APPENDIX **G**

ACCIDENT MODIFICATION FACTORS FOR MEDIAN WIDTH

INTRODUCTION

Studies on the effect of median width have shown that increasing width reduces cross-median crashes, but the amount of reduction varies across studies. The effect of median width on median-related or all crashes is even less clear. The objective of this study was to develop AMFs for median width for different types of roads.

METHODOLOGY

The preferred method for developing an AMF is to conduct a before-after study in which the treatment installation/removal/change date is known, and thus the safety before and after this date can be tracked. The current state-of-the-art methodology for conducting such studies makes use of an empirical Bayes (EB) approach, which helps to account for issues such as regression to the mean, changes in traffic volumes, and changes in crashes over time that are due to other factors (e.g., weather). However, there are a number of treatments in the roadway environment that are not "installed" or changed in a manner that allows for a before-after study. Median width is one such treatment. It is very unlikely that the median width on a highway will ever be changed without making other significant changes to the geometric cross-section. For example, the most common change in median width would occur when additional travel lanes are being added to the left-hand side of a roadway, thus narrowing the median. The fact that there was a significant change other than the median width does not easily allow one to isolate the effects of the change in width in an EB before-after evaluation. In this case, a cross-section model that predicts safety on the basis of varying median widths, traffic volumes, and other factors is still probably the most feasible option for determining the expected safety benefits as median width changes.

In this evaluation, negative binomial (NB) regression models were developed with crash frequency as the dependent variable and site characteristics such as traffic volume, shoulder width, and median with as independent variables. The parameter estimates from the NB models were used to develop AMFs for median width. The analysis focused on total crashes, cross-median crashes, and probable cross-median crashes. Whether a crash was cross-median was deduced based on the location of the crash and the movement preceding the crash.

The model form was log-linear. With this model form, the expected crash frequency is related to the independent variables as follows:

$$Y = \exp(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots.\beta_n X_n) \qquad \text{G1)}$$

where:

Y is the expected frequency of crashes,

X_1 through X_n are independent variables, and

β_0 through β_n are coefficients that need to be estimated.

In a negative binomial model, the variance is related to the mean as follows:

$$Var(y_i) = E(y_i) + k(E(y_i))^2 \tag{G2)}$$

where:

$Var(y_i)$ is the variance,

$E(y_i)$ is the mean, and

k is the overdispersion parameter.

Typically, k is assumed as a constant value while estimating the NB models. Hauer (2001) argued that assuming k as a constant provides too much weight to shorter sections and not enough weight to longer sections. He advocated estimating k on a per-mile basis. (*1*) In this study, for each dependent variable, models were estimated with the overdispersion parameter as a constant, and also with the overdispersion parameter on a per-mile basis. Based on the following goodness of fit statistics, the better model was chosen:

$$\text{AIC} = -2L(\hat{\theta}) + 2p \tag{G3)}$$

$$\text{AICC} = -2L(\hat{\theta}) + 2pn/(n-p-1) \tag{G4)}$$

$$\text{BIC} = -2L(\hat{\theta}) + p\log(n) \tag{G5)}$$

where:

$L(\hat{\theta})$ is the maximized log likelihood function,

$\hat{\theta}$ is the vector of estimated parameters,

p is the number of parameters, and

n is the number of observations.

The main purpose of these information criteria is to compare different models using their minimized 'minus twice the log likelihood value', but to add a penalty based on the number of parameters. In other words, the AIC, AICC, and BIC are a penalized version of -2 log likelihood and the penalty depends on the number of parameters, p. Based on these criteria, the model with the smallest AIC, AICC, and/or BIC is identified as the best model. For the models that were estimated, the CURE procedure was used to determine if the functional form of the independent variables was reasonable. (*2*)

Data

Ten years of data from 1993 to 2002 on divided roadway sections in California were obtained from the Highway Safety Information System (HSIS). HSIS has a crash file providing detailed information about individual crashes; a roadway file that has data on traffic volume and other site characteristics; and, an intersection/ramp file that shows the location of intersections and ramps. Data for about 27,131 mile-years of divided roadway sections without median barriers were extracted from HSIS. Sites where the two sides of the roadway were on separate grades were eliminated. To the extent possible, only "traversable" median locations were included in the data set. A preliminary analysis of the data revealed that median widths 100 feet or above were coded as 99 feet in the dataset. Hence, all sections with median width coded as 99 feet or above were removed. Sections with 'variable median width' were also removed. In addition, whenever the type of access control changed for a particular year, we eliminated data for that section for that year. Eliminating these sections resulted in 19,933 mile-years. Table G-1 shows the number of mile-years by access control, number of lanes, and type of area (i.e., rural/urban).

Table G-1. Mile years by roadway type.

Level of Access Control	No. of lanes	Area Type	
		Rural	Urban
Partial or No Access Control	4	3,258	1,549
	5+	70	107
Full Access Control	4	8,331	3,037
	5+	1,604	1,970

For roads with partial or no access control and more than 4 lanes, the number of mile-years was minimal, and hence, this group was not considered for the analysis. Table G-2 shows the total number of crashes and cross median plus probable cross median crashes (referred to as cross median crashes) for the different roadway types. Cross median crashes represent between 3 and 6% of total crashes in roads with full access control, and about 12% of total crashes in roads with partial or no access control. Roads with full access control experience relatively fewer cross median crashes probably because they generally have larger medians. In our sample, the average median width for roads with full access control ranged from 55 to 60 feet, whereas the average median width for roads with partial or no access control ranged from 29 to 40 feet.

Table G-2. Number of crashes (total and cross-median) by roadway type.

Level of Access Control	No. of lanes	Area Type					
		Rural			Urban		
		Total	Cross Median	% Cross Median	Total	Cross Median	% Cross Median
Partial or No Access Control	4	13,255	1,593	12.0%	28,185	3,438	12.2%
Full Access Control	4	33,009	1,961	5.9%	35,690	1,554	4.4%
	5+	12,624	548	4.3%	43,385	1,507	3.5%

Full access control roads in rural areas with more than 4 lanes had relatively few number of cross median crashes (i.e., 548), and we were not able to develop satisfactory models for this group. Hence, AMFs were not developed for this group.

Independent Variables

The independent variables extracted from HSIS and used in the development of the models included:

- ln(AADT/10000): This is defined as the natural logarithm of (AADT/10,000)
- AADT/10,000: AADT divided by 10000
- ln(section length): This is defined as natural logarithm of segment length.
- Median Width (in feet)
- Right shoulder width (in feet – this was the average of the values from both sides of the road)
- Design speed: This was included as a categorical variable with two categories, 55 mph or lower (L) and 60 mph or higher (H).
- Terrain: 'F' for flat, 'M' for mountainous, and 'R' for rolling terrain.
- Influence: This was included as a categorical variable. It was defined as follows: 0 = Current segment is within the influence of a ramp or intersection. 1 = Current segment is within the influence of a ramp or intersection. Sections within 0.30 miles of ramps were considered under the influence of a ramp. Sections within 250 feet of at-grade intersections were considered under the influence of an intersection.
- Access: This applies only for road sections that are not controlled access. This variable was defined as C = no access control; E = partial access control.

RESULTS

Tables G-3 through G-12 show the results of the negative binomial regression models that were developed. For each model, the tables provide the parameter estimates, standard errors, and some descriptive statistics showing the range of AADT and median width for that particular road type. Separate models were developed for total crashes and cross median crashes. If k was estimated on a per-mile basis, it is shown as k (per mile) in the table.

Table G-3. Model for total crashes (full access control, 4 lanes, rural).

Model		Total Accidents		
Parameter		Estimate	Standard Error	Pr > ChiSq
Intercept		1.1391	0.04674	<.0001
ln(AADT/10000)		0.836	0.03706	<.0001
AADT/10000		0.1068	0.0129	<.0001
ln(section length)		0.9516	0.008047	<.0001
Median Width (ft)		-0.00357	0.000401	<.0001
Right shoulder width (ft)		-0.03805	0.00524	<.0001
influence	0	-0.4049	0.01775	<.0001
influence	1	0	.	.
k (per mile)		0.08923	0.003095	
Log Likelihood		-4283.0599		

Descriptive Statistics	Min.	Mean	Max.	Sum
Number of sections				28,824
Section length (miles)	0.001	0.289	4.425	8330.55
Number of crashes per section	0	1.145	48	33009
AADT	2400	23560.240	119000	
Median Width (ft)	4	59.544	98	

Table G-4. Model for cross median crashes (full access control, 4 lanes, rural).

Model		Cross Median Accidents		
Parameter		Estimate	Standard Error	Pr > ChiSq
Intercept		-0.6841	0.1289	<.0001
ln(AADT/10000)		0.6911	0.04552	<.0001
AADT/10000				
ln(section length)		0.9706	0.02829	<.0001
Median Width (ft)		-0.01537	0.001406	<.0001
Right shoulder width (ft)		-0.03896	0.01601	0.015
influence	0	-0.1294	0.06157	0.0356
influence	1	0	.	.
k		0.6027	0.1053	.
Log Likelihood		-5890.6724		

Descriptive Statistics	Min.	Mean	Max.	Sum
Number of sections				28,824
Section length (miles)	0.001	0.289	4.425	8330.55
Number of crashes per section	0	0.068	5	1961
AADT	2400	23560.240	119000	
Median Width (ft)	4	59.544	98	

Table G-5. Model for total crashes (full access control, 4 lanes, urban)

Model		Total Accidents		
Parameter		Estimate	Standard Error	Pr > ChiSq
Intercept		1.4821	0.06772	<.0001
ln(AADT/10000)		0.7788	0.05549	<.0001
AADT/10000		0.1192	0.01401	<.0001
ln(section length)		0.9288	0.009357	<.0001
Median Width (ft)		-0.00547	0.000619	<.0001
Right shoulder width (ft)		-0.02706	0.007469	0.0003
influence	0	-0.7133	0.02552	<.0001
influence	1	0	.	.
k		0.5953	0.01474	.
Log Likelihood		-3855.7		
Descriptive Statistics	Min.	Mean	Max.	Sum
Number of sections				21,188
Section length (miles)	3.55E-15	0.143	3.018	3037.38
Number of crashes per section	0	1.684	95	35690
AADT	4410	38346.820	131000	
Median Width (ft)	4	56.512	98	

Table G-6. Model for cross median accidents (full access control, 4 lanes, urban).

Model		Cross Median Accidents		
Parameter		Estimate	Standard Error	Pr > ChiSq
Intercept		-0.8847	0.231	0.0001
ln(AADT/10000)		0.7829	0.0644	<.0001
AADT/10000				
ln(section length)		0.9369	0.0342	<.0001
Median Width (ft)		-0.0112	0.0022	<.0001
Right shoulder width (ft)		-0.0157	0.0263	0.5496
influence	0	-0.5798	0.0833	<.0001
influence	1	0	0	.
k		2.3057	0.2168	
Log Likelihood		-4676.6162		
Descriptive Statistics	Min.	Mean	Max.	Sum
Number of sections				21,188
Section length (miles)	3.55E-15	0.143	3.018	3037.38
Number of crashes per section	0	0.073	6	1554
AADT	4410	38346.820	131000	
Median Width (ft)	4	56.512	98	

Table G-7. Model for total crashes (no/partial access control, 4 lanes, rural).

Model		Total Accidents		
Parameter		Estimate	Standard Error	Pr > ChiSq
Intercept		2.0494	0.08852	<.0001
ln(AADT/10000)		0.6152	0.04965	<.0001
AADT/10000		0.1436	0.02215	<.0001
ln(section length)		0.7117	0.01384	<.0001
Median Width (ft)		-0.00461	0.000799	<.0001
Right shoulder width (ft)		-0.07804	0.008981	<.0001
influence	0	-1.0837	0.03325	<.0001
influence	1	0	.	.
Access	C	-0.1316	0.03884	0.0007
Access	E	0	.	.
k		0.8501	0.0294	.
Log Likelihood		-7265.0683		

Descriptive Statistics	Min.	Mean	Max.	Sum
Number of sections				14,998
Section length (miles)	1.42E-14	0.217	3.021	3258.42
Number of crashes per section	0	0.884	23	13,255
AADT	1001	17080.940	90000	
Median Width (ft)	5	40.659	94	

Table G-8. Model for cross median crashes (no/partial access control, 4 lanes, rural).

Model		Cross Median Accidents		
Parameter		Estimate	Standard Error	Pr > ChiSq
Intercept		1.5637	0.1969	<.0001
ln(AADT/10000)		0.7802	0.0469	<.0001
AADT/10000				<.0001
ln(section length)		0.8248	0.03476	<.0001
Median Width (ft)		-0.01695	0.002002	<.0001
Right shoulder width (ft)		-0.134	0.02103	<.0001
influence	0	-1.6761	0.08378	<.0001
influence	1	0	.	.
Access	C	-0.1662	0.08537	0.0515
Access	E	0	.	.
k		1.7113	0.1643	.
Log Likelihood		-4194.9527		

Descriptive Statistics	Min.	Mean	Max.	Sum
Number of sections				14,998
Section length (miles)	1.42E-14	0.217	3.021	3258.42
Number of crashes per section	0	0.106	8	1593
AADT	1001	17080.940	90000	
Median Width (ft)	5	40.659	94	

Table G-9. Model for total crashes (no/partial access control, 4 lanes, urban).

Model		Total Accidents		
Parameter		Estimate	Standard Error	Pr > ChiSq
Intercept		1.5148	0.07321	<.0001
ln(AADT/10000)		0.9874	0.06715	<.0001
AADT/10000		-0.07511	0.02472	0.0024
ln(section length)		0.5556	0.01324	<.0001
Median Width (ft)		-0.00533	0.000897	<.0001
Right shoulder width (ft)		0.03946	0.005495	<.0001
Design Speed	≥ 60 mph	0.118	0.02483	<.0001
Design Speed	≤ 55 mph	0	.	.
influence	0	-1.4333	0.02764	<.0001
influence	1	0	.	.
Access	C	-0.05191	0.02878	0.0713
Access	E	0	.	.
k		1.4461	0.02892	.
Log Likelihood		-892.2		

Descriptive Statistics	Min.	Mean	Max.	Sum
Number of sections				16,825
Section length (miles)	1.78E-15	0.092	3.797	1549.22
Number of crashes per section	0	1.675	43	28,185
AADT	1880	26098.420	150000	
Median Width (ft)	5	29.139	94	

Table G-10. Model for cross median crashes (no/partial access control, 4 lanes, urban).

Model		Cross Median Accidents		
Parameter		Estimate	Standard Error	Pr > ChiSq
Intercept		-0.04944	0.1482	0.7388
ln(AADT/10000)		1.6187	0.1735	<.0001
AADT/10000		-0.4436	0.06375	<.0001
ln(section length)		0.4616	0.02869	<.0001
Median Width (ft)		-0.0134	0.002049	<.0001
Right shoulder width (ft)		0.02485	0.01065	0.0196
Design Speed	≥ 60 mph			
Design Speed	≤ 55 mph			
influence	0	-1.8731	0.06459	<.0001
influence	1	0	.	.
Access	C	0.1364	0.06147	0.0265
Access	E	0	.	.
k		3.1937	0.1509	.
Log Likelihood		-6870.4274		0

Descriptive Statistics	Min.	Mean	Max.	Sum
Number of sections				16,825
Section length (miles)	1.78E-15	0.092	3.797	1549.22
Number of crashes per section	0	0.204	22	3438
AADT	1880	26098.420	150000	
Median Width (ft)	5	29.139	94	

Table G-11. Model for total crashes (full access control, 5 or more lanes, urban).

Model		Total Accidents			
Parameter		Estimate	Standard Error	Pr > ChiSq	
Intercept		1.9878	0.08712	<.0001	
ln(AADT/10000)		0.9453	0.05042	<.0001	
AADT/10000		0.0142	0.005224	0.0066	
ln(section length)		0.8287	0.009055	<.0001	
Median Width (ft)		-0.00744	0.000629	<.0001	
Right shoulder width (ft)		-0.07469	0.004995	<.0001	
influence	0	-0.6475	0.01992	<.0001	
influence	1	0	.	.	
k (per mile)		0.06616	0.001439	.	
Log Likelihood		-13100.2			
Descriptive Statistics		Min.	Mean	Max.	Sum
Number of sections					15,945
Section length (miles)		0.001	0.124	1.344	1970.46
Number of crashes per section		0	2.721	57	43385
AADT		2555	86745.220	282000	
Median Width (ft)		10	63.458	94	

Table G-12. Model for cross median accidents (full access control, 5 or more lanes, urban).

Model		Cross Median Accidents			
Parameter		Estimate	Standard Error	Pr > ChiSq	
Intercept		-0.1329	0.3464	0.7013	
ln(AADT/10000)		1.4279	0.2167	<.0001	
AADT/10000		-0.1275	0.0236	<.0001	
ln(section length)		1.0944	0.03535	<.0001	
Median Width (ft)		-0.01151	0.002344	<.0001	
Right shoulder width (ft)		-0.09313	0.0205	<.0001	
influence	0	-0.7497	0.08002	<.0001	
influence	1	0	.	.	
k (per mile)		0.354	0.03606	.	
Log Likelihood		-4031.4000			
Descriptive Statistics		Min.	Mean	Max.	Sum
Number of sections					15,945
Section length (miles)		0.001	0.124	1.344	1970.46
Number of crashes per section		0	0.095	13	1507
AADT		2555	86745.220	282000	
Median Width (ft)		10	63.458	94	

DISCUSSION OF RESULTS

Following are some results based on the coefficients of the various independent variables in the NB models:

- Except in no/partial access controlled roads in urban areas, increase in AADT seems to be associated with increase in total crashes. In no/partial access controlled roads in urban areas (see Table G-9), coefficient for AADT/10000 is negative whereas the coefficient for ln(AADT/10000) is positive, indicating that total crashes start decreasing for high AADT values.
- In no/partial access controlled roads and full access controlled roads with more than 5 lanes, cross median crashes start decreasing at high AADT values (see Tables G-10 and G-12 where coefficient for AADT/10000 is negative whereas the coefficient for ln(AADT/10000) is positive). Qin et al. (2006) found that single vehicle crashes are lower at higher AADT values (probably because they are a function of vehicle speed). (*3*) Based on this argument, it is not surprising that cross median crashes which probably depend on speed to a great extent, may decrease at higher AADT values when vehicle speeds start to go down.
- In the models with full controlled access, the coefficient for ln(section length) is between 0.80 and 1.10, whereas for no/partial access controlled roads, it is between 0.4 and 0.82. Some researchers prefer including section length as an offset (i.e., forcing the coefficient for ln(section length) to be 1), which ensures the predicted number of number crashes to be proportional to section length. As the coefficient moves farther away from 1, it usually implies that section length may be correlated with some causal factors that are either missing or not perfectly accounted for in the model.
- All the models indicate that sections within the influence of a ramp or intersection have more crashes compared to sections outside the influence of ramps and intersections.
- The coefficient for median width is negative in all the models indicating that as median width increases, total crashes and cross median crashes decrease.
- The coefficient for right shoulder width is negative in all the models except for no/partial access controlled roads in urban areas. The reason for a positive coefficient for right shoulder width is not clear.
- Design speed was statistically significant only for the model developed for total accidents in non/partially access controlled roads. The coefficients imply that there may be more crashes in roads with higher design speeds.
- Access control (partial versus no access control) was included as a variable for the four models that were estimated for roads with non/partial access control. Three out of the four models imply that roads with no access control have fewer crashes compared to roads that have partial access control. This is a little unexpected and the specific reasons for this result are not clear.

ACCIDENT MODIFICATION FACTORS FOR MEDIAN WIDTH

Tables G-13 and G-14 show the AMFs for median width derived from the NB models for total (all) crashes and cross median crashes. The AMFs were calculated by using 10 feet as the nominal median width (i.e., AMF = 1.0). It is clear that increasing median width is associated with a reduction in total crashes as well cross median crashes. Here are some findings regarding the AMFs:

- As expected, median width has a larger effect on cross median crashes compared to total crashes.
- The AMFs for cross median crashes are very similar for the two urban roadway types with full access control (i.e., with 4 lane and 5+ lane).
- The AMFs for cross median crashes are very similar for the two rural roadway types.
- The AMFs for total crashes are very similar for the two 4 lane urban roadway types (with full access control and partial or no access control).

Overall, the AMFs are quite similar to those obtained from previous studies that were also based on cross sectional models. (*4, 5, 6, 7, 8*) However, this study used a much larger sample of mile-years and crashes in arriving at the AMFs, and hence, recommended for in the final report of this study.

Table G-13. AMFs for median width for roads with full access control.

Median Width (ft)	Rural, 4 Lanes, Full Access Control		Urban, 4 Lanes, Full Access Control		Urban, 5+ Lanes, Full Access Control	
	Total Crashes	Cross Median Crashes	Total Crashes	Cross Median Crashes	Total Crashes	Cross Median Crashes
10	1.00	1.00	1.00	1.00	1.00	1.00
20	0.96	0.86	0.95	0.89	0.93	0.89
30	0.93	0.74	0.90	0.80	0.86	0.79
40	0.90	0.63	0.85	0.71	0.80	0.71
50	0.87	0.54	0.80	0.64	0.74	0.63
60	0.84	0.46	0.76	0.57	0.69	0.56
70	0.81	0.40	0.72	0.51	0.64	0.50
80	0.78	0.34	0.68	0.46	0.59	0.45
90	0.75	0.29	0.65	0.41	0.55	0.40
100	0.73	0.25	0.61	0.36	0.51	0.35

Table G-14. AMFs for median width for roads with partial or no access control.

Median Width (ft)	Rural, 4 Lanes, Partial or No Access Control		Urban, 4 Lanes, Partial or No Access Control	
	Total Crashes	Cross Median Crashes	Total Crashes	Cross Median Crashes
10	1.00	1.00	1.00	1.00
20	0.95	0.84	0.95	0.87
30	0.91	0.71	0.90	0.76
40	0.87	0.60	0.85	0.67
50	0.83	0.51	0.81	0.59
60	0.79	0.43	0.77	0.51
70	0.76	0.36	0.73	0.45
80	0.72	0.31	0.69	0.39
90	0.69	0.26	0.65	0.34
100	0.66	0.22	0.62	0.30

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