APPENDIX **C**

SAFETY EFFECTS OF FOUR-LANE TO THREE-LANE CONVERSIONS

INTRODUCTION

The analysis undertaken examined the safety impacts of converting four lane roadways to 3 lane roadways where the middle lane is now a double left-turn lane. The site locations are in urbanized areas.

The basic objective was to estimate the change in total crashes. A secondary objective was to compare the results with those from a previous study which used full Bayes modeling and time series data for a group of treated and comparison sites matched on a one to one basis (*1*).

Data were acquired from two sources. The first was provided from the Iowa DOT and the second was available from the Highway Safety Information System. Both datasets had been prepared for previous analyses of four to three lane conversions (*1,2*).

METHODOLOGY

The general analysis methodology used is different from those used in the past, benefiting from significant advances made in safety analysis for the conduct of observational before-after studies. That book also provides guidance on study design elements such as size and selection criteria for treatment and comparison groups and the pooling of data from diverse sources. All these are crucial elements in successfully conducting a study to obtain results that will have wide applicability.

Specifically, the analysis:

- Properly accounts for regression-to-the-mean
- Overcomes the difficulties of using crash rates in normalizing for volume differences between the before and after periods
- Reduces the level of uncertainty in the estimates of safety effect
- Provides a foundation for developing guidelines for estimating the likely safety consequences of contemplated treatments
- Properly accounts for differences in crash experience and reporting practice in amalgamating data and results from diverse jurisdictions

In the EB approach the change in safety for a given crash type at a location is given by:

$$\lambda - \pi \qquad \text{C1)}$$

where: λ is the expected number of crashes that would have occurred in the after period without treatment and π is the number of reported crashes in the after period.

In estimating λ, the effects of regression to the mean and changes in traffic volume were explicitly accounted for using safety performance functions (SPFs) relating crashes to traffic flow and other relevant factors. Annual SPF multipliers were calibrated to account for the temporal effects on safety of variation in weather, demography, crash reporting and so on.

In the EB procedure, the SPF is used to first estimate the number of crashes that would be expected in each year of the before period at locations with traffic volumes and other characteristics similar to the one being analyzed. The sum of these annual SPF estimates (P) is then combined with the count of crashes (x) in the before period at a treatment site to obtain an estimate of the expected number of crashes (m) before treatment. This estimate of m is:

$$m = w_1(x) + w_2(P), \quad \text{C2)}$$

where: the weights w_1 and w_2 are estimated from the mean and variance of the regression estimate as:

$$w_1 = P/(P + 1/k) \quad \text{C3)}$$

$$w_2 = 1/k(P + 1/k), \quad \text{C4)}$$

where: k is a constant for a given model and is estimated from the SPF calibration process with the use of a maximum likelihood procedure. (In that process, a negative binomial distributed error structure is assumed with k being the dispersion parameter of this distribution.)

A factor is then applied to m to account for the length of the after period and differences in traffic volumes between the before and after periods. This factor is the sum of the annual SPF predictions for the after period divided by P, the sum of these predictions for the before period. The result, after applying this factor, is an estimate of λ. The procedure also produces an estimate of the variance of B, the expected number of crashes that would have occurred in the after period without treatment.

The estimate of λ is then summed over all sites in a treatment group of interest (to obtain λ_{sum}) and compared with the count of crashes during the after period in that group (π_{sum}). The variance of λ is also summed over all sections in the treatment group.

The Index of Effectiveness (θ) is estimated as:

$$\theta = (\pi_{sum}/\lambda_{sum}) \,/\, \{1 + [Var(\lambda_{sum})/\lambda_{sum}^2]\}. \quad \text{C5)}$$

The standard deviation of θ is given by:

$$Stddev(\theta) = [\theta^2\{[Var(\pi_{sum})/\pi_{sum}^2] + [Var(\lambda_{sum})/\lambda_{sum}^2]\} \,/\, [1 + Var(\lambda_{sum})/\lambda_{sum}^2]^2]^{0.5} \quad \text{C6)}$$

The percent change in crashes is in fact $100(1-\theta)$; thus a value of $\theta = 0.7$ with a standard deviation of 0.12 indicates a 30 percent reduction in crashes with a standard deviation of 12%.

DATA COLLECTION

This section provides a summary of the databases acquired.

Iowa Study Data

The data used for a previous study were obtained for re-analysis. These included 15 treated sites. In addition, a large reference group was separately provided in order to estimate the SPFs required for an empirical Bayes analysis.

Table C-1. Summary of converted segments.

Number of Sites = 15			
Variable	Mean	Minimum	Maximum
Years before	17.53	11.00	21.00
Years after	4.47	1.00	11.00
Crashes/mile-year before	23.74	4.91	56.15
Crashes/mile-year after	12.19	2.27	30.48
AADT before	7,987	4,854	11,846
AADT after	9,212	3,718	13,908
Length (mi.)	1.02	0.24	1.72

Table C-2. Summary of reference data.

Number of Sites = 296			
Variable	Mean	Minimum	Maximum
Years	21.8	5	23
Crashes/mile-year	26.8	0.2	173.7
AADT	8,621	296	27,530
Length (mi.)	0.99	0.27	3.38

Year	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Total Crashes	6685	7111	7992	8494	7954	7543	8202	8738	8961	9030	8736	9212
Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	
Total Crashes	9361	9367	9189	8652	8588	8398	8389	7249	7329	7112	7465	

HSIS Study Data

The data used for a previous study were obtained for re-analysis (*2*). This dataset included 30 treated sites and 51 comparison sites. The treated and comparison sites were located in the cities of Bellevue and Seattle in Washington and Mountain View, Oakland, Sacramento, San Francisco, San Leandro and Sunnyvale California. The comparison sites were matched to be similar in terms of functional class, type of development, speed limit, intersection spacing and access control.

Table C-3. Summary of converted intersections.

Number of Sites = 30			
Variable	Mean	Minimum	Maximum
Years before	4.7	1.8	8.5
Years after	3.5	0.6	8.8
Crashes/mile-year before	28.57	0.00	111.10
Crashes/mile-year after	24.07	0.00	107.62
AADT before	11,928	5,500	24,000
AADT after	12,790	6,194	26,376
Length (mi.)	0.84	0.08	2.54

Table C-4. Summary of reference data.

Number of Sites = 51			
Variable	Mean	Minimum	Maximum
Years	7.82	4.50	12.17
Crashes/mile-year	42.19	5.96	169.73
AADT	15,208	1,933	26,100
Length (mi.)	0.95	0.10	3.31

DEVELOPMENT OF SAFETY PERFORMANCE FUNCTIONS (SPFS)

This section presents the safety performance functions (SPFs) developed. Generalized linear modeling was used to estimate model coefficients using the software package SAS and assuming a negative binomial error distribution, all consistent with the state of research in developing these models.

In specifying a negative binomial error structure, the "dispersion" parameter, k, which relates the mean and variance of the regression estimate, is iteratively estimated from the model and the data. The value of k is such that the smaller its value the better a model is for a given set of data.

Iowa Study

The model form is as follows:

accidents/year = a_y(length)exp(b_o)(AADT)^{b_1}

The parameter estimates are shown in Table C5.

Table C5. SPF Parameter estimates for Iowa study data.

Parameter	estimate	Standard error
b_o	-8.4439	0.5906
b_1	1.2917	0.0661
K	0.4117	0.0323

Table C6 shows values of a_y, a series of yearly calibration factors to reflect temporal changes.

Table C6. Annual multipliers for Iowa SPFs.

Year	a_y	Year	a_y
1982	1.24	1994	1.12
1983	1.29	1995	1.12
1984	1.29	1996	1.08
1985	1.41	1997	1.00
1986	1.29	1998	0.93
1987	1.20	1999	0.89
1988	1.22	2000	0.89
1989	1.25	2001	0.77
1990	1.24	2002	0.78
1991	1.21	2003	0.75
1992	1.15	2004	0.78
1993	1.15		

HSIS Study

The model form is as follows:

accidents/year = exp(b_o)(length)^{b1}(AADT)^{b2}

The parameter estimates are shown in Table C7.

Table C7. SPF parameter estimates for HSIS study data.		
parameter	estimate	Standard error
b_o	-3.6323	1.4249
b_1	0.7182	0.1321
b_2	0.5722	0.1509
k	0.2270	0.0450

The data did not allow for yearly calibration factors to be used.

RESULTS

Estimates of the index of effectiveness, θ, for the crash frequency analysis are given in Table C-8.

Table C-8. Results.		
Dataset	θ	Standard error
Iowa	0.534	0.020
HSIS	0.811	0.025
All	0.707	0.016

DISCUSSION AND CONCLUSIONS

As can be seen, the measured effects from the two databases differ markedly. The IA database indicates a 47% reduction in total crashes while the HSIS (CA and WA) data indicates a 19% decrease. The difference may be a function of traffic volumes and characteristics of the urban environments where the road diets were implemented. The sites in IA ranged in AADT from 3,718 to 13,908 and were predominately on US or State routes in small urban towns with an average population of 17,000. The sites in Washington and California ranged in AADT from 6,194 to 26,376 and were predominately on corridors in suburban environments that surrounded larger cities with an average population of 269,000. In addition, in Iowa there appeared to be a calming effect as evidenced in a study (*3*) of one site that revealed a 4-5 mph reduction in 85th percentile free flow speed and a 30% reduction in percentage of vehicles traveling more than 5 mph over the speed limit (i.e., vehicles traveling 35 mph or higher). Our speculation is that this calming effect would be less likely in the larger cities in the HSIS study where the approaching speed limits (and traffic speeds) might have been lower to start with.

The "new" Iowa results also seem to be incompatible with those in the earlier Iowa analysis (*1*) of the same treatment site data. However, the 25% reduction reported in that study were average effects per mile derived by comparing average crashes per mile after treatment with average crashes per mile expected without the treatment, and, as such are not comparable to the "new" results since sites of different lengths are weighted equally. (The new results are overall effects that provide more weight to sites of longer length.) In addition, the “new” results use a much larger comparison group than the previous study, which used an equal number of treatment and comparison sites.

REFERENCES

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