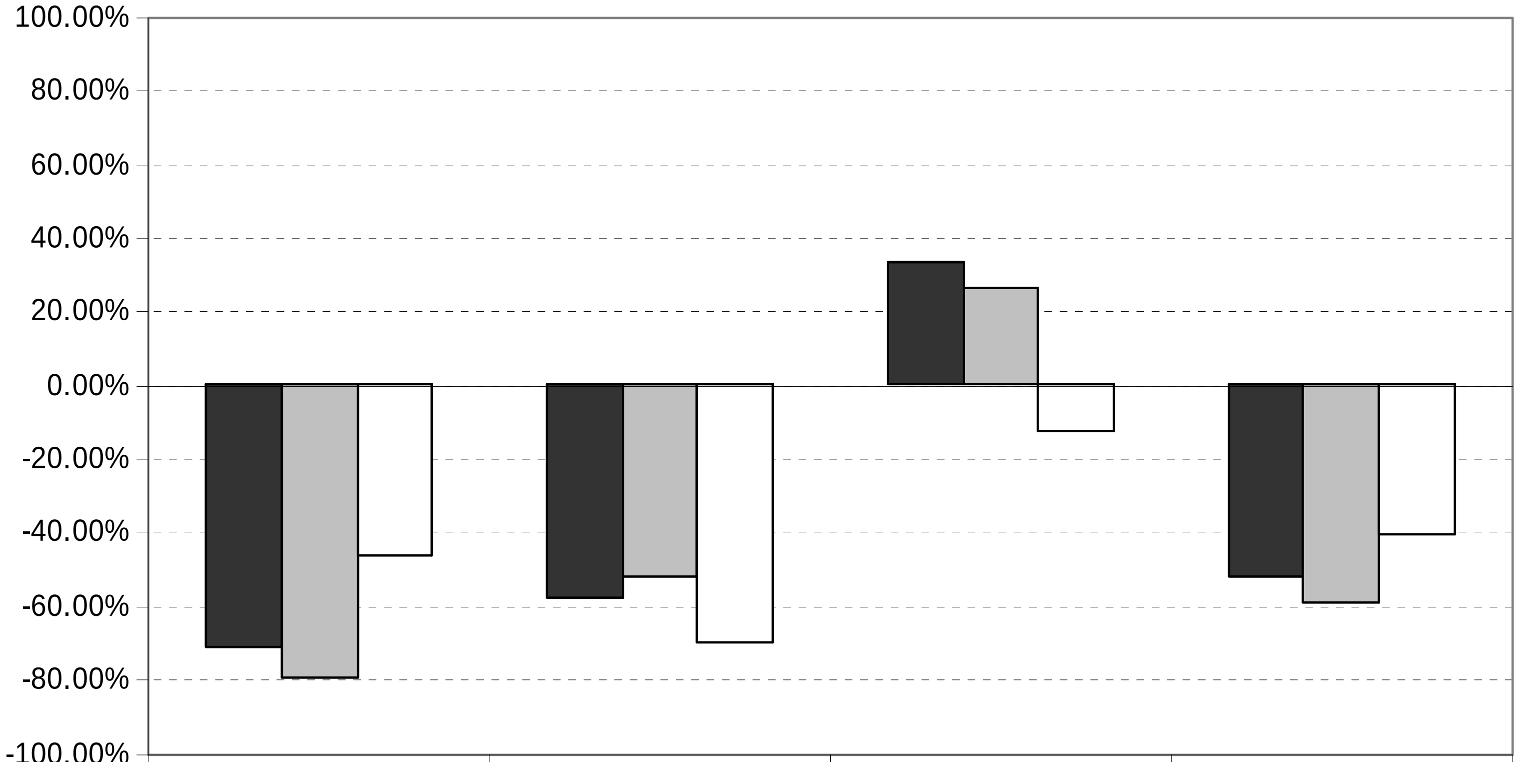
- Estimate of π = number of crashes observed during the before period (K), corrected for exposure.
- Assumptions:
  - Geometry, road user behavior, weather, and many other factors same in *Before* and *Program* periods.
  - No treatments or improvements other than the installation of the speed enforcement cameras during the program period.
  - Probability that crashes are reported is the same in both periods, and the reporting threshold has not changed.
- We correct for traffic volume increases over time on the estimates on expected crashes

Traffic Volume Correction Factors

Correction factors for traffic volumes are assumed to be proportional to traffic volumes (exposure). This assumption is quite reasonable considering that peak period crashes are not analyzed.

Traffic Volume Count Station	**2001**	**2002**	**2003**	**2004**	**2005**	**2006***
Exit 34 Scottsdale Rd	65,000	67,600	69,400	100,000	142,000	163300
Exit 36 Princess Dr	-	-	80,000	103,000	124,000	142600
Exit 37 Frank Lloyd Wright Blvd	85,000	88,400	90,700	105,000	123,000	141450
Exit 39 Raintree Dr	81,000	84,200	86,400	110,000	115,000	132250
Exit 40 Cactus Rd	90,000	93,600	96,000	118,000	123,000	141450
Exit 41 Shea Blvd	90,000	93,600	96,000	119,000	131,000	150650
Correction Factor, r(tf)	2.12	2.04	1.68	1.33	1.15	1.00

RESULTS: Before and After (BA) % Increase in Crashes (with traffic correction)



	Single Vehicle	Side-swipe (same)	Rear-end	Total
Crash Frequencies	-71.12%	-57.85%	33.24%	-51.88%
PDO Crashes	-79.44%	-52.05%	26.16%	-59.03%
Total Injuries	-46.09%	-70.26%	-12.57%	-40.34%

RESULTS: BA crash frequencies (w/ traffic volume correction)

	Collision Type	Crash Estimates		Delta (δ)		Theta (θ)	
		Phi	Lambda	Estimate	Std.Dev	Estimate	Std.Dev
Total Crashes	Single Vehicle	47.47	14	**33.47**	7.84	**0.29**	0.16
	Side-swipe (same)	15.61	7	**8.61**	4.75	**0.42**	0.28
	Rear-end	13.26	19	-5.74	5.68	1.33	0.38
	Other	9.93	2	**7.93**	3.45	**0.18**	0.30
	Total	86.27	42	**44.27**	11.33	**0.48**	0.13
PDO Crashes	Single Vehicle	37.91	8	**29.91**	6.78	**0.21**	0.17
	Side-swipe (same)	11.51	6	**5.51**	4.18	**0.48**	0.32
	Rear-end	8.51	12	-3.49	4.53	1.26	0.45
	Other	6.96	1	**5.96**	2.82	**0.13**	0.33
	Total	64.90	27	**37.90**	9.59	**0.41**	0.14
Total Injuries	Single Vehicle	11.98	7	**4.98**	4.36	**0.54**	0.32
	Side-swipe (same)	5.73	2	**3.73**	2.78	**0.30**	0.38
	Rear-end	10.44	10	**0.44**	4.52	**0.87**	0.38
	Other	4.38	1	**3.38**	2.32	**0.19**	0.39
	Total	32.52	20	**12.52**	7.25	**0.60**	0.21

* Bold numbers indicate crash reduction.

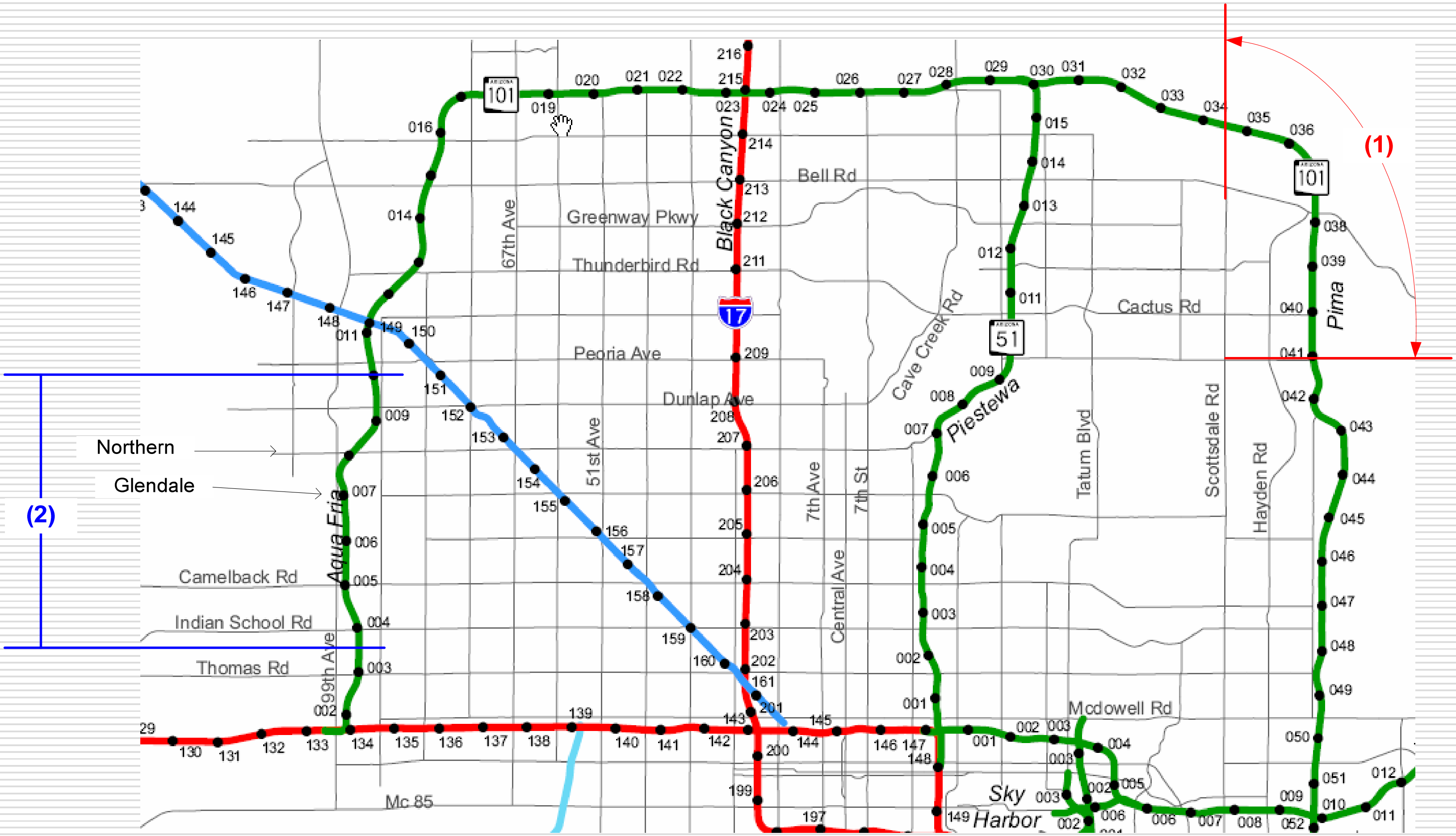
Delta is estimated reduction in crashes; Theta is crash modification factor

Analysis II: BA Study with Comparison Group

- Offers an improvement over the simple before-after study by accounting for trends in crashes over time *in addition to exposure changes* (e.g. road users, weather, vehicle fleet, etc.)
- Assumes that the comparison site is unaffected by the countermeasure (no spillover)
- Crash trends are similar to enforcement zone (101 west side)
- Assumptions are tested

Analysis II: BA Study with Comparison Group

(1) Enforcement zone: MP 34.51– MP 41.06 (Approximately 6.5 miles)
(2) Comparison zone: MP 3.5 – MP 10 (6.5 miles)

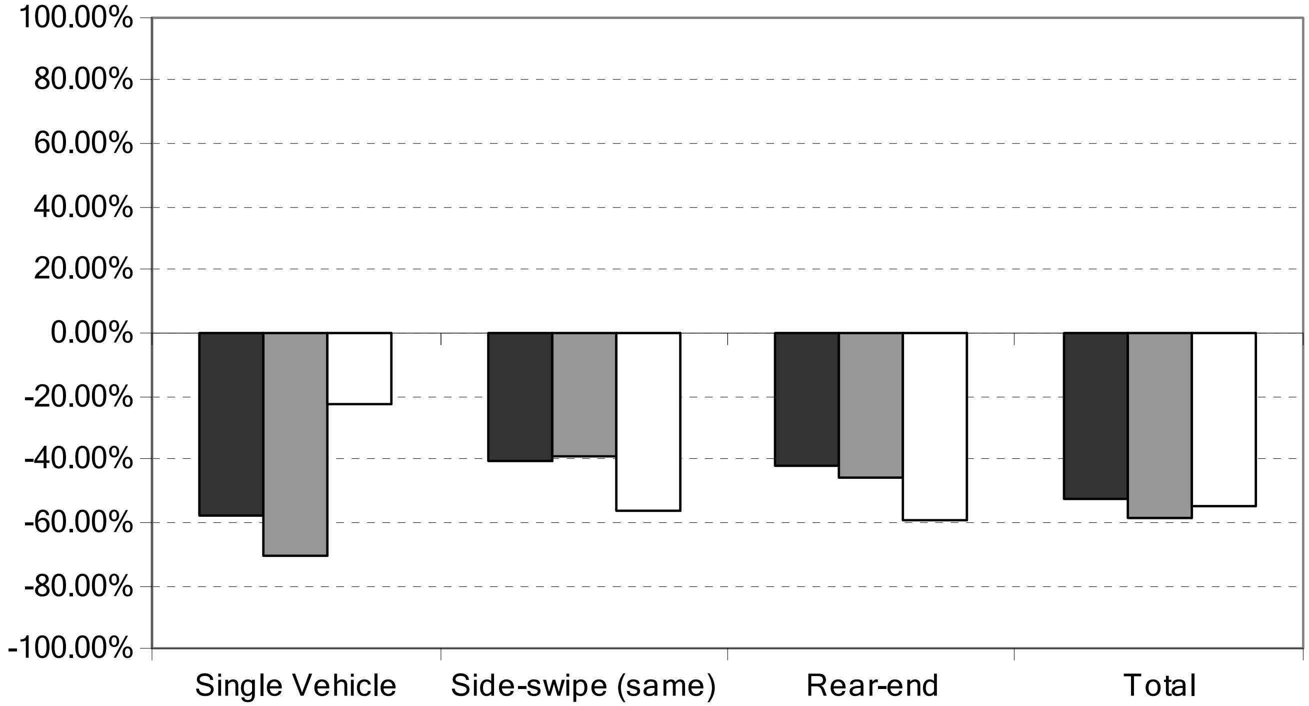


Estimates of the comparison ratios

- Comparison ratio is the ratio of crashes before to 'during' (e.g. rear-ends before/rear-ends program)
- Comparison ratios greater than 1 indicate an increase while ratios less than 1 indicate a decrease (e.g. overall crashes increased 23% at comparison site)

Crash Type	Non-peak Period	
	Comparison ratio (CR)	s.d. (CR)
Rear-end	**2.57**	0.49
Single-vehicle	0.85	0.18
Side-swipe (same)	**1.00**	0.31
Total	**1.23**	0.15

RESULTS: BA with Comparison Group, % Increase in Crashes



	Single Vehicle	Side-swipe (same)	Rear-end	Total
■ Crash Frequencies	-58.05%	-40.30%	-42.27%	-52.41%
■ PDO Crashes	-70.26%	-38.78%	-45.71%	-58.74%
□ Total Injuries	-22.29%	-55.88%	-59.48%	-54.61%

Rear-end crashes are reduced by reflecting the safety changes in the comparison site.

RESULTS: BA w/ comparison group, crash frequencies

	Collision Type	Crash Estimates		Delta		Theta	
		Phi	Lambda	Estimate	Std.dev	Estimate	Std.dev
Total Crashes	Single Vehicle	30.53	14	**16.53**	6.67	**0.44**	0.21
	Side-swipe (same)	17.00	7	**10.00**	4.90	**0.39**	0.26
	Rear-end	11.30	19	-7.70	5.50	1.55	0.43
	Other	23.59	2	**21.59**	5.06	**0.08**	0.20
	Total	82.41	42	**40.41**	11.15	**0.50**	0.13
PDO Crashes	Single Vehicle	24.55	8	**16.55**	5.71	**0.31**	0.22
	Side-swipe (same)	12.67	6	**6.67**	4.32	**0.44**	0.30
	Rear-end	7.45	12	-4.55	4.41	1.42	0.49
	Other	15.98	1	**14.98**	4.12	**0.06**	0.24
	Total	60.64	27	**33.64**	9.36	**0.44**	0.15
Total Injuries	Single Vehicle	7.22	7	**0.22**	3.77	**0.85**	0.43
	Side-swipe (same)	5.67	2	**3.67**	2.77	**0.30**	0.38
	Rear-end	8.22	10	-1.78	4.27	1.09	0.44
	Other	11.41	1	**10.41**	3.52	**0.08**	0.27
	Total	32.52	20	**12.52**	7.25	**0.60**	0.21

Before-After with Comparison Conclusions:

- Crashes appear to be increasing w/o intervention on the 101 (about 23%) due to trends (not account ed for in simple B-A)
- Decreases from the program are larger when accounting for the ‘natural’ increase in crashes
- Even rear-end crashes that appeared to increase in the Simple B-A decrease when corrected for crash trends
- The Program appears to be effective in reducing all crash types

Analysis III: Empirical Bayesian (EB) BA Study

- Accounts for Regression-to-the-mean bias resulting from site selection bias (sites selected due to high crash count)
- 'Corrects' for expected random fluctuations in crashes
- Relies on relationship between safety and traffic volumes on 101
- Entire 101 and 2001 through 2005 data used to estimate safety performance functions

Empirical Bayesian (EB) BA study theory

- It is desirable to consider the possible regression-to-the-mean (RTM) bias in traffic safety studies and the safety performance function.
- The best estimate of **phi** is:

$$E[\kappa \mid K] = w \cdot E[\kappa] + (1 - w) \cdot K; \quad w = \frac{E[\kappa]}{E[\kappa] + Var[\kappa]}$$

- $E[\kappa \mid K]$: The expected crash frequency for the zone given observed crash frequency K
- $E[\kappa]$: The average crash frequency of the reference group
- $Var[\kappa]$: The variation around $E[\kappa]$
- w : EB weight (between 0 and 1)

Empirical Bayesian estimates

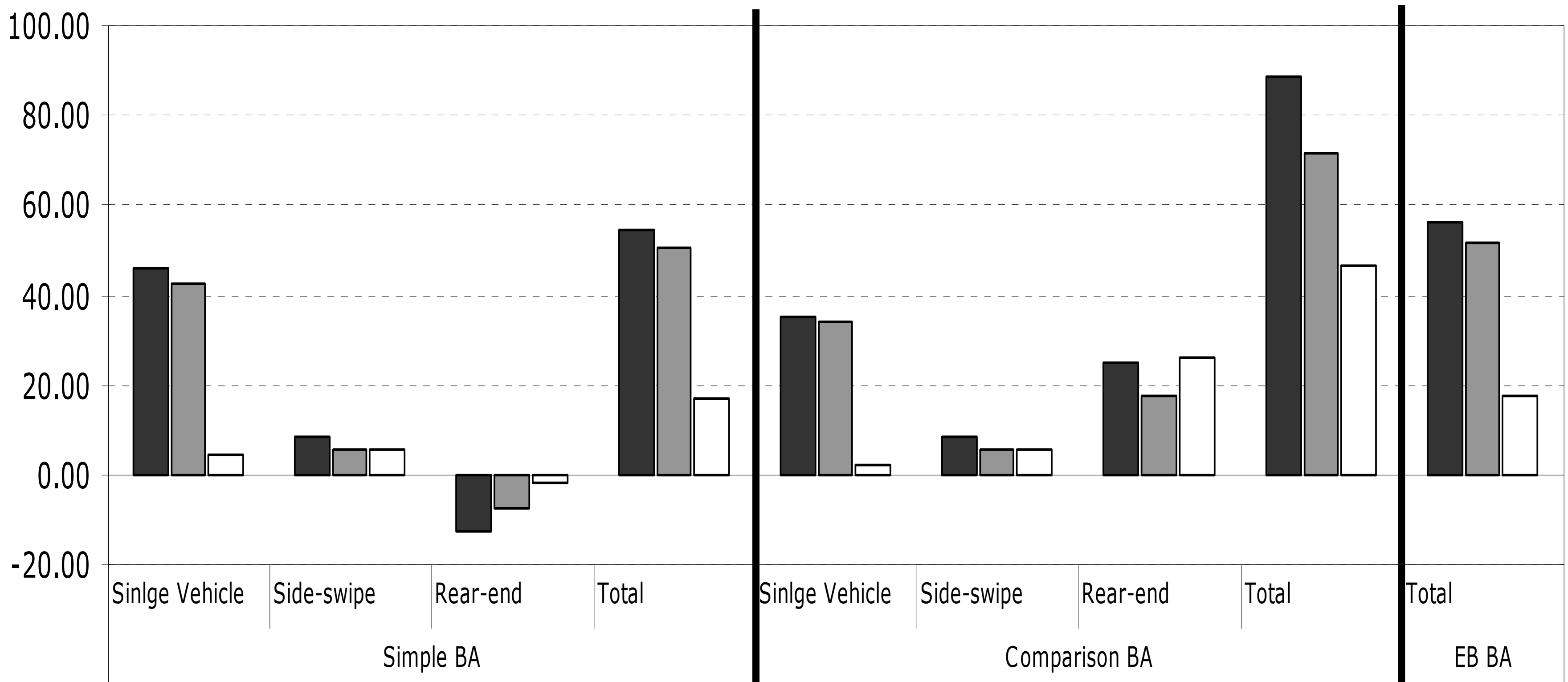
- Modeling results show that the observed crash counts (K) in the enforcement zone are less than the expected crash counts of the reference group (entire 101).
- Enforcement site does not appear to represent ‘high risk’ freeway site—the 101 Scottsdale enforcement site was ‘safer than average’ prior to the program.

Total	Expected Crash Count	Observed Crash Count	EB Estimate
Crash frequencies	76.67	71.6	72.34
PDO Crashes	55.07	53.4	53.91
Injuries	31.36	29.8	30.09

EB Analysis Conclusions:

- Scottsdale Enforcement Zone was not the ‘least safe’ 101 site prior to the Program (safer than average)
- Accounting for regression-to-the-mean and non-linear safety performance functions still shows positive effects of the program for all crashes
- The Program appears to be effective

Comparison of Analysis Method Results
Number of crashes and injuries *Reduced* per year



	Simple BA				Comparison BA				EB BA
	Sinlge Vehicle	Side-swipe	Rear-end	Total	Sinlge Vehicle	Side-swipe	Rear-end	Total	Total
Crash Frequencies	45.86	8.41	-12.61	54.65	35.11	8.41	24.67	88.59	56.07
PDO Frequencies	42.81	5.35	-7.26	50.45	34.20	5.35	17.40	71.55	51.42
Total Injuries	4.59	5.35	-1.53	16.82	1.93	5.35	26.14	46.37	17.37

Estimated Benefit of Photo Enforcement on Traffic Safety (Crash Costs Only)

Economic Analysis

- Crash costs obtained from extensive national research on full costs of motor vehicle crashes (NHTSA, 2000; Economic Impact of Motor Vehicle Crashes)
- Costs are AZ-specific and include hospital charges by injury severity category (occurring on AZ high-speed freeways)
- Utilize inflation adjusted costs from:

  National Hospital Discharge Survey

  National Health Interview Survey

  AZ hospital cost/charge information

  CHAMPUS data on physician costs

  National Medical Expenditure Survey

  National Council on Compensation Insurance

  Crashworthiness Data System

Economic Analysis (cntd.)

- Crash Severity is based on the KABCO severity scale (National Safety Council).
  - K = Killed; A = disabling injury; B = evident injury; C = possible injury; O = property damage only (no apparent injury).

- *Medical Costs* include: Professional, hospital, emergency department, drugs, rehabilitation, long-term care
- *Other Costs* include: Police/ambulance/fire, insurance administration, loss of wages, loss of household work, legal/court costs, property damage
- *Quality of Life Costs* include: Based on Quality Adjusted Life Years (approximately $92k/QALY)

Crash cost estimates for crash types occurring on AZ high-speed freeways (202, 51, and 101) by severity level

Collision type	Crash severity	Final Medical Cost	Total Other Cost	Quality of Life Cost	Total Cost
Single-vehicle	K	$162,870	$1,340,063	$2,111,828	$3,614,761
	A	$122,790	$200,291	$361,020	$684,101
	B	$24,104	$61,295	$88,104	$173,503
	C	$13,545	$34,771	$45,343	$93,659
	O	$15,527	$41,402	$50,277	$107,206
Side-swipe (same direction)	K	$119,065	$1,651,039	$2,496,842	$4,266,946
	A	$133,636	$301,959	$442,205	$877,801
	B	$27,504	$80,482	$86,291	$194,277
	C	$16,354	$65,398	$64,673	$146,425
	O	$15,826	$62,247	$50,530	$128,604
Rear-end	K	$71,037	$1,608,206	$2,441,687	$4,120,929
	A	$70,820	$162,469	$239,725	$473,013
	B	$39,899	$100,244	$152,827	$292,971
	C	$28,785	$77,037	$113,695	$219,517
	O	$30,643	$77,278	$117,022	$224,942
Other Crashes	K	$77,949	$1,200,900	$1,784,243	$3,063,092
	A	$97,374	$236,524	$310,713	$644,611
	B	$15,431	$62,216	$60,957	$138,604
	C	$8,557	$42,965	$43,917	$95,439
	O	$3,421	$34,919	$11,019	$49,359

Annualized Estimated Crash Benefits, $1000's

Analysis method	Collision type	Crash severity					
		K	A	B	C	O	Total
Simple before and after study with traffic flow correction	Single Vehicle	$1,589	-$233	$1,686	-$282	$6,128	$8,888
	Side-swipe (same)	$0	$0	$645	$380	$1,355	$2,380
	Rear-end	$0	-$1,439	-$80	-$217	-$1,499	-$3,235
	Other	$2,388	$283	$131	$154	$562	$3,519
	Total	$3,977	-$1,388	$2,382	$34	$6,546	$11,551
Before and after study with a comparison group	Single Vehicle	$1,425	-$1,266	$1,026	-$421	$3,390	$4,154
	Side-swipe (same)	$0	$0	$743	$373	$1,638	$2,754
	Rear-end	$0	-$1,576	-$257	-$397	-$1,958	-$4,187
	Other	$4,454	$937	$403	$650	$1,413	$7,857
	Total	$5,879	-$1,905	$1,914	$206	$4,484	$10,578

Scottsdale 101 Program Conclusions

- Detection frequencies increased over 800%, average speeds decreased almost 10 mph
- All crashes except rear-ends were reduced; however rear-end injuries were reduced.
- Crash type ‘trade-offs’ are common for safety countermeasures (signalization, red light cameras, etc.)
- Estimated benefits range from $10 to $11 M/yr (considering only crash costs)

Overall Conclusions (Continued)

- The results are likely to be conservative (under-estimate benefits) because:
  - Scottsdale site safer than average
  - Other costs and benefits not included (congestion, enforcement, risk, travel time)
  - All assumptions conservative (time of day, traffic volume increase)

Planned Future Work

- Analyze all SR 101 crashes in 2006
- Examine additional comparison sites and crashes
- Examine car-following effects (headways)
- Update databases (detections and speed)
- Increase sample size of comparison sites to improve efficiency of estimates
- Focus on implementation recommendations and guidelines

Planned Future Work (cntd.)

- Compute additional costs and benefits of program (travel time losses, incident related congestion costs, reduced enforcement costs, and reduced officer risk)
- We are currently conducting a micro-simulation of the network to estimate travel time impacts
- We expect the travel time impact to net positive (i.e. overall time savings from program)

Thank you!