Impacts on State and Local Agencies for Maintaining Traffic Signs Within Minimum Retroreflectivity Guidelines

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Research and Development
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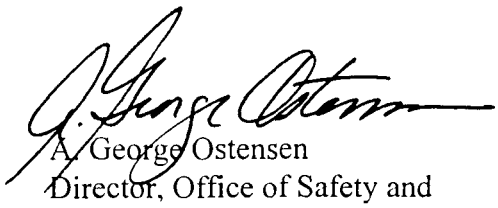
FOREWORD

This report presents the results of a study which assessed the applicability and practicality of the minimum-maintained levels of sign retroreflectivity proposed by FHWA. This was accomplished through a survey of highway signs in 16 participating states and 9 local agencies. From the survey it was estimated that approximately 5% of signs would have to be replaced to meet the recommended values. Although some agencies may have to increase their signing budgets, the informational and safety value of highway signing will be substantially increased.

Sufficient copies of the report are being distributed by FHWA to provide a minimum of two copies to each FHWA regional and division office, and five copies to each State highway agency. Direct distribution is being made to division offices.



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NOTICE

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16. Abstract
The FHWA has developed guidelines for minimum retroreflectivity levels for four groups of signs: 1) yellow/orange-on-black warning signs, 2) black-on-white regulatory signs, 3) white-on-red regulatory signs, and 4) white-on-green guide signs. As part of the development of these recommended values, the FHWA obtained the assistance of several State and local highway agencies. These agencies assisted by measuring the retroreflectivity of a pre-determined sample of signs, providing data on sign replacement costs, and commenting on the proposed retroreflectivity values and their ability to maintain their signs within these levels. This and other data that was collected independently was used to assess the anticipated economic impact of replacing signs to meet the recommended values.

The report presents data on percentage of signs by the various types of retroreflective sheeting for both States and local agencies, a distribution of age of signs by type of sheeting, and the percentage of signs that would not meet the minimum retroreflectivity values. The report also presents a summary of the data and comments provided by the participating agencies related to the minimum retroreflectivity values. Based on additional sign inventory information provided by a small sample of State and local jurisidictions, an estimate of the number of signs by type per mile was determined. This data, with the data on sign replacement and replacement costs, were used to estimate the total cost for replacing signs on the Nation's highways to meet the proposed minimum retroreflectivity values.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
AREA				
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3

NOTE: Volumes greater than 1000 l shall be shown in m^3.

MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact)				
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
FORCE and PRESSURE or STRESS				
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
AREA				
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3

MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
TEMPERATURE (exact)				
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
FORCE and PRESSURE or STRESS				
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380

(Revised September 1993)

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INTRODUCTION

Section 406(a) of the 1993 Department of Transportation Appropriations Act required the Secretary of Transportation to revise the *Manual on Uniform Traffic Control Devices* to include a standard for a minimum level of retroreflectivity that must be maintained for traffic signs.[1] (It also required a similar standard for pavement markings, but this report does not address that standard.) To support this requirement, the Federal Highway Administration (FHWA) has developed and is conducting a comprehensive research and demonstration program to address the various retroreflectivity performance issues. The research studies identified a range of minimum levels of retroreflectivity for four groups of signs; created a sign management system (a computerized sign inventory and management system); and developed strategies for State and local agencies to comply with the proposed minimum retroreflectivity levels in a cost-effective manner.

As part of this program the FHWA obtained the assistance of several State and local highway agencies to evaluate the applicability and practicality of:

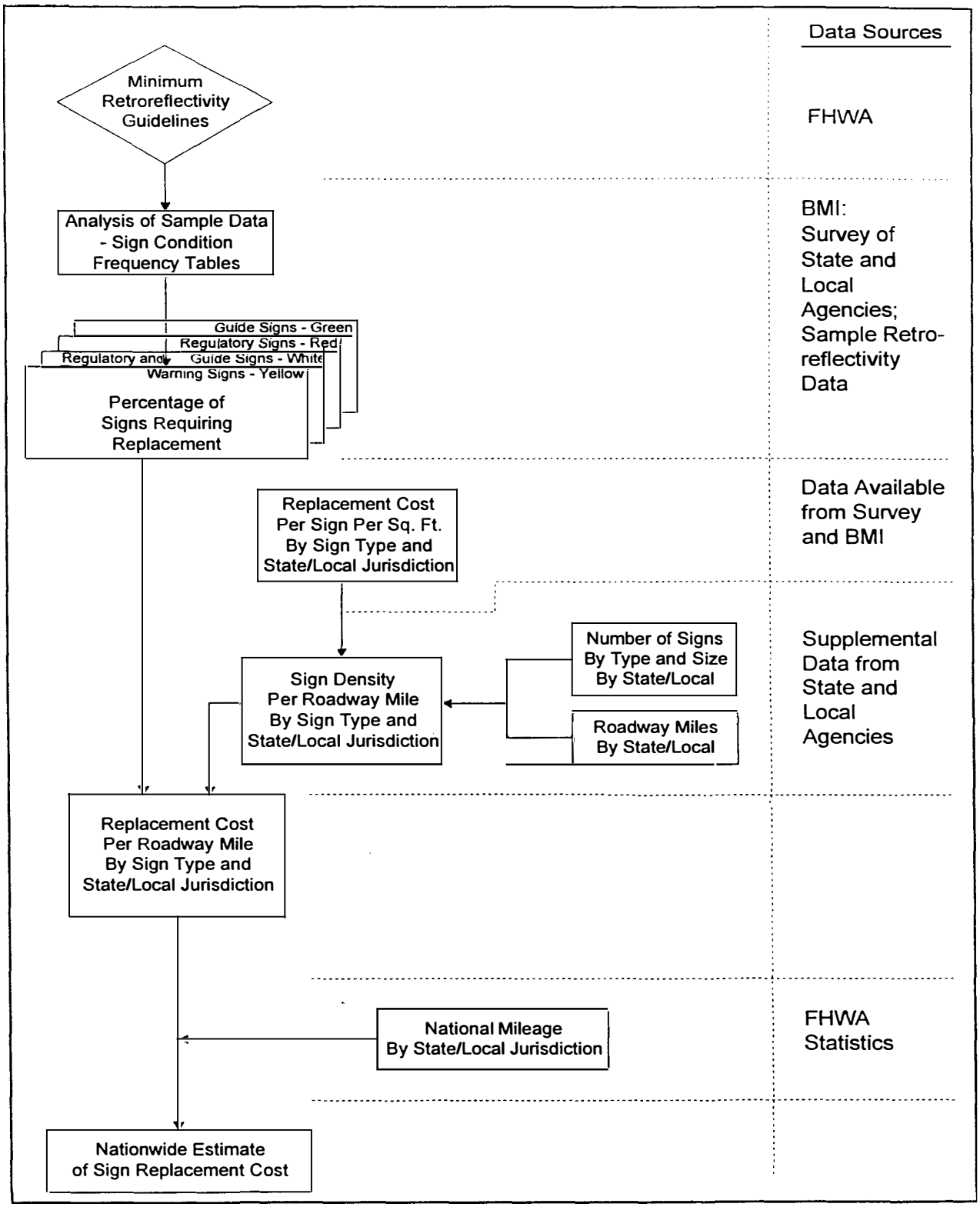
(1) The minimum-maintained levels of sign retroreflectivity proposed by FHWA, and

(2) The hand-held retroreflectometer that measures sign retroreflectivity.

This evaluation was conducted by several State and local highway agencies using the retroreflectometers provided by the FHWA. Each agency was asked to measure retroreflectivity of a representative sample of their signs according to the sampling plan provided by the FHWA. Each agency was to provide a report that included the sign retroreflectivity data. The agencies were also requested to include in the report a discussion on the estimated number of signs that would have to be replaced under the candidate minimum levels of retroreflectivity, the cost of sign replacement, and the ease of using the hand-held retroreflectometer to collect the data. BMI received all of this information and sign retroreflectivity data for collation and analysis.

In addition, BMI performed a supplemental analysis of the economic impact of replacing signs to meet the requirements of the guidelines for minimum levels of retroreflectivity. This analysis involved acquiring samples of sign inventory (i.e., the number of signs by type on the jurisdiction's road system) from a few agencies to estimate the number of signs by type per mile. This information and other data were used to develop a nationwide estimate of signs and sign replacement costs.

This report presents the results of these analyses. The flowchart in figure 1 shows the evaluation process employed to perform this study. Apart from various steps in the evaluation, the figure also shows the sources of the relevant data and information.



1 mi = 1.6 km 1 ft^2 = 0.09 m^2

Figure 1. Evaluation process.

GUIDELINES FOR MINIMUM LEVELS OF INSERVICE RETROREFLECTIVITY

A series of FHWA studies on retroreflectivity requirements for traffic signs resulted in the proposed minimum values for four groups of signs. The grouping was based on the color of sign sheeting, which, in general, also followed the functional classification of these signs. The four groups of signs identified are as follows:

- Group 1. Black Legend on Yellow or Orange Background Warning Signs
- Group 2. Black or Black-and-Red Legend on White Background Regulatory or Guide Signs
- Group 3. White Legend on Red Background Regulatory Signs
- Group 4. White Legend on Green Background Guide Signs

Within each group, sub-groups were defined by different combinations of various factors that include sign size, sheeting material type, and roadway speed limit. Wherever sign size was selected as a sub-grouping criterion, three size groups were selected. Where speed limit was selected as a factor, two levels of roadway speed were selected. When selected as a sub-grouping factor, four types of sheeting material were selected. The types of sheeting material selected are shown below:

- Type I - Engineering grade (EG)
- Type II - Super engineering grade (SEG)
- Type III - High-intensity grade (HI)
- Type IV and VII - High-intensity prismatic grades (HIP)

A minimum retroreflectivity value was proposed for each sub-group. These proposed values for the four sign groups are shown in tables 1 through 4, respectively. The values in each cell of these tables are the coefficient of retroreflectivity (R_A) in candelas per lux per square meter ($cd/lx/m^2$) for the corresponding sub-group. These values are based on an observation angle of 0.2° and an entrance angle of -4°.

DATA PROVIDED BY STATE AND LOCAL AGENCIES

The data received from the various agencies consisted of the following:

- Retroreflectivity measurements made on a sample of signs along with other relevant information on those signs such as, size, color, sheeting type, etc.
- Results of the analysis that some agencies performed on their data.
- Sign replacement cost information.
- Assessments of the ease of using a sign retroreflectometer for inspecting signs.
- Assessments of the proposed guidelines and the impacts of their implementation on the agency's operations.

Table 1. Guidelines on minimum retroreflectivity levels for black-on-yellow/orange warning signs†.

Legend	Material Type	Sign Size (in)		
		>=48	36	<=30
Bold Symbol*	ALL	15	20	25
Fine Symbol and Word	I	20	30	35
	II	25	35	45
	III	30	45	55
	IV and VII	40	60	70

† R_A for yellow/orange background only
All table values in cd/lx/m^2
1 in = 25.4 mm

*Warning signs with bold symbols:

MUTCD Code	Sign Type	MUTCD Code	Sign Type
W1-1	Turn	W3-1a	Stop Ahead
W1-2	Curve	W3-2a	Yield Ahead
W1-3	Reverse Turn	W3-3	Signal Ahead
W1-4	Reverse Curve	W4-1	Merge
W1-5	Winding Road	W4-2	Lane Reduction
W1-6	Large Arrow	W4-3	Added Lane
W1-7	Double Head Arrow	W6-1	Divided Highway Begins
W1-8	Chevron	W6-2	Divided Highway Ends
W2-1	Cross Road	W6-3	Two-Way Traffic
W2-2	Side Road	W8-5	Slippery When Wet
W2-4	T Intersection	W11-2	Advance Pedestrian Crossing
W2-5	Y Intersection	W11A-2	Pedestrian Crossing
		W20-7a	Flagger Ahead

Table 2. Guidelines on minimum retroreflectivity levels for black/(black-and-red)-on-white regulatory/guide signs†.

Material Type	Traffic Speed (mi/h)					
	45 or greater			40 or less		
	Sign Size (in)					
	>=48	30-36	<=24	>=48	30-36	<=24
I	25	35	45	20	25	30
II	30	45	55	25	30	35
III	40	55	70	30	40	45
IV and VII	50	70	90	40	50	60

† R_A for white background only
All table values in cd/lx/m^2
1 in = 25.4 mm
1 mi/h = 1.6 km/h

Table 3. Guidelines on minimum retroreflectivity levels for white-on-red regulatory signs.

Sheeting Color	Traffic Speed (mi/h)					
	45 or greater			40 or less		
	Sign Size (in)					
	>=48	36	<=30	>=48	36	<=30
White (legend)	35	45	50	35	30	35
Red (background)	8	8	8	5	5	5

All table values in cd/lx/m^2
1 in = 25.4 mm
1 mi/h = 1.6 km/h

Note: Since both the legend and the background of these signs is retroreflectorized, a minimum maintained contrast ratio of 4:1 has also been established. If the retroreflectivity value for either the white or red material falls below the value specified in the table or if the retroreflectivity of the white material divided by the retroreflectivity of the red material is less than 4 (four), the sign should be replaced.

Table 4. Guidelines on minimum retroreflectivity levels for white-on-green guide signs.

	Sheeting Color	Traffic Speed (mi/h)	
		45 or greater	40 or less
Ground-Mounted	White (legend)	35	25
	Green (background)	7	5
All table values in cd/lx/m^2 1 mi/h = 1.6 km/h			

Every agency's report did not include all of the above components. Some agencies did not provide information on sign replacement cost, while some others provided no assessment of the impacts and ease of implementing the guidelines. Some agencies provided only the sign retroreflectivity readings. Table 5 lists the agencies providing some or all of the required data.

The sign retroreflectivity data was to be received in the form of a series of tables with data on each sign to include the MUTCD code, material type, installation date, and the field measured values of the legend and/or background coefficient of retroreflection, i.e., R_A. These tables were also to include the legend and/or background color, the sign size, and speed limit. Unfortunately, not all the agencies provided the full data base. Various agencies provided incomplete data sets with some missing the installation date, sign size, or some other data element. Also, some agencies submitted retroreflectivity measurements that were highly questionable (e.g. high values for some very old signs and vice-versa, measurements for black (opaque) legends, etc.). Several data sets also included cheveron markings and parking signs that were not to be included in the analyses. Whenever the data was judged to be highly questionable or undesirable, it was excluded from the analysis. Most of the data was provided in hard copy format with only a few agencies able to provide in a computer file format.

SIGN REPLACEMENT ESTIMATES

Some of the data were excluded as a result of the quality control assessment discussed in the previous section. Tables 6 through 9 show the sample size, i.e., the number of signs used in the analysis for each cell of each of the four sign groups. Two values are shown in each cell, one for State highway agencies and the other for local agencies. For each of the four tables, the numbers in individual cells represent the number of signs used in the analysis, which may be less than the total number of signs surveyed by the agencies. Appendix A provides several tables that detail the sample size for each agency by cells for each sign group. All the data were assembled in a spreadsheet format and were analyzed in a number of ways, which are reported here.

Table 5. State and local agencies participating in survey.

State Agencies	Local Agencies
Arizona	Black Hawk County, IA
California	Clinton County, IA
Georgia	Delaware County, NY
Iowa	City of Eugene, OR
Kansas	City of Garland, TX
Michigan	City of Grand Coulee, WA
Mississippi	Linn County, IA
Missouri	McLeod County, MN
New York	Sedgwick County, KS
Ohio	
Oklahoma	
Texas	
Utah	
Virginia	
Washington	
West Virginia	

Table 6. Sample size for black-on-yellow/orange warning signs.

Legend	Material Type	Sign Size (in)		
		>=48	36	<=30
Bold Symbol	ALL	888/233*	552/76	391/1040
Fine Symbol and Word	I	148/1	143/111	128/228
	II	0/0	4/0	0/14
	III	275/6	158/203	46/118
	IV and VII	13/0	11/0	0/0

* Total signs from State jurisdictions/Total signs from local jurisdictions
1 in= 25.4 mm

Table 7. Sample size for black/(black-and-red)-on-white regulatory signs.

Material Type	Traffic Speed (mi/h)					
	45 or greater			40 or less		
	Sign Size (in)					
	>=48	30-36	<=24	>=48	30-36	<=24
I	551/0*	480/58	581/255	155/0	377/131	467/346
II	0/0	23/0	0/0	0/0	0/0	2/0
III	375/0	177/57	151/39	0/0	180/102	180/105
IV and VII	0/0	54/0	0/0	0/0	0/0	0/0

* Total signs from State jurisdictions/Total signs from local jurisdictions
1 in = 25.4 mm
1 mi/h = 1.6 km/h

Table 8. Sample size for white-on-red regulatory signs.

	Traffic Speed (mi/h)					
	45 or greater			40 or less		
	Sign Size (in)					
	>=48	36	<=30	>=48	36	<=30
All Signs	656/50*	608/22	360/565	256/0	681/55	849/385

* Total signs from State jurisdictions/Total signs from local jurisdictions
1 in = 25.4 mm
1 mi/h = 1.6 km/h

Table 9. Sample size of white-on-green guide signs.

	Traffic Speed (mi/h)	
	45 or greater	40 or less
Ground-Mounted	743/194*	757/116

* Total signs from State jurisdictions/Total signs from local jurisdictions
1 mi/h = 1.6 km/h

Distribution of signs by material type, by age, and by combination of material type and age were developed and cumulative percentage graphs were also developed. Graphs in figures 2 and 3 show the distribution of signs by material type and by age of sign, respectively. Cumulative percentage distribution of signs of various material types by age are shown in figures 4 and 5 for the State and local jurisdictions, respectively. These plots also show the percentage of signs older than 5, 10, and 15 years. This analysis demonstrates that local jurisdictions have a significantly higher percentage of Type I sheeting signs than the States. It should be noted that Type I sheetings have lower retroreflectivity and shorter life than Type III sheetings. It was also found that local jurisdictions have a larger percentage of older signs (10 to 15 years or older) than do the States.

Frequency tables and cumulative percentage distributions were developed for the standardized R_A, which is the ratio of measured R_A to the proposed minimum R_A for each of the four sign groups, for both the sign legend and the background sheeting color, wherever applicable. Similarly, detailed distributions for each of the individual sub-groups of the four sign groups were also developed. From the cumulative percentage distributions of the standardized R_A, the value corresponding to the ratio of 1 (i.e., measured R_A equal to minimum R_A) represented the percentage of signs not meeting the proposed requirements.

As a summary, table 10 shows the percentage of signs requiring replacement for not meeting the proposed minimum retroreflectivity levels, by jurisdiction type, for each of the four sign groups as well as all signs combined. Assuming that the sample of signs measured truly represents the conditions of the four groups of traffic signs nationwide, then about 5.5 percent of the total signs in the Nation would not meet the proposed minimum retroreflectivity levels and would need to be replaced. This estimate is based on the retroreflectivity of sign background sheeting.

Considering the sign legend sheeting retroreflectivity, only about 2.7 percent of the signs would not meet the suggested levels. The data analysis indicated that the signs under local jurisdictions would, in general, have a higher replacement rate as compared to those under State jurisdictions. The percentage of signs under local jurisdictions that would need replacement is higher than 5 percent for all sign groups, whereas, the percentage of State signs to be replaced is

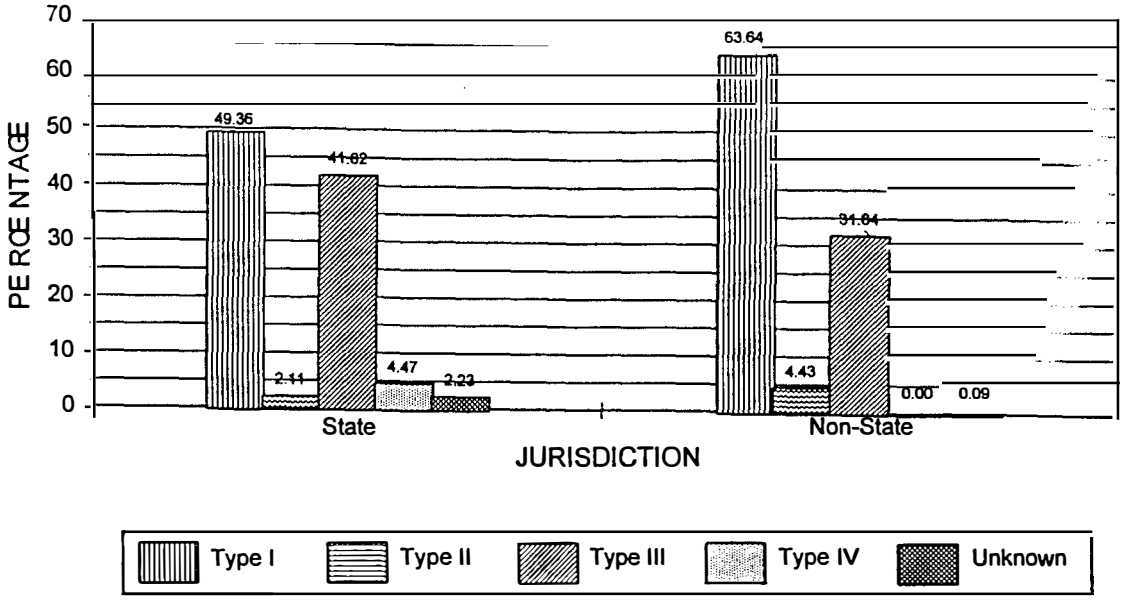


Figure 2. Distribution of signs by sheeting material type for State and local jurisdictions.

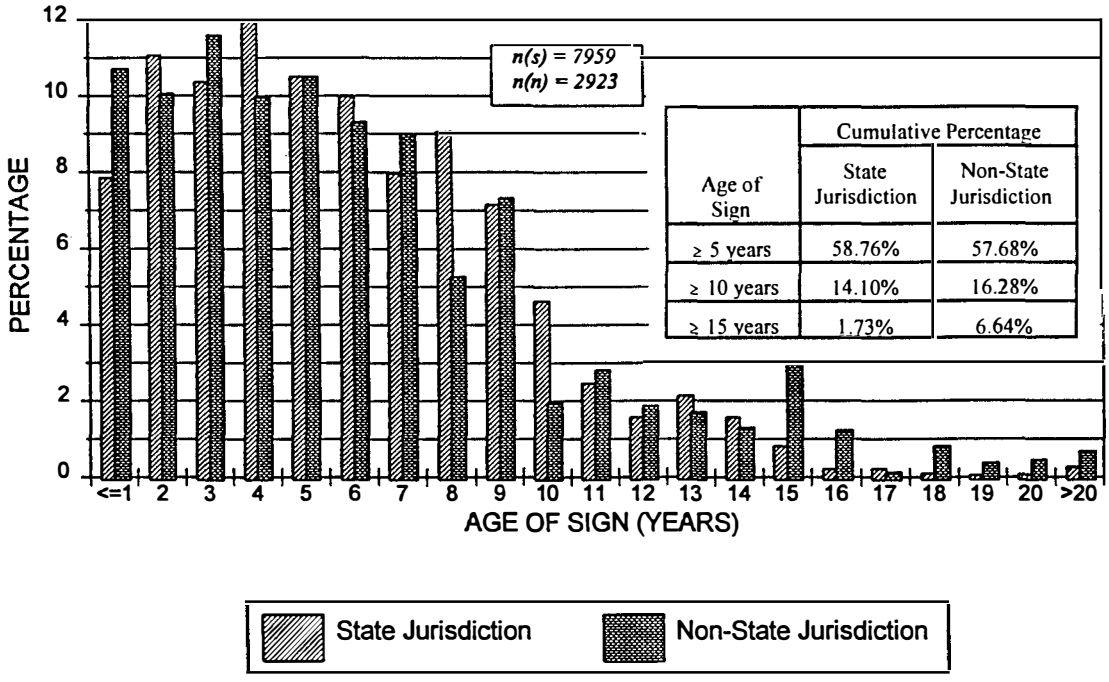
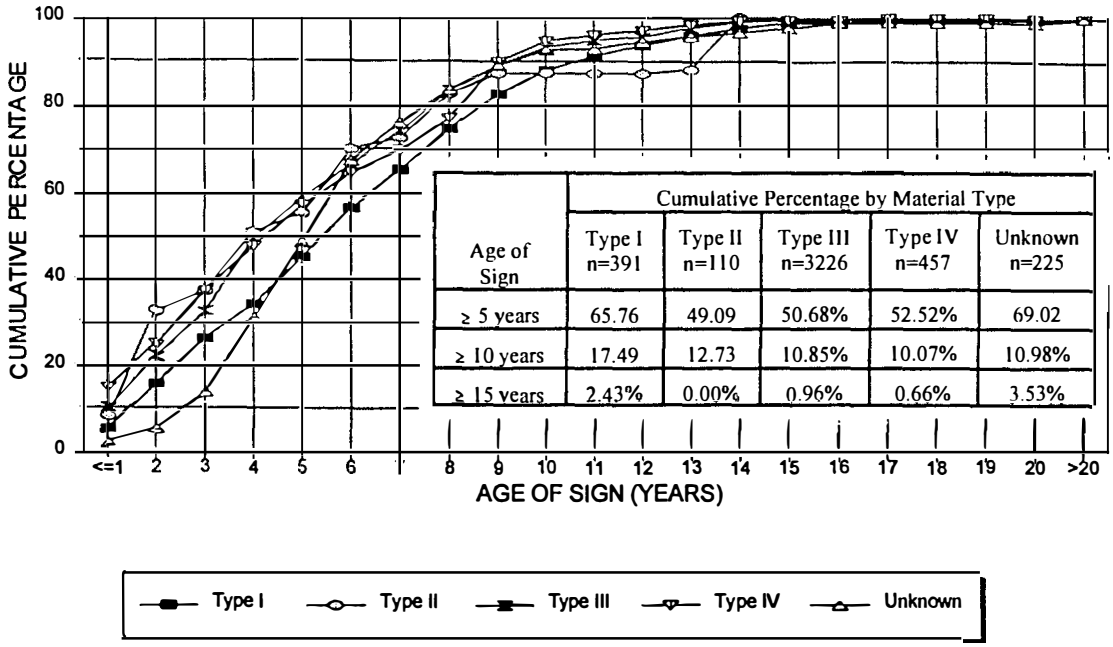
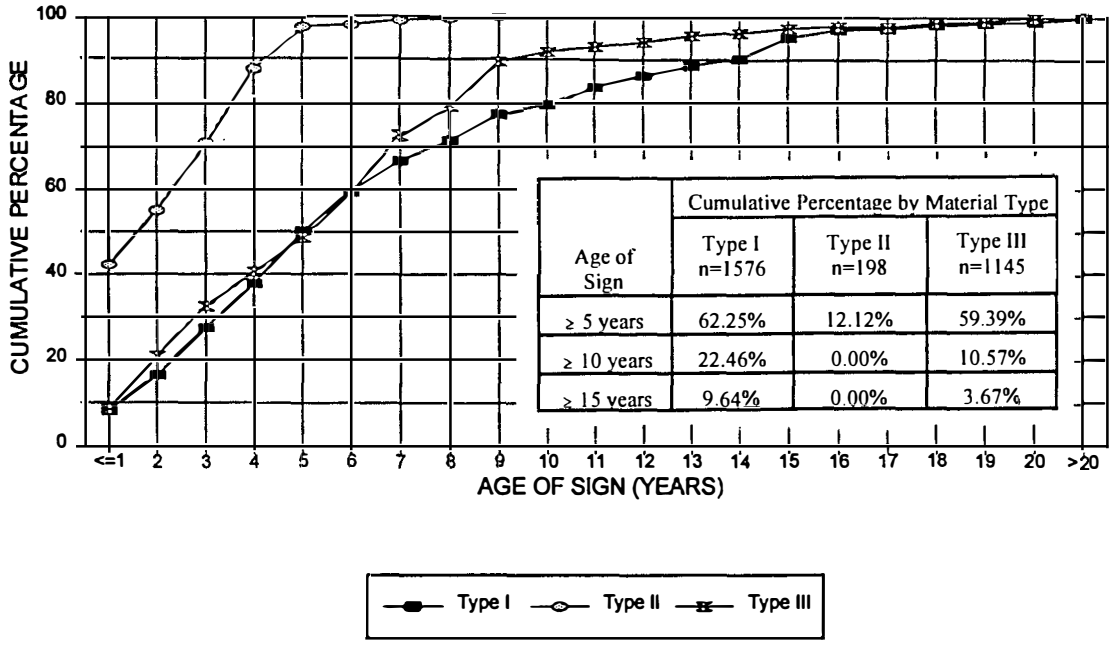


Figure 3. Distribution of signs by age for State and local jurisdictions.



Age of Sign	Cumulative Percentage by Material Type				
	Type I n=391	Type II n=110	Type III n=3226	Type IV n=457	Unknown n=225
≥ 5 years	65.76	49.09	50.68%	52.52%	69.02
≥ 10 years	17.49	12.73	10.85%	10.07%	10.98%
≥ 15 years	2.43%	0.00%	0.96%	0.66%	3.53%

Figure 4. Distribution of signs under State jurisdictions by age and sheeting material type.



Age of Sign	Cumulative Percentage by Material Type		
	Type I n=1576	Type II n=198	Type III n=1145
≥ 5 years	62.25%	12.12%	59.39%
≥ 10 years	22.46%	0.00%	10.57%
≥ 15 years	9.64%	0.00%	3.67%

Figure 5. Distribution of signs under local jurisdictions by age and sheeting material type.

less than 5 percent for all groups, except for group 4 signs, i.e., white-on-green guide signs. This result can be attributed to the higher percentage of Type I sheeting signs under local jurisdictions, as displayed in figure 2. Also, as shown in figures 2 and 3, the signs under local jurisdictions are older than those under State jurisdictions, which also explains the need for higher replacement rates for local jurisdictions. For group 4 (white-on-green) signs, however, more than 9.5 percent of the signs under State jurisdiction would need replacement as compared to only about 3 percent of those under local jurisdictions. This situation could be attributed to the significantly higher number of guide signs under State jurisdiction.

Table 10. Percentage of signs not meeting the minimum R_A values.

Sign Group	Sheeting Color	Jurisdiction		
		State	Local	Combined
Group 1	Yellow (background)	3.01	9.51	5.77
Group 2	White (background)	3.68	6.86	4.40
Group 3	White (legend)	1.67	3.44	2.11
	Red (background)	4.31	7.80	5.15
Group 4	White (legend)	3.77	5.81	4.13
	Green (background)	9.61	2.90	8.46
All Signs	Legend	2.31	3.98	2.69
	Background	4.48	8.00	5.48

The most crucial group of signs for local jurisdiction is the black-on-yellow/orange warning signs, i.e., group 1 signs. Based on the proposed minimum values almost 10 percent (9.5 percent) of these signs would need replacement. The next crucial group is the white-on-red regulatory signs (group 3) of which, about 8 percent would need replacement. This group is composed mostly of Stop, Yield, Do-Not-Enter and Wrong-Way signs. While group 1 includes a large variety of signs, group 3 includes only about 4 signs.

The percentage of signs within each cell that would have to be replaced for all State agencies combined and for all local agencies combined, are shown in tables 11 through 14, for each sign group, respectively. A blank cell indicates that either there was no data available for that cell or the available sample size was too small to reliably estimate the average replacement value. It should be noted that the percentage of signs not meeting the proposed minimum values varied from cell to cell within each sign group.

Table 11. Percentage of black-on-yellow/orange warning signs with measured R_A less than or equal to minimum R_A.

Jurisdiction Type	Legend	Material Type	Sign Size (in)		
			>=48	36	<=30
State	Bold Symbol	ALL	2.25	3.44	1.79
	Fine Symbol and Word	I	0.68	9.79	9.38
		II	-*	-	-
		III	1.09	3.8	-
		IV and VII	-	-	-
Local	Bold Symbol	ALL	2.15	9.21	7.02
	Fine Symbol and Word	I	-	34.23	26.32
		II	-	-	-
		III	-	3.94	1.69
		IV and VII	-	-	-

* - insufficient sample size or no data available
1 in = 25.4 mm

RESPONSES FROM AGENCIES

As part of the evaluation, the participating jurisdictions were asked to provide the FHWA with comments on the candidate values of sign retroreflectivity tested, as well as a discussion of the following:

- The number of signs that would have to be replaced.
- The percentage of signs that would have to be replaced.
- The cost of replacement using the candidate minimum levels of retroreflectivity.
- The ease of using the hand-held Model 920 L retroreflectometer (if used).
- Recommended changes and comments.

Table 12. Percentage of black/(black-and-red)-on-white regulatory/guide signs with measured R_A less than or equal to minimum R_A.

Jurisdiction Type	Material Type	Traffic Speed (mi/h)					
		45 or greater			40 or less		
		Sign Size (in)					
		>=48	30-36	<=24	>=48	30-36	<=24
State	I	3.63	3.96	7.92	5.16	4.51	3.85
	II	-*	-	-	-	-	-
	III	0.27	0.00	2.65	-	0.56	1.67
	IV and VII	-	1.85	-	-	-	-
Local	I	-	3.45	10.20	-	7.63	10.40
	II	-	-	-	-	-	-
	III	-	0.00	-	-	0.98	0.00
	IV and VII	-	-	-	-	-	-

* - insufficient sample size or no data available
1 in = 25.4 mm
1 mi/h = 1.6 km/h

Table 13. Percentage of white-on-red regulatory signs with measured R_A less than or equal to minimum R_A.

Jurisdiction Type	Sheeting Color	Traffic Speed (mi/h)					
		45 or greater			40 or less		
		Sign Size (in)					
		>=48	36	<=30	>=48	36	<=30
State	White (L)	1.37	0.82	4.72	1.95	0.64	1.88
	Red (B)	5.34	6.58	8.06	2.73	2.50	3.42
Local	White (L)	0.00	-*	5.31	-	5.45	0.52
	Red (B)	0.00	-	10.44	-	3.64	5.71

* - insufficient sample size or no data available
1 in = 25.4 mm
1 mi/h = 1.6 km/h

Table 14. Percentage of white-on-green guide signs with measured R_A less than or equal to minimum R_A.

Jurisdiction Type	Sheeting Color	Traffic Speed (mi/h)	
		45 or greater	40 or less
State	White (L)	4.08	3.49
	Green (B)	8.49	10.70
Local	White (L)	7.22	3.45
	Green (B)	2.58	3.45
1 mi/h = 1.6 km/h			

This section provides the results of these assessments.

The level to which each jurisdiction responded to the above items varied considerably – from no response, i.e., only the sign reteroreflectivity measurements were provided, to a complete report that responded to each item. Tables 15 and 16 summarize the information provided by various State and non-State jurisdictions, respectively.

Percentage of Signs to be Replaced

The second column in both tables presents the responses by each jurisdiction about the percentage of signs that were at or below the minimum values and would have to be replaced. Since some data from most of the jurisdictions had to be discarded for a number of reasons, the values shown do not correspond to the values determined by BMI, which provides a composite percentage of signs to be replaced collectively under State and non-State jurisdictions but does not provide the results of the R_A analysis by individual jurisdiction.

As indicated by the values, there is wide variation among the jurisdictions and among the colors and types of sheeting. In general the State jurisdictions would have more signs meeting the minimum values than would the local jurisdictions. Some jurisdictions would have a relatively low replacement rate, while others might have a significantly high rate, which, for the most part, is attributed to having old, Type I signs.

Although the data presented earlier provides a more accurate assessment of the national percentage of the signs needing replacement, this information indicates that it can be expected that some jurisdictions, especially non-State, may have a significantly higher percentage of their signs with R_A values lower than the proposed minimum values. This can be attributed to the fact that local jurisdictions have higher percentage of older Type I sheeting material signs than States.

Table 15. Summary of sign retroreflectivity survey responses– State jurisdictions.

STATE DOT	Percent of Signs to be Replaced	Total Cost ($) for Replacement	Total Cost ($) Per Sign	Impact on Budgets and Staffing	Comments & Suggestions
California	Not provided	Not provided	Not provided	Not provided	It may not be productive to create a minimum value for red signs if the ink gets more transparent as it ages.
Georgia	2% of flatsheet signs; 250 guide signs	$150,000 for flatsheet signs $1,150,000 for guide signs Total= $1,300,000	$30 for standard signs; $4,600 for guide signs	No staffing level changes, but substantial impact on budget.	Not provided
Iowa	< 1	$50,000	$20 for non-guide signs	Small number of signs affected, so no impact.	Not provided
Kansas	2.7	$4,574,880	$225.92 average	Not Provided	Had problems with Model 920; values for guide signs should be guidelines; values for warning & regulatory should be standards; concern for red color fade; recommend a 10-year compliance date.
Michigan	2.5 (Type I)	Not provided	Not provided	Gathering/documenting all signs would be monumental task; most likely, replacing all signs on every road where older, Type I sheeting exists, would require sufficient funds.	Signs evaluated with both ART 920L and METS van (problems with documenting roadway speed limits, sign sizes, and sign sheeting type); simplify minimum standards; establish detailed guidelines.
Mississippi	Black on yellow: 0.5 to 2.0; White on red: 4.8; Black on white: 1.0 to 2.5; White on green: 2.1 to 2.4	$12,538,000	Not provided	Increased funding for sign replacement, equipment maintenance, personnel, etc.	Not provided

Table 15. Summary of sign retroreflectivity survey responses–State jurisdictions (continued).

STATE DOT	Percent of Signs to be Replaced	Total Cost ($) for Replacement	Total Cost ($) Per Sign	Impact on Budgets and Staffing	Comments & Suggestions
New York	13 for Type I signs; <1 for Type IV signs	Not provided	Not provided	See comments	Intend to use high-intensity sheeting, which will cost more initially but should prove cost-effective because of longer life.
Ohio	7.35 Statewide	$2,406,319 Statewide	$42 to $538 depending on sign/type/size	Will need 76 additional personnel; 38 additional vehicles; 38 reflectometers = $8,700,000/year (assumes measuring of all signs).	Need procedure for measuring R_A of button copy; several comments on proposed minimums.
Oklahoma	10	$12,000,000 statewide initially	Not provided	Budget/staff would need to be increased dramatically.	Not provided
Virginia	<1	Not Provided	$50 for standard sign	Small impact on budget and staffing.	Not provided
Washington	Black on yellow: 27.5; Black on white: 1.7 to 5.9; White on red: 22; White on green: 9.8	$2,914,920	$10/ft^2 for non-guide signs	Requirements: Staffing - 2 additional people in each district; a reflectometer for each team and a system to test older signs first.	Model 920L easy to use but very slow and impractical for all signs; need faster method.
West Virginia	10 of Type I signs	$3,500,000	Not provided	Replacement cost is double the annual budget.	Minimum R_A values for white-on-red signs is too high; using minimum value based on 50% of AASHTO standards of retroreflectivity would be an efficient and cost-effective solution to evaluating sign conditions.

1 ft^2 = 0.09 m^2

Table 16. Summary of sign retroreflectivity survey responses–local jurisdictions.

LOCAL DOT	Percent of Signs to be Replaced	Total Cost ($) for Replacement	Total Cost ($) Per Sign	Impact on Budgets and Staffing	Comments & Suggestions
Black Hawk County, IA	White on red: 23; Black on white: 19; Black on yellow: 13	$50,000/year	$76	Not definite about impacts on staffing and budget would be.	Some problems encountered with equipment such as battery power switch easily turns on by accident and blows fuses; concern over liability with standard.
Clinton County, IA	Black on yellow: 1.9; Black on white: 18.75 (all Type I)	Not provided	Not provided	No effect on budget or staffing.	Not provided
Delaware County, NY	Black on yellow: 12.8; Black on white: 2; White on red: 61	$19,536	$16.25-warning; $29.15-regulatory	Large impact on budget; would change to Type III sheeting.	Noted issues of high R_A value for faded red color.
City of Eugene, OR	7	$184,000	$120	Significant impact on budget.	Candidate levels generally seem reasonable except for red; use of reflectometer is too labor intensive.
Garland, TX	18	$1,860	$20 (materials only)	Increase of two persons to staff; impact to budget due to lack of funds not budgeted for program.	Not provided
Grand Coulee, WA	41.47	$8,729	$7 (materials only)	Initial replacement would be a large expense.	Model 920 was easy to use; SMS program should prove to be cost effective.
Linn County, IA	33 (Type I) 0 (Type III)	$57,293 - Type I $97,276.30, if changed to Type III	$23.50 - Type I $39.90 - Type III	Add 2 to 4 part time employees for period of 6 to 8 months for 1 to 2 years. Estimated cost would be about $40,000.	Not provided
McLeod County, MN	21.7	$60,000 - if all at once	$16 - Type I (materials only)	Over long run, costs should be less.	Not provided
Sedgwick County, KS	< 2 % except for Type I stop signs	Not provided	$50 for stop signs	Over long run, should not feel drain on funds.	Do not understand why high-intensity needs replacement sooner than lower grade.

Total Cost for Sign Replacement

The third column shows the total replacement cost for all the signs within the jurisdiction that are estimated to be below the minimum R_A value based on the sample surveyed. The values range widely, which is a function of the percentage of signs found lower than the minimum R_A; the value estimated for replacing a sign; and the total signs within the jurisdiction. These cost estimates need to be examined in context of each jurisdiction's values for these factors.

Total Cost per Sign

The fourth column in both tables shows the unit cost for replacing signs for those jurisdictions providing data. Again, there is wide variation in the unit costs. There was no consistency in how the jurisdictions established a unit cost with some considering only the materials cost and others considering both materials and labor. Obviously, the sign size is a factor in estimating sign replacement cost, but only a few agencies considered this in their estimates.

Impacts on Budgets and Staffing

The fifth column in both tables summarizes the comments from each jurisdiction related to how meeting the minimum R_A requirement might affect their budgets and staffing. The summary comments for each jurisdiction should be reviewed in context with the results of their estimates of the amount of sign replacement, their expectations on sign inspection requirements, and costs anticipated. Several agencies, State and non-State, are estimating a significant impact on their budgets because of the perceived need for additional staff for sign inventory and inspections, and more equipment (reflectometers and even vehicles). Others see that, except for some higher than normal initial costs, over the long run the costs should not be any higher.

Other Comments

The last column in both tables provides additional comments from the jurisdictions. Some comments address the minimum R_A values and some are related to the ease of using the reflectometer. The comments are self-explanatory.

NATIONWIDE ESTIMATE OF SIGN REPLACEMENT COSTS

A supplemental analysis was performed to determine the nationwide costs for replacing signs that do not now (i.e. when the surveys were made) meet the proposed guidelines for minimum retroreflectivity. To arrive at this estimate, determination of the following were necessary: (1) an estimate of the number of signs requiring replacement, (2) an estimate of sign densities (i.e. number of signs per mile), and (3) the cost of replacing signs. Estimating each of these items required several other data and information. The survey and analysis of sign

retroreflectivity data from the State and local jurisdictions reported earlier provided the estimate of sign replacement. The number of signs to be replaced depended primarily on the selection of proposed minimum values. Sign densities were obtained from the total number of signs in service under various State and local jurisdictions and total roadway miles covered by those signs. The sign replacement cost estimates were developed from the survey results and data available with BMI. The procedures associated with the estimation process in steps 2 and 3 above are explained below.

Sign Densities

Samples of total number of signs by type and size and total roadway miles covered by these signs were obtained from two State and seven local jurisdictions, which are identified in table 17. Special data needs, that is, a precise inventory of signs by MUTCD code, size and sheeting type and the corresponding mileage, limited the participation of jurisdictions.

The sign data were assigned to appropriate cells under four groups based on the criteria selected earlier. The total number of signs under State and local jurisdictions and the road miles covered by them are shown in table 18. Tables 19 through 26 show the total number of signs sampled within each cell of the four sign groups for the State and local jurisdictions. These tables present the number of signs as a percentage of the total signs in that table and as a percentage of total signs sampled. Similar tables in appendix B show in detail the number of signs sampled in each cell, from each participating State and local agency.

Using this sample data as representative, sign density (i.e., number of signs per mile) estimates for State and local jurisdictions were developed for each of the cells for all the four sign groups. The calculated average size (square feet) of the sign within each cell provided an estimate for material quantity required for a sign within each cell.

Table 17. State and local agencies providing supplemental data.

State Agencies	Local Agencies
Pennsylvania	Holidaysburg Borough, PA
Washington	Lower Paxton, PA
	McLeod County, MN
	Missoula County, MT
	Pierce County, WA
	Ravalli County, MT
	White Township, PA

Table 18. Total number of signs and road miles by State and local jurisdiction.

Jurisdiction Type	Sign Group	Number of Signs	Total Road Miles
State	Group 1	24,971	4,694
	Group 2	30,968	
	Group 3	13,873	
	Group 4	1,793	
	Total	71,605	
Local	Group 1	11,750	3,296
	Group 2	6,954	
	Group 3	7,936	
	Group 4	182	
	Total	26,822	
1 mi = 1.6 km			

Table 19. Total number of black-on-yellow/orange warning signs under State jurisdiction.

Legend	Material Type	Sign Size (in)								
		>=48			36			<=30		
		No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total
Bold Symbol	ALL	862	3.45	1.20	1,524	6.10	2.13	9,325	37.34	13.02
Fine Symbol and Word	I	353	1.41	0.49	1,240	4.97	1.73	7,235	28.97	10.10
	II	-*	-	-	-	-	-	-	-	-
	III	204	0.82	0.28	3,728	14.93	5.21	500	2.00	0.70
	IV and VII	-	-	-	-	-	-	-	-	-

* - No signs of this type in the sample
1 in = 25.4 mm

Table 20. Total number of black-on-yellow/orange warning signs under local jurisdiction.

Legend	Material Type	Sign Size (in)								
		>=48			36			<=30		
		No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total
Bold Symbol	ALL	6	0.05	0.02	147	1.25	0.55	5,221	44.43	19.47
Fine Symbol and Word	I	0	0.00	0.00	728	6.20	2.71	5,523	47.00	20.59
	II	-*	-	-	-	-	-	-	-	-
	III	0	0.00	0.00	117	1.00	0.44	0	0.00	0.00
	IV and VII	-	-	-	8	0.07	0.03	-	-	

* - No signs of this type in the sample
1 in = 25.4 mm

Table 21. Total number of black/(black-and-red)-on-white regulatory signs under State jurisdictions.

Material Type	Traffic Speed (mi/h)																	
	45 or greater									40 or less								
	Sign Size (in)																	
	>=48			30-36			<=24			>=48			30-36			<=24		
	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total
I	76	0.25	0.11	834	2.69	1.16	18,005	58.14	25.14	81	0.26	0.11	390	1.26	0.54	8,994	29.04	12.56
II	-*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
III	43	0.14	0.06	114	0.37	0.16	1,484	4.79	2.07	0	0.00	0.00	19	0.06	0.03	928	3.00	1.30
IV and VII	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

* - No signs of this type in the sample
1 in = 25.4 mm
1 mi/h = 1.6 km/h

Table 22. Total number of black/(black-and-red)-on-white regulatory signs under local jurisdictions.

Material Type	Traffic Speed (mi/h)																	
	45 or greater									40 or less								
	Sign Size (in)																	
	>=48			30-36			<=24			>=48			30-36			<=24		
	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total
I	14	0.20	0.05	0	0.00	0.00	78	1.12	0.29	0	0.00	0.00	845	12.15	3.15	6,017	86.53	22.43
II	-*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
III	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
IV and VII	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

* - No signs of this type in the sample
1 in = 25.4 mm
1 mi/h = 1.6 km/h

Table 23. Total number of white-on-red regulatory signs under State jurisdiction.

Traffic Speed (mi/h)																	
45 or greater									40 or less								
Sign Size (in)																	
>=48			36			<=30			>=48			36			<=30		
No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total
72	0.52	0.10	1,054	7.60	1.47	8,512	61.36	11.89	23	0.17	0.03	204	1.47	0.28	4,008	28.89	5.60
1 in = 25.4 mm 1 mi/h = 1.6 km/h																	

Table 24. Total number of white-on-red regulatory signs under local jurisdiction.

Traffic Speed (mi/h)																	
45 or greater									40 or less								
Sign Size (in)																	
>=48			36			<=30			>=48			36			<=30		
No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total
2	0.03	0.01	360	4.54	1.34	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	7,574	95.44	28.24
1 in = 25.4 mm 1 mi/h = 1.6 km/h																	

Table 25. Total number of white-on-green guide signs under State jurisdiction.

	Traffic Speed (mi/h)					
	45 or greater			40 or less		
	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total
Ground-Mounted	1,394	77.75	1.95	399	22.25	0.56
1 mi/h = 1.6 km/h						

Table 26. Total number of white-on-green guide signs under local jurisdiction.

	Traffic Speed (mi/h)					
	45 or greater			40 or less		
	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total
Ground-Mounted	45	24.73	0.17	137	75.27	0.51
1 mi/h = 1.6 km/h						

Sign Replacement Costs

There are various factors, such as, material type, fabrication costs, labor and equipment costs etc., that influence the cost of a traffic sign. Various jurisdictions across the Nation use different rates for labor and equipment. Therefore, it was difficult to derive an average cost of installing a new sign or replacing an old sign with a new one. Based on the research into the survey responses discussed earlier and other data available with BMI, the data indicated that the final costs of sign replacement varied greatly. A summary of the survey results is tabulated in tables 27 and 28 for State and local jurisdictions, respectively. Additional cost comparisons available for State jurisdictions are presented in table 29.

It was observed that the material cost (sheeting cost) per square foot was more or less uniform across the country, whereas as the final replacement costs varied to a large degree. Although, detailed levels of cost estimates were not readily available for most of the local jurisdictions, the final cost of a sign converted to unit cost, i.e., sign installed cost per square foot was found to be comparable for some State jurisdictions. Hence, the unit cost of sign installation was selected as a basis to estimate the national cost of replacing signs not meeting the proposed

Table 27. Sign replacement costs for State jurisdictions–summary of survey results.

State Jurisdiction	Base	Unit Cost	Remarks
Arizona	Type I Type III	\$0.74 per ft^2 \$3.74 per ft^2	Sheeting Costs only; Posts - \$25 to \$30; Labor - \$18/hr
Georgia	Average Cost	\$30.00 per sign	5000 signs need replacement; total approx cost = \$150,000
Iowa	Type I on Aluminum Type III on Aluminum	\$5.83 per ft^2 \$8.98 per ft^2	Sign Replacement Costs; Type III on Extrusions = \$16.06/sq. ft.
Kansas	Average Cost	\$225.92 per sign	
Ohio	Type I Type III	\$9.06 per ft^2 \$11.06 per ft^2	Installed costs (non-guide signs); Guide signs = \$11.26
Pennsylvania	Type I Type III	\$0.74 per ft^2 \$3.74 per ft^2	Sheeting Costs only.
Virginia	Average Cost	\$50.00 per sign	Average replacement cost
Washington	Average Cost	\$10.00 per ft^2	Installed costs, excluding posts
West Virginia	Average Cost	\$74.00 per sign	47,000 signs need replacement; approx cost = \$3,500,000
1 ft^2 = 0.09 m^2			

minimum retroreflectivity values. Based on these analyses, the unit costs of installing new signs used for this study were: \$9.00 per ft^2 (\$100.00 per m^2) for Type I material and \$11.25 per ft^2 (\$101.25 per m^2) for Type III material. These costs do not include the cost of removing the old signs.

It was assumed that out of all the Type I sheeting signs needing replacement, one-half (i.e., 50 percent) will be replaced by Type I material whereas the other half will be replaced using Type III sheeting and 100 percent of the Type III sheeting signs needing replacement will be replaced by Type III sheetings only. (Because the survey did not include any signs with Type II or IV sheeting, an estimate of the number of signs with these types cannot be provided and no assumption was made as to how many signs might be replaced with these sheeting types.)

Table 28. Sign replacement costs for local jurisdictions–summary of survey results.

Local Jurisdiction	Base	Unit Cost	Remarks
Black Hawk County, IA	Average cost	$38.00 per sign	Materials only. Equipment & labor costs are normally at least 100% of material costs.
Delaware County, NY	Type I Type III	$16.25 per sign $38.52 per sign	Sheet+Blank (materials only); posts not included.
Eugene, OR	Average installation cost	$120 per sign	Including personnel, equipment and materials.
Grand Coulee, WA	Average cost	$7.00 per ft^2	Materials only.
Linn County, IA	Type I Type III	$23.50 per sign $39.90 per sign	Unspecified whether with or without labor costs
McLeod County, MN	Type I Type III	$16.00 per sign $32.00 to $40.00 per sign	Materials only.
Sedgwick County, KS	Type II Type III	$50.00 per sign $62.00 per sign	Including labor.

1 ft^2 = 0.09 m^2

Table 29. Supplemental sign replacement cost comparisons for State jurisdictions.

State DOT	Finished Sign Cost			Installed Sign Cost			Unit Cost (per sq ft) for Installed Sign			Remarks
	Type I	Type III	Any	Type I	Type III	Any	Type I	Type III	Any	
PA	$14.50*	$33.25*		$49.50	$68.25		$7.92	$10.92		* For 30 in by 30 in Warning sign
				(Finished Cost + $35.00)						
MD			$33.31*							* For 30 in by 30 in Warning sign
OH							$9.06	$11.06	$10.46	
WA									$10.00	
IA							$5.83*	$8.98*		* Reported as replacement cost

1 ft^2 = 0.09 m^2
1 in = 25.4 mm

Using the sign density (number of signs per mile), percentage of sign to be replaced, average sign size (square feet per sign), and the estimated sign installation cost per square foot of the sign, the sign costs per mile of the roadway were computed for each cell of the four groups of sign for State and local jurisdictions separately. Table 30 shows the aggregated costs for each sign group for Type I signs, Type III signs, and combined costs by jurisdiction type. These costs were computed as follows:

$$C_g = \sum C_c$$

where,

$$C_c = \{(P*N)/M\}*S*U$$

where,

C_g = Aggregate sign installation cost per mile for a sign group
C_c = Sign installation cost per mile for an individual cell within that group
P = Percenatge of signs within a cell to be replaced
N = Total number of signs under the jurisdiction type
M = Total miles covered by N signs
S = Average size (square foot) of sign within a cell
U = Unit cost of sign per square foot.

The sign replacement cost per mile of the roadway for the local jurisdictions was computed to be $49.26, and for the State jurisdictions it was $41.40. This indicates that the local jurisdictions will have an higher impact on their budgets than the State jurisdictions, if the signs were to be replaced based on the proposed minimum retroreflectivity values. These costs do not include the cost of sign removal and disposal, if any. Also these costs do not reflect the likely recylcing of some of the materials, thereby overestimating the costs. Most of the State and local agencies also have some form of sign replacement program in place, hence, may not require additional staff or equipment to replace signs that are identified for replacement for not meeting the minimum retroreflectivity values. It should, however, be recognized that these estimates are based on a limited survey and estimates for local jurisdictions may not be accurately applicable to large cities.

National road miles under the State and local jurisdictions were obtained from *Highway Statistics* (1993).[2] Using the national road miles and the estimated replacement costs per mile, total national costs for replacing the signs not meeting the minimum retroreflectivity guidelines were computed. These values are shown in table 31.

Table 30. Number of sample signs, sign densities and installation costs for State and local jurisdiction.

Sign Group	State Jurisdiction					Local Jurisdiction				
	# of Signs	Density (signs/ mile)	Replaced Sign Cost/Mile			# of Signs	Density (signs/ mile)	Replaced Sign Cost/Mile		
			Type I	Type III	Total			Type I	Type III	Total
Group 1	24,971	5.32	$4.99	$6.24	$11.22	11,750	3.57	$13.95	$17.43	$31.38
Group 2	30,968	6.60	$6.93	$8.66	$15.59	6,954	2.11	$4.51	$5.63	$10.14
Group 3	13,873	2.96	$5.26	$6.57	$11.83	7,936	2.41	$3.40	$4.25	$7.65
Group 4	1,793	0.38	$1.23	$1.53	$2.76	182	0.06	$0.04	$0.05	$0.09
Total	71,605	15.25	$18.40	$23.00	$41.40	26,822	8.14	$21.89	$27.37	$49.26
1 mi = 1.6 km										

Table 31. National road miles and sign replacement costs by jurisdiction type.

	Jurisdiction Type	
	State	Local
National Mileage	791,305	2,924,233
Sign Installation Cost (per mile)	$41.40	$49.26
Total National Cost	$32,759,673	$144,044,867
1 mi = 1.6 km		

DISCUSSION

The purpose of this analysis was to assess the national impact of implementing the FHWA proposed guidelines for minimum levels of retroreflectivity of traffic signs, on State and local highway agencies. Based on the data collected by several State and local agencies nationwide that reflected the condition of signs in 1994, about 5 percent of the signs under the State jurisdictions and about 8 percent of those under local jurisdictions on an overall basis would not meet the proposed minimum retroreflectivity values, and hence, would need to be replaced. However, there is likely to be significant variation among the jurisdictions as to the number of signs not meeting the minimum value requirements. This variation is likely to be more significant among various local agencies than among State agencies. Some local agencies may be required to replace significantly higher percentage of their signs than others.

The local agencies will have a higher percentage of their signs not meeting the minimum requirements than the States, which could be attributed to several factors. Some key factors include the higher percentage of signs with Type I (engineering grade) sheeting and higher percentage of older signs in service. Local agencies typically use Type I sheeting signs because of their lower costs, but they have shorter life and lower levels of retroreflectivity (R_A) than Type II (super-engineering grade) and Type III (high intensity or high performance) sheetings. Also, the signs in local jurisdictions are not replaced as frequently as those under State control and are in service for longer durations than they should be. The signs under State jurisdictions are, in general, in good condition.

Signs in service under State jurisdictions were found to be more densely placed, i.e., significantly higher number of signs in use per roadway mile, than those under local jurisdictions. Because of the significantly higher quantity of signs, the sign cost per square foot and the cost per mile were lower for States than local agencies. However, no data was available from any large city. The density of signs for local jurisdictions available from the survey, therefore, may not accurately reflect the actual magnitude of number of signs per roadway mile, as the large cities normally have a higher density of signs than the participating jurisdictions. Based on the data available on the sign replacement costs, the estimated costs of installing a new sign were about $42 and $50 per mile of the roadway for the State and local agencies, respectively. However, the costs for various types of signs vary significantly.

The total costs, nationally, of replacing all the signs not meeting the minimum values were estimated to be about $32 million for the State agencies combined and $144 million for the local agencies combined. It should be noted that this is the total cost of replacing all the signs failing the minimum retroreflectivity requirements at one time. Practically, all such signs will not and cannot be replaced at one time. The sign replacement rates are not likely to be any significantly greater than the normal rates. Most agencies do replace their signs on the need basis, and hence, have a sign replacement program of some sort. As far as replacing the signs is concerned, many agencies, therefore, will not likely feel any additional impact of implementing the minimum retroreflectivity guidelines. The measurement of sign retroreflectivity and adopting a new sign

inventory program to include retroreflectivity would have some initial additional impact on agencies' budgets. In fact, by properly managing the sign maintenance programs and replacement schedules in a well organized manner, the additional impact on budget, if any, can be significantly minimized. This investment in a planned manner, in turn, would pay higher returns to the local and State agencies in the long run as these improvements now are likely to reduce the overall maintenance and replacement rates of their traffic signs in future.

APPENDIX A. TABLES OF SIGNS SAMPLED FOR RETROREFLECTIVITY BY AGENCIES

Table 32. Sign retroreflectivity data summary by sign group–State jurisdictions.

JURISDICTION	NUMBER OF MEASURED SIGNS USED IN ANALYSIS				
	GROUP 1	GROUP 2	GROUP 3	GROUP 4	TOTAL
Arizona	328	306	150		784
California	67	57	415	130	669
Georgia	148	337	150	88	723
Iowa	127	222	266	100	715
Kansas	259	261	166	55	741
Michigan	67	95	55	114	331
Missouri	50	149	150	100	449
Mississippi	137	219	212	140	708
New York	100	318	200	100	718
Ohio	314	252	189		755
Oklahoma	82	50	300	50	482
Texas	240	205	175	125	745
Utah	139	150	100	175	564
Virginia	150	213	300	75	738
Washington	178	176	234	183	771
Wisconsin	247	511	225		983
West Virginia	124	232	123	65	544
TOTAL	2,757	3,753	3,410	1,500	11,420

Table 33. Sign retroreflectivity data summary by sign group–local jurisdictions.

JURISDICTION	NUMBER OF MEASURED SIGNS USED IN ANALYSIS				
	GROUP 1	GROUP 2	GROUP 3	GROUP 4	TOTAL
Linn Co., IA	295	63	128	13	499
Black Hawk Co., IA	566	80	100		746
Clinton Co., IA	210	121	84	81	496
Sedgwick Co., KS	125	104	172	102	503
McLeod Co., MN	162	143	207		512
Delaware Co., NY	325	100	100		525
City of Eugene, OR	257	282	170	50	759
City of Garland, TX	90	200	116	64	470
TOTAL	2,030	1,093	1,077	310	4,510

Table 34. Cell nomenclature.

Black-on-yellow/orange warning signs (Group 1)

Legend	Material Type	Sign Size (in)		
		>=48	36	<=30
Bold Symbol	ALL	T1A	T1B	T1C
Fine Symbol and Word	I	T1D	T1E	T1F
	II	T1G	T1H	T1I
	III	T1J	T1K	T1L
	IV and VII	T1M	T1N	T1O

Black/(black-and-red)-on-white regulatory and guide signs (Group 2)

Material Type	Traffic Speed (mi/h)					
	45 or greater			40 or less		
	Sign Size (in)					
	>=48	30-36	<=24	>=48	30-36	<=24
I	T2A	T2B	T2C	T2M	T2N	T2O
II	T2D	T2E	T2F	T2P	T2Q	T2R
III	T2G	T2H	T2I	T2S	T2T	T2U
IV and VII	T2J	T2K	T2L	T2V	T2W	T2X

White-on-red regulatory signs (Group 3)

Sheeting Color	Traffic Speed (mi/h)					
	45 or greater			40 or less		
	Sign Size (in)					
	>=48	36	<=30	>=48	36	<=30
White (legend) Red (background)	T3A	T3B	T3C	T3D	T3E	T3F

White-on-green guide signs (Group 4)

	Sheeting Color	Traffic Speed (mi/h)	
		45 or greater	40 or less
Ground-Mounted	White (legend) Green (background)	T4A	T4B

1 in = 25.4 mm
1 mi/h = 1.6 km/h

Table 35. Cell by cell sample size of sign retroreflectivity data by State agencies.

ARIZONA	
CELL*	COUNT
T1A	71
T1B	66
T1C	40
T1D	23
T1E	19
T1F	37
T1K	72
T2A	49
T2B	95
T2C	79
T2N	8
T2O	75
T3B	10
T3C	67
T3E	23
T3F	50
TOTAL	784

CALIFORNIA	
CELL	COUNT
T1A	46
T1B	21
T2A	38
T2N	19
T3A	160
T3B	90
T3E	165
T4A	78
T4B	52
TOTAL	669

GEORGIA	
CELL	COUNT
T1A	43
T1B	25
T1C	47
T1D	6
T1E	24
T1F	3
T2A	24
T2B	46
T2C	50
T2G	26
T2H	3
T2M	50
T2N	39
T2O	99
T3B	50
T3F	100
T4A	38
T4B	50
TOTAL	723

IOWA	
CELL	COUNT
T1A	23
T1C	42
T1J	29
T1L	33
T2G	57
T2H	59
T2T	56
T2U	50
T3A	58
T3B	56
T3C	50
T3E	50
T3F	52
T4A	50
T4B	50
TOTAL	715

KANSAS	
CELL	COUNT
T1A	79
T1C	91
T1D	10
T1F	29
T1J	40
T1L	10
T2A	50
T2B	62
T2C	59
T2I	34
T2N	56
T3A	53
T3B	54
T3E	59
T4B	55
TOTAL	741

MICHIGAN	
CELL	COUNT
T1A	6
T1B	27
T1C	6
T1E	4
T1F	1
T1J	9
T1K	13
T1L	1
T2B	1
T2C	3
T2G	29
T2H	2
T2I	15
T2O	12
T2T	4
T2U	29
T3A	1
T3B	13
T3C	8
T3E	3
T3F	30
T4A	44
T4B	70
TOTAL	331

MISSOURI	
CELL	COUNT
T1B	43
T1E	7
T2B	49
T2C	50
T2O	50
T3B	50
T3C	50
T3F	50
T4A	50
T4B	50
TOTAL	449

MISSISSIPPI	
CELL	COUNT
T1A	52
T1B	61
T1M	13
T1N	11
T2C	94
T2K	54
T2N	71
T3A	72
T3B	69
T3E	71
T4A	71
T4B	69
TOTAL	708

NEW YORK	
CELL	COUNT
T1A	100
T2A	125
T2B	48
T2H	50
T2N	50
T2T	45
T3A	50
T3E	50
T3F	100
T4A	50
T4B	50
TOTAL	718

OHIO	
CELL	COUNT
T1A	47
T1B	105
T1C	107
T1E	16
T1F	16
T1J	16
T1K	5
T1L	2
T2B	63
T2C	63
T2G	63
T2H	63
T3D	63
T3E	63
T3F	63
TOTAL	755

* Note: Refer to table 34 for cell labels.

Table 35. Cell by cell sample size of sign retroreflectivity data by State agencies (continued).

OKLAHOMA	
CELL*	COUNT
T1A	17
T1B	47
T1J	16
T1K	2
T2B	50
T3A	50
T3B	50
T3C	50
T3D	50
T3E	50
T3F	50
T4A	50
TOTAL	482

TEXAS	
CELL	COUNT
T1A	173
T1D	49
T1J	18
T2A	125
T2G	2
T2M	30
T2N	34
T2O	14
T3A	87
T3D	68
T3F	20
T4A	72
T4B	53
TOTAL	745

UTAH	
CELL	COUNT
T1B	40
T1E	20
T1J	63
T1K	16
T2C	49
T2I	27
T2O	47
T2U	27
T3F	100
T4A	100
T4B	75
TOTAL	564

VIRGINIA	
CELL	COUNT
T1A	45
T1B	25
T1J	30
T1K	50
T2G	64
T2I	75
T2U	74
T3A	50
T3B	100
T3C	75
T3F	75
T4A	75
TOTAL	738

WASHINGTON	
CELL	COUNT
T1A	72
T1B	61
T1D	21
T1E	20
T1H	4
T2A	65
T2B	20
T2E	23
T2N	25
T2O	41
T2R	2
T3B	66
T3E	72
T3F	96
T4B	183
TOTAL	771

WISCONSIN	
CELL	COUNT
T1A	79
T1C	58
T1D	39
T1F	42
T1J	29
T2A	75
T2C	72
T2G	75
T2M	75
T2N	75
T2O	64
T2T	75
T3A	75
T3D	75
T3E	75
TOTAL	983

WEST VIRGINIA	
CELL	COUNT
T1A	35
T1B	31
T1E	33
T1J	25
T2B	46
T2C	62
T2G	59
T2O	65
T3C	60
T3F	63
T4A	65
TOTAL	544

* Note: Refer to table 34 for cell labels.

Table 36. Cell by cell sample size of sign retroreflectivity data by local agencies.

Linn Co., IA	
CELL*	COUNT
T1B	29
T1C	87
T1E	40
T1F	96
T1K	27
T1L	16
T2C	34
T2I	16
T2N	5
T2O	6
T2U	2
T3B	22
T3C	106
T4A	13
TOTAL	499

Black Hawk Co., IA	
CELL	COUNT
T1A	33
T1B	12
T1C	197
T1D	1
T1E	52
T1F	52
T1J	6
T1K	170
T1L	43
T2B	8
T2C	28
T2H	4
T2I	23
T2O	8
T2T	1
T2U	8
T3C	100
TOTAL	746

Clinton Co., IA	
CELL	COUNT
T1C	117
T1E	4
T1F	30
T1K	6
T1L	53
T2O	76
T2U	45
T3C	84
T4A	81
TOTAL	496

Sedgwick Co., KS	
CELL	COUNT
T1C	105
T1I	14
T1L	6
T2H	53
T2T	51
T3A	50
T3C	62
T3F	60
T4A	50
T4B	52
TOTAL	503

McLeod Co., MN	
CELL	COUNT
T1C	162
T2C	143
T3C	97
T3F	110
TOTAL	512

Delaware Co., NY	
CELL	COUNT
T1A	200
T1C	125
T2O	100
T3C	100
TOTAL	525

City of Eugene, OR	
CELL	COUNT
T1C	176
T1F	81
T2N	76
T2O	106
T2T	50
T2U	50
T3E	55
T3F	115
T4B	50
TOTAL	759

City of Garland, TX	
CELL	COUNT
T1B	35
T1C	27
T1E	15
T1F	13
T2B	50
T2C	50
T2N	50
T2O	50
T3C	16
T3F	100
T4A	50
T4B	14
TOTAL	470

* Note: Refer to table 34 for cell labels.

Table 37. Cell by cell sample size of black-on-yellow/orange warning signs under State jurisdictions.

Legend	Material Type	Jurisdiction	Sign Size (in)								
			>=48			36			<=30		
			No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total
Bold Symbol	ALL	Pennsylvania	704	3.18	1.07	876	3.95	1.34	8059	36.36	12.30
		Washington	158	5.63	2.60	648	23.08	10.65	1266	45.09	20.82
		Total	862	3.45	1.20	1524	6.10	2.13	9325	37.34	13.02
Fine Symbol and Word	I	Pennsylvania	353	1.59	0.54	1215	5.48	1.85	6525	29.44	9.96
		Washington	0	0.00	0.00	25	0.89	0.41	710	25.28	11.67
		Total	353	1.41	0.49	1240	4.97	1.73	7235	28.97	10.10
	II		-	-	-	-	-	-	-	-	-
	III	Pennsylvania	204	0.92	0.31	3728	16.82	5.69	499	2.25	0.76
		Washington	0	0.00	0.00	0	0.00	0.00	1	0.04	0.02
		Total	204	0.82	0.28	3728	14.93	5.21	500	2.00	0.70
	IV and VII		-	-	-	-	-	-	-	-	-

1 in = 25.4 mm

Table 38. Cell by cell sample size of black/(black-and-red)-on-white regulatory signs under State jurisdictions.

Material Type	Jurisdiction	Traffic Speed (mi/h)																	
		45 or greater									40 or less								
		Sign Size (in)																	
		>=48			30-36			<=24			>=48			30-36			<=24		
		No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total
I	Pennsylvania	76	0.25	0.12	665	2.20	1.01	17405	57.63	26.56	81	0.27	0.12	390	1.29	0.60	8994	29.78	13.73
	Washington	0	0.00	0.00	169	21.98	2.78	600	78.02	9.87	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
	Total	76	0.25	0.11	834	2.69	1.16	18005	58.14	25.14	81	0.26	0.11	390	1.26	0.54	8994	29.04	12.56
II		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
III	Pennsylvania	43	0.14	0.07	114	0.38	0.17	1484	4.91	2.26	0	0.00	0.00	19	0.06	0.03	928	3.07	1.42
	Washington	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
	Total	43	0.14	0.06	114	0.37	0.16	1484	4.79	2.07	0	0.00	0.00	19	0.06	0.03	928	3.00	1.30
IV and VII		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

1 mi/h = 1.6 km/h
1 in = 25.4 mm

Table 39. Cell by cell sample size of white-on-red regulatory signs under State jurisdictions.

Jurisdiction	Traffiic Speed (mi/h)																	
	45 or greater									40 or less								
	Sign Size (in)																	
	>=48			36			<=30			>=48			36			<=30		
	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total
Pennsylvania	72	0.62	0.11	561	4.86	0.86	6665	57.79	10.17	23	0.20	0.04	204	1.77	0.31	4008	34.75	6.12
Washington	0	0.00	0.00	493	21.07	8.11	1847	78.93	30.37	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
Total	72	0.52	0.10	1054	7.60	1.47	8512	61.36	11.89	23	0.17	0.03	204	1.47	0.28	4008	28.89	5.60

1 mi/h = 1.6 km/h
1 in = 25.4 mm

Table 40. Cell by cell sample size of white-on-green guide signs under State jurisdictions.

	Jurisdiction	Traffic Speed					
		45 or greater			40 or less		
		No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total
Ground-Mounted	Pennsylvania	1229	75.49	1.88	399	24.51	0.61
	Washington	165	100.00	2.71	0	0.00	0.00
	Total	1394	77.75	1.95	399	22.25	0.56

1 mi/h = 1.6 km/h

Table 41. Cell by cell sample size of black-on-yellow/orange warning signs under local jurisdictions.

Legend	Material Type	Jurisdiction	Sign Size (in)								
			>=48			36			<=30		
			No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total
Bold Symbol	ALL	Holidaysburg	0	0.00	0.00	1	1.72	0.16	30	51.72	4.66
		Lower Paxton	0	0.00	0.00	1	0.15	0.03	248	36.85	8.29
		White Twp.	0	0.00	0.00	0	0.00	0.00	51	25.50	7.49
		Missoula Co.	0	0.00	0.00	14	4.86	2.05	107	37.15	15.67
		Pierce Co.	0	0.00	0.00	59	0.74	0.35	3665	46.04	21.93
		Ravalli Co.	6	0.74	0.35	58	7.13	3.36	397	48.77	22.97
		McLeod Co.	0	0.00	0.00	14	0.80	0.41	723	41.15	21.39
		Total	6	0.05	0.02	147	1.25	0.55	5221	44.43	19.47
Fine Symbol and Word	I	Holidaysburg	0	0.00	0.00	6	10.34	0.93	21	36.21	3.26
		Lower Paxton	0	0.00	0.00	57	8.47	1.91	367	54.53	12.27
		White Twp.	0	0.00	0.00	9	4.50	1.32	140	70.00	20.56
		Missoula Co.	0	0.00	0.00	15	5.21	2.20	152	52.78	22.25
		Pierce Co.	0	0.00	0.00	2	0.03	0.01	4121	51.77	24.65
		Ravalli Co.	0	0.00	0.00	56	6.88	3.24	297	36.49	17.19
		McLeod Co.	0	0.00	0.00	583	33.18	17.25	425	24.19	12.57
		Total	0	0.00	0.00	728	6.20	2.71	5523	47.00	20.59
	II		-	-	-	-	-	-	-	-	-
	III	Holidaysburg	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
		Lower Paxton	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
		White Twp.	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
		Missoula Co.	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
		Pierce Co.	0	0.00	0.00	113	1.42	0.68	0	0.00	0.00
		Ravalli Co.	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
		McLeod Co.	0	0.00	0.00	4	0.23	0.12	0	0.00	0.00
		Total	0	0.00	0.00	117	1.00	0.44	0.00	0.00	0.00
	IV and VII	Holidaysburg	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
		Lower Paxton	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
		White	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
		Missoula	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
		Pierce	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
		Ravalli	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
		McLeod	0	0.00	0.00	8	0.46	0.24	0	0.00	0.00
		Total	-	-	-	8	0.07	0.03	-	-	-

1 in = 25.4 mm

Table 42. Cell by cell sample size of black/(and/or red)-on-white regulatory signs under local jurisdictions.

Material Type	Jurisdiction	Traffic Speed (mi/h)																	
		45 or greater									40 or less								
		Sign Size (in)																	
		>=48			30-36			<=24			>=48			30-36			<=24		
		No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total
I	Holidaysburg	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	1	0.50	0.16	200	99.50	31.06
	Lower Paxton	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	643	76.28	21.50	200	23.72	6.69
	White Twp.	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	3	1.55	0.44	190	98.45	27.90
	Missoula Co.	14	6.64	2.05	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	16	7.58	2.34	181	85.78	26.50
	Pierce Co.	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	158	3.72	0.95	4091	96.28	24.48
	Ravalli Co.	0	0.00	0.00	0	0.00	0.00	78	16.63	4.51	0	0.00	0.00	1	0.21	0.06	390	83.16	22.57
	McLeod Co.	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	23	2.92	0.68	765	97.08	22.63
	Total	14	0.20	0.05	0	0.00	0.00	78	1.12	0.29	0	0.00	0.00	845	12.15	3.15	6017	86.53	22.43
II		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
III	Holidaysburg	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
	Lower Paxton	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
	White Twp.	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
	Missoula Co.	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
	Pierce Co.	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
	Ravalli Co.	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
	McLeod Co.	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
	Total	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00
IV and VII		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

1 mi/h = 1.6 km/h
1 in = 25.4 mm

Table 43. Cell by cell sample size of white-on-red regulatory signs under local jurisdictions.

Jurisdiction	Traffic Speed (mi/h)																	
	45 or greater									40 or less								
	Sign Size (in)																	
	>=48			36			<=30			>=48			36			<=30		
	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total
Holidaysburg	0	0.00	0.00	1	0.26	0.16	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	384	99.74	59.63
Lower Paxton	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	1475	100.00	49.31
White Twp.	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	288	100.00	42.29
Missoula Co.	0	0.00	0.00	14	12.50	2.05	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	98	87.50	14.35
Pierce Co.	0	0.00	0.00	292	6.48	1.75	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	4214	93.52	25.21
Ravalli Co.	2	0.58	0.12	27	7.89	1.56	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	313	91.52	18.11
McLeod Co.	0	0.00	0.00	26	3.14	0.77	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	802	96.86	23.73
Total	2	0.03	0.01	360	4.54	1.34	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	7574	95.44	28.24

1 mi/h=1.6km/h
1in = 25.4 mm

Table 44. Cell by cell sample size of white-on-green guide signs under local jurisdictions.

	Jurisdiction	Traffic Speed (mi/h)					
		45 or greater			40 or less		
		No. of Signs	% of Group	% of Total	No. of Signs	% of Group	% of Total
Ground-Mounted	Holidaysburg	0	0.00	0.00	0	0.00	0.00
	Lower Paxton	0	0.00	0.00	0	0.00	0.00
	White Twp.	0	0.00	0.00	0	0.00	0.00
	Missoula Co.	0	0.00	0.00	72	100.00	10.54
	Pierce Co.	0	0.00	0.00	0	0.00	0.00
	Ravalli Co.	38	36.89	2.20	65	63.11	3.76
	McLeod Co.	7	100.00	0.21	0	0.00	0.00
	Total	45	24.73	0.17	137	75.27	0.51

1 mi/h = 1.6 km/h

REFERENCES

1. *Manual on Uniform Traffic Control Devices*, Federal Highway Administration, Washington, DC. 1988

2. *Highway Statistics, 1993*, Federal Highway Administration, Washington, DC. 1993