An Implementation Guide for Minimum Retroreflectivity Requirements for Traffic Signs

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FOREWORD

This report presents information aimed at providing guidance to agencieson all levels on how they can cost-effectively meet the minimum maintained retroreflectivity guidelines for traffic signs while maintaining the signs on their highways. Over time, traffic signs deteriorate, losing their retroreflective properties and color. Eventually, the sign may be rendered undetectable and illegible, which could possibly create an unsafe driving environment. This report presents information essential for maintaing a system of highway signing that will serve the driving population in the most efficient manner possible.

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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16. Abstract

Although the *Manual on Uniform Traffic Control Devices for Streets and Highways* stipulates that all warning and regulatory signs be illuminated or reflectorized to show the same color and shape by day or night, there are no specific guidelines for required retroreflectivity levels. Therefore, the FHWA embarked on a comprehensive research program which resulted in recommended guidelines for minimum retroreflectivity values for four types of signs: yellow or orange warning signs, white on red regulatory signs, white regulatory signs, and white on green guide signs. The retroreflectivity values developed for each group of signs are considered the retroreflectivity levels below which the sign would be inadequate for meeting the nightime visibility requirements for most drivers, and therefore, should be programmed for replacement.

To assist agencies in developing a cost-effective program for timely replacement of ineffective signs, this document was prepared. Initially the report describes the principles of retroreflectivity, the types of retroreflective materials, and the proposed minimum retroreflectivity guidelines. Then, the report presents the concept of a sign management system, and provides guidance for developing a sign inventory, conducting sign inspections, and maintaining signs. The report concludes with discussing options that State and local agencies can follow for replacing their ineffective signs and offers a minimum and desirable program.

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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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BACKGROUND

Traffic signing is a critical component of any road because it is the medium by which the highway agency communicates with the users (motorists, bicyclists, and pedestrians), providing information related to regulations, warnings, and directional guidance. As stated in section 1A-2 of the *Manual on Uniform Traffic Control Devices (MUTCD)*, "To be effective, a traffic control device should meet five basic requirements:[1]

1. Fulfill a need.
2. Command attention.
3. Convey a clear, simple meaning.
4. Command respect of road users.
5. Give adequate time for proper response."

When applied to traffic signs, this means that among other requirements, the traffic signs must be detectable and legible at a sufficient distance commensurate with their purpose. The term detectable is used to mean that the sign, while not necessarily completely legible, can be seen or detected by the user from a prescribed distance. Legible means that the sign message, either words or symbols, can be read or recognized from a prescribed distance. The critical features of any sign must apply under both day and night conditions.

Traffic signs are designed to satisfy these visual requirements by meeting specifications for size of the sign, and in particular the size of the letters, numerals, and symbols; by the use of certain colors designated for type of message; and by the material used for the sign face. To ensure that the user can detect and read the sign during night conditions, retroreflective materials are commonly used.[1] These materials consist of one of several grades or types of retroreflective sheeting, containing either micro-sized beads or prisms, and/or retroreflective prismatic-type buttons. Principles of retroreflectivity are described later in this document.

Over time traffic signs can deteriorate in a number of ways, but the primary mechanism is the loss of retroreflectivity and the fading of the color portions. When the former condition occurs, the sign becomes undetectable and illegible at night unless illuminated by a light source at the sign. When the latter occurs, the sign will lose its distinguishing color, which for signs such as the STOP sign and other red background signs is critical, and will lose its contrast condition making it less detectable and legible, even during daytime.

When signs are not maintained to an adequate legibility level during both, day and night conditions, highway users will miss the message resulting in possible inconvenience, misdirection, and even accidents. Inadequate and poorly maintained signage is often cited as the

[1]A small percentage of signs may be internally illuminated, such as street name signs and intersection control signs, or externally illuminated, such as overhead guide signs on freeways. For the latter, the material for the legend, and, for most guide signs, the green background is typically retroreflective.

contributing factor to accidents and has been the primary factor in numerous tort liability claims across the country.

PURPOSE OF THE GUIDE

Given the importance of the retroreflectivity properties of a sign to meet motorists' detection and legibility needs, the Federal Highway Administration (FHWA) is considering issuing guidelines on the minimum level of retroreflectivity required for certain types of signs.[2] These minimum levels would be considered thresholds below which the sign would be considered inadequate and should be replaced.

With the issuance of and in support of the national guidelines, the FHWA is providing guidelines on how agencies of all levels could cost-effectively meet these minimum maintained retroreflectivity guidelines while maintaining traffic signs on their highways. The purpose of this guide is to document these guidelines.

Key to maintaining signs at an effective level is a sign management system, which, as will be explained, is a series of coordinated activities from sign acquisition and installation to eventual replacement. The level of sophistication of a sign management system will be dependent upon the needs, desires, and capabilities of the individual agency.

To assist the agencies in developing their sign management system and meeting the minimum retroreflectivity requirements, the following is presented in this guide:

- An explanation of the principles of retroreflectivity and minimum retroreflectivity requirements.
- Elements of a comprehensive Sign Management System.
- Procedures for establishing a sign inventory.
- Procedures for conducting sign inspections.
- Sign maintenance considerations.
- Options for implementing and meeting the minimum retroreflectivity requirements.

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[2] Section 406(a) of the 1993 Department of Transportation Appropriation Act required the Secretary of Transportation to revise the MUTCD to include a standard for minimum level of retroreflectivity that must be maintained for traffic signals.

- Suggested minimum and desirable programs for meeting the minimum retroreflectivity requirements.

PRINCIPLES OF RETROREFLECTIVITY

Before describing minimum retroreflectivity requirements and how they can be met, a basic understanding of the principles of retroreflectivity is needed. The basic principle of retroreflection is that the light coming from a light source is returned or reflected back in the direction of the source. This is accomplished through the use of spherical reflectors (micro-sized glass beads) or cube-corner reflectors (micro-sized prisms) as illustrated in figure 1. The light source is typically the vehicle headlight, and candlepower, or its metric equivalent candela, is the unit of measurement for this light. The intensity of this light on the sign surface is known as **illuminance** and is measured in terms of foot-candles or lux in metric equivalent. The light that is returned to the observer near the light source is known as **luminance** and is measured as candelas per square foot or square meter. Luminance is, therefore, what the motorist actually sees when the vehicle headlights hit the sign.

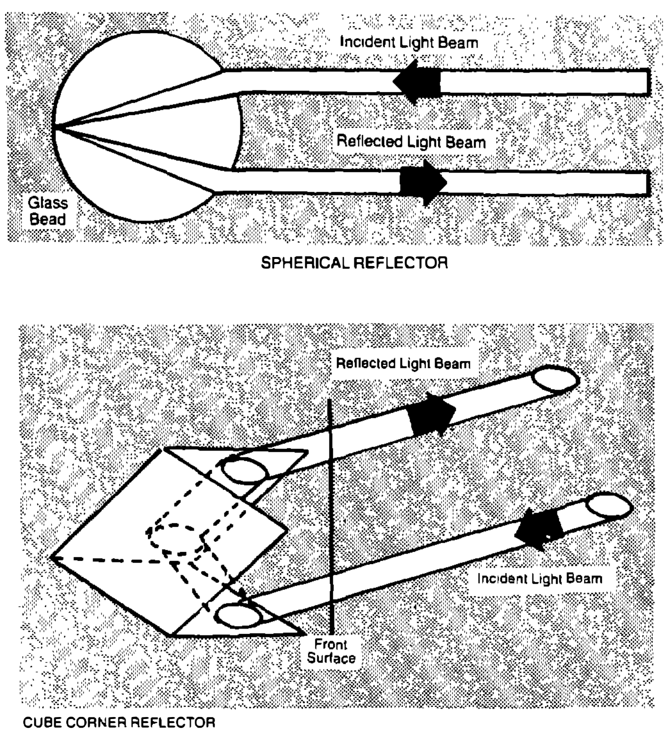

Figure 1. Types of retroreflectors.

Retroreflective materials are basically constructed with either micro-sized glass beads or prisms to provide their retroreflective properties. The principal feature that distinguishes various types of retroreflective materials is the coefficient of retroreflection (R_A). (The various types of retroreflective sheetings will be described in the next section.) This property is precisely defined in American Society for Testing and Materials (ASTM) "E 808 Practice for Describing Retroreflection", but basically it can be defined as the amount of light (i.e., luminance measured as candelas per square foot or square meters) that comes out from the retroreflective material per amount of light coming in from the light source, i.e., the vehicle headlights (i.e., illuminance measured as foot-candels or lux).(2) [3] The R_A value is expressed as candelas per foot candle per square foot ($cd/fc/ft^2$) in English or candelas per lux per square meter ($cd/lx/m^2$) in metric measurements. The higher the R_A value, the brighter the material appears to the motorist.

The retroreflectance of sheeting materials is always described in context of an important property, its angularity, which is defined by the entrance (of the light) and the observation (by the motorist) angles. These two angles are depicted in figure 2 for a roadside, post-mounted sign and an overhead sign. The entrance (or incidence) angle is the angle formed between a light beam striking the surface of a sign and a line coming out perpendicular from the surface. The observation angle is the angle between the incoming light beam and the reflected light beam as it is seen by the motorist. These angles change with distance between the vehicle and the sign, and are a function of the location of the sign and the vehicle (for the entrance angle) and the height of the driver's eye with respect to the vehicle headlamps (for the observation angle).

While the R_A is sensitive to changes in both the observation and entrance angles, it is much less sensitive to the entrance angle, except at large angles. For ASTM Type I, II, and III retroreflective sheeting materials substantial change in R_A does not occur at entrance angles less than 20 degrees and for some materials significant change does not begin until the entrance angle exceeds 30 degrees.

Unlike the case of the entrance angle, even the slightest change in the observation angle can have dramatic effects on R_A. Since the distance between the driver's eye and the light source is fixed, every time the distance between the observer and the target sign is doubled, the observation angle is cut in half. Due to its high degree of sensitivity, the observation angle plays the most important role in the calculation of R_A.

The "angularity" of the sign refers then, to the range of angles at which a sign will remain retroreflective. An entrance angle of 30 degrees is considered wide for highway signing.

Since a retroreflective material is supposed to reflect all the light directly back to the source, ideally, the observation angle should be zero. However, in reality this is not the case since the

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[3] The ASTM specifications discussed throughout this Guide are found in reference number 2, which is a compendium of standards related to color and appearance measurement.

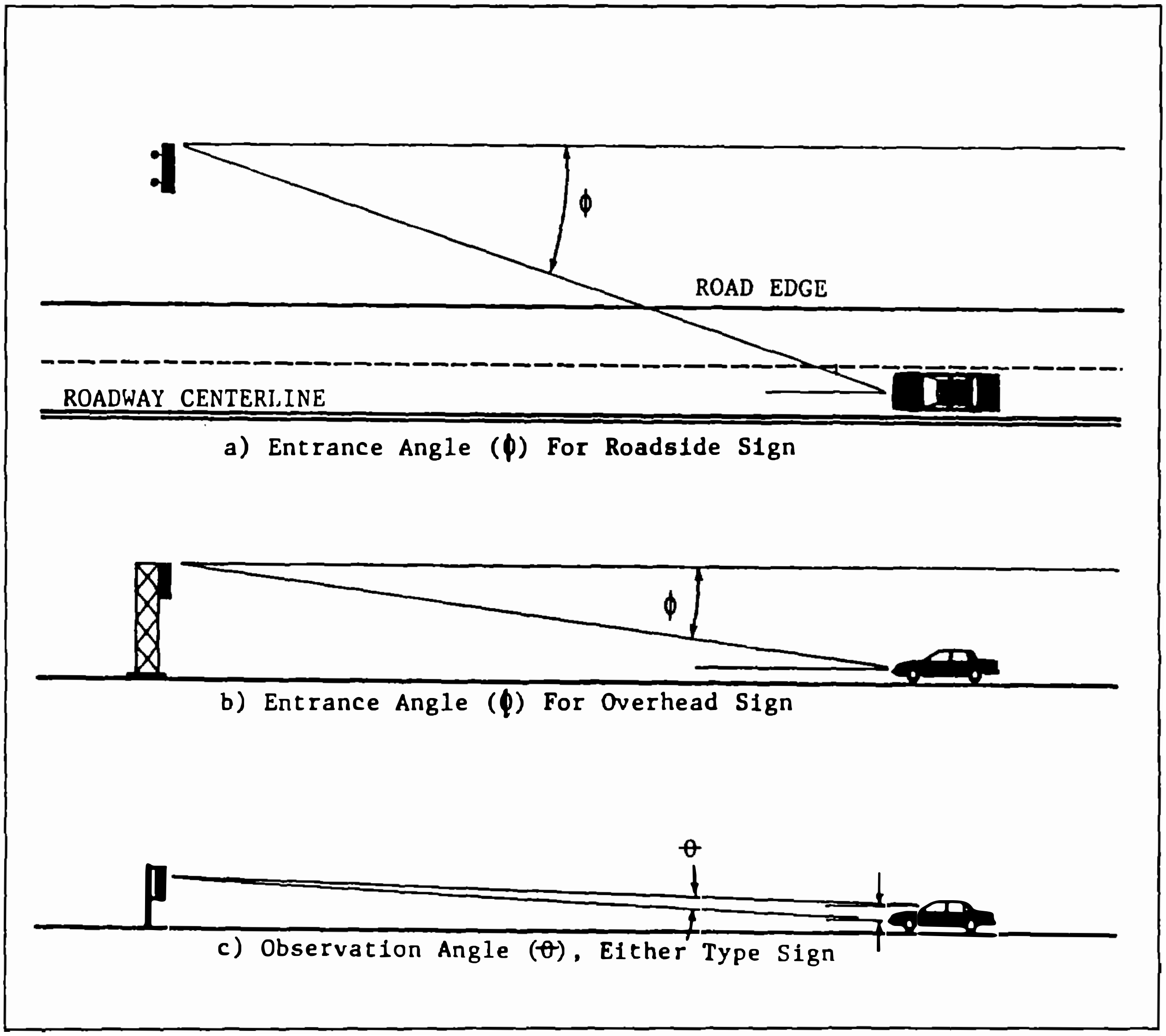

Figure 2. Illustration of entrance and observation angles under actual highway conditions.

driver's eye is higher than the vehicle headlight and can range from 21 in (0.5 m) for small cars to as much as 64 in (1.6 m) for large trucks. A wide observation angle is anything over 2 degrees.

Finally, the cone of reflected light refers to the spreading of the reflected light beam. A good retroreflector will have a very small cone, with most of the reflected light being within 3 degrees of the incoming light ray.

Minimum retroreflectance is prescribed at two observation angles, and two entrance angles and for each different type of sheeting of different colors. The two observation angles of +0.2 and +0.5 degrees equate to a viewing distance of 500 ft (152 m) and 200 ft (61 m), respectively assuming that the driver height is 21 in (0.5 m) above the headlight. The two entrance angles are -4 and +30 degrees. The 30 degrees is considered to be the widest angle between the driver and any sign that would have to be seen. The -4 degrees is intended to be for signs close to the edge of the roadway but oriented away from the perpendicular to avoid the specular reflection that occurs at 0 degrees.

TYPES OF RETROREFLECTIVE SHEETING MATERIALS

The retroreflectivity of signs is accomplished by using either retroreflective sheeting for both the legend and the background or, in the case of some large guide signs, using retroreflective elements that are housed in white embossed aluminum frames cut in the shape of letters, symbols and borders. This so-called "button copy" is then attached (riveted) to retroreflective sheeting or non-retroreflective enamel-coated material. For the vast majority of roadside signs, retroreflective sheeting is used for both the background and the legend.

Over the years industry has developed different types of retroreflective sheeting materials using either a glass bead or a prism as a method for providing the retroreflective properties. As new products are developed the classification has changed and expanded to accommodate these materials. The most recent and most recognized classification of retroreflective sheeting material for traffic signs (and delineators which use retroreflective sheeting) is found in the ASTM Standard Specification for Retroreflective Sheeting for Traffic Control, D 4956-93. [2] Of the six classes identified in that specification, the following four relate to highway signing:

- Type I — A medium-intensity retroreflective sheeting referred to as "engineering grade" which is typically enclosed lens glass-bead sheeting.

- Type II — A medium-intensity retroreflective sheeting sometimes referred to as "super-engineering grade" which is typically enclosed lens glass-bead sheeting.

- Type III — A high-intensity retroreflective sheeting which is typically encapsulated glass-bead retroreflective material.

- Type IV — A high-intensity retroreflective sheeting which is typically a non-metallized microprismatic retroreflective element material.

One of the distinguishing features of these four types is their basic construction. Types I and II are enclosed lens type sheeting, type III is an encapsulated lens type sheeting, and type IV is a prismatic lens type sheeting. Their basic construction is depicted in figure 3.

The principal characteristic that distinguishes the various types of retroreflective sheeting is the coefficient of retroreflection, R_A, provided at different entrance and observation angles. Tables 1 through 4 provide the minimum R_A values for the four types listed above. The FHWA

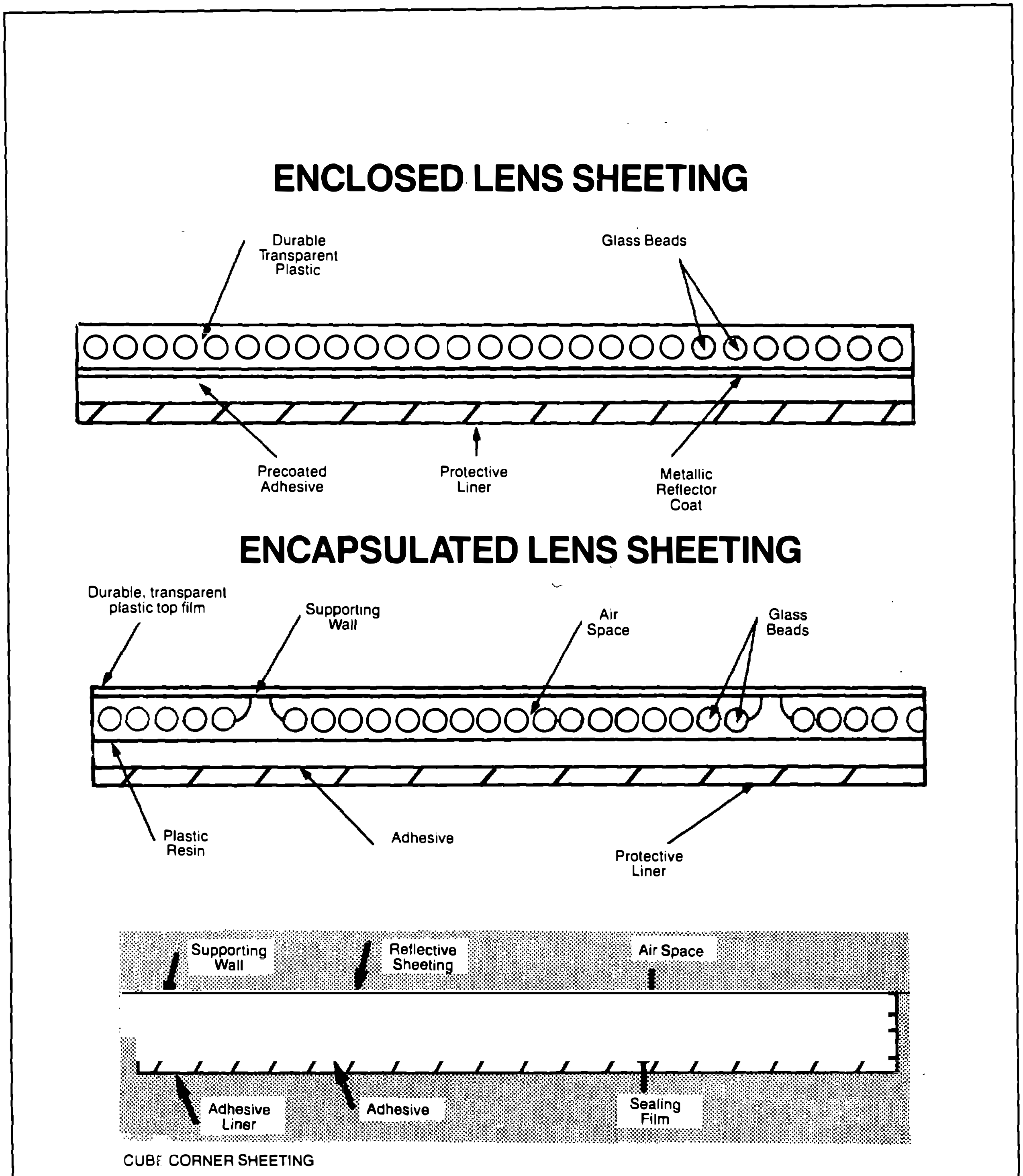

Figure 3. Physical composition of three types of retroreflective sheeting.

has adopted these specifications in their *Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects, FP-96*, with one exception for type I brown sheeting, which is noted at the bottom of table 1.[3] Individual States have their own specifications which may differ slightly from the values shown in these tables.

Table 1. Minimum coefficient of retroreflection for Type I sheeting.

Observation Angle (Deg.)	Entrance Angle (Deg.)	Coefficient of Retroreflection[a]						
		White	Yellow	Orange	Green	Red	Blue	Brown[b]
0.2	-4	70	50	25	9.0	14.0	4.0	1.0
0.2	+30	30	22	7.0	3.5	6.0	1.7	0.3
0.5	-4	30	25	13	4.5	7.5	2.0	0.3
0.5	+30	15	13	4.0	2.2	3.0	0.8	0.2

[a] $cd/fc/ft^2$ ($cd/lx/m^2$)
[b] FHWA FP-96 specifies 2 $cd/fc/ft^2$ at 0.2° observation angle and -4° entrance angle, 1.0 $cd/fc/ft^2$ at 0.2° observation angle and +30° entrance angle and at 0.5° observation angle and -4° entrance angle, and 0.5 $cd/fc/ft^2$ at 0.5° observation angle and +30° entrance angle

SOURCE: Refs. (2,3)

Table 2. Minimum coefficient of retroreflection for Type II sheeting.

Observation Angle (Deg.)	Entrance Angle (Deg.)	Coefficient of Retroreflection[a]						
		White	Yellow	Orange	Green	Red	Blue	Brown
0.2	-4	140	100	60	30	30	10	5
0.2	+30	60	36	22	10	12	4	2
0.5	-4	50	33	20	9	10	3	2
0.5	+30	28	20	12	6	6	2	1

[a] $cd/fc/ft^2$ ($cd/lx/m^2$)

SOURCE: Refs. (2,3)

Another microprismatic material has been developed by at least one company which will likely be classified as Type VII. It has been identified as diamond grade material and has two types:

- Type A sheeting is wide angle retroreflective sheeting with optimized performance over a broad range of observation angles.

- Type B sheeting is wide angle retroreflective sheeting with optimized performance at narrow observation angles and with extended entrance angle performance.

Table 3. Minimum coefficient of retroreflection for Type III sheeting.

Observation Angle (Deg.)	Entrance Angle (Deg.)	Coefficient of Retroreflection[a]						
		White	Yellow	Orange	Green	Red	Blue	Brown
0.1[b]	-4	300	200	120	54	54	24	14
0.1[b]	+30	180	120	72	32	32	14	10
0.2	-4	250	170	100	45	45	20	12
0.2	+30	150	100	60	25	25	11	8.5
0.5	-4	95	62	30	15	15	7.5	5
0.5	+30	65	45	25	10	10	5	3.5

[a] cd/fc/ft^2 (cd/lx/M^2)
[b] Values for 0.1° observation angle are supplementary requirements that shall apply only when specified by the purchaser in the contract or order.

SOURCE: Refs. (2,3)

Table 4. Minimum coefficient of retroreflection for Type IV sheeting.

Observation Angle (Deg.)	Entrance Angle (Deg.)	Coefficient of Retroreflection[a]						
		White	Yellow	Orange	Green	Red	Blue	Brown
0.1[b]	-4	400	270	160	56	56	32	12
0.1[b]	+30	120	75	48	13	13	7	3
0.2	-4	250	170	100	35	35	20	7
0.2	+30	80	54	34	9	9	5	2
0.5	-4	135	100	64	17	17	10	4
0.5	+30	55	37	22	6.5	6.5	3.5	1.4

[a] cd/fc/ft^2 (cd/lx/m^2)
[b] Values for 0.1° observation angle are supplementary requirements that shall apply only when specified by the purchaser in the contract or order.

SOURCE: Refs. (2,3)

Tables 5 and 6 provide the R_A values for these two types as provided by its manufacturer.

It is emphasized that the R_A values found in tables 1 through 6 are for distinguishing the various types and are minimum values for new material. R_A values for newly purchased sheeting are often times higher than the minimum values for each of the types. However these R_A values are ore not what the driver necessarily needs for adequate detection and recognition of the sign at night. While in general, "brighter is better" especially, when signs need to be conspicuous among competing and distracting light sources at night, in many situations most drivers require a minimum level in order to discern the sign at a sufficient distance. The retroreflectivity values that are needed by the driver, and which, therefore, should be provided as a minimum are discussed next.

Table 5. Minimum coefficient of retroreflection for proposed type VII-A sheeting.

Observation Angle (Deg.)	Entrance Angle (Deg.)	Coefficient of Retroreflection[a]			
		White	Yellow	Blue	Green
0.20	-4	430	350	20	45
0.33	-4	300	250	15	33
0.50	-4	250	200	10	25
1.00	-4	80	65	4	10
0.20	30	235	190	11	24
0.33	30	150	130	7	18
0.50	30	170	140	7	19
1.00	30	50	40	2.5	5
0.20	40	150	125	6	15
0.33	40	85	75	4	8
0.50	40	35	30	1.5	3.5
1.00	40	20	17	0.7	2

[a] $cd/fc/ft^2$ ($cd/lx/m^2$)

Source: 3M Company

Note: This table contains non-proprietary information

Table 6. Minimum coefficient of retroreflection for proposed type VII-B sheeting.

Observation Angle (Deg.)	Entrance Angle (Deg.)	Coefficient of Retroreflection[a]			
		White	Yellow	Blue	Green
0.20	-4	800	660	215	80
0.20	30	400	340	100	85
0.20	45	145	85	25	12
0.20	60	35	23	6.6	2
0.50	-4	200	160	45	20
0.50	30	100	85	26	10
0.50	45	75	60	17	6
0.50	60	30	20	6.4	2

[a] cd/fc/ft² (cd/lx/m²)

Source: 3M Company
Note: This table contains non-proprietary information

MINIMUM RETROREFLECTIVITY REQUIREMENTS

In anticipation of a national guideline on minimum maintained retroreflectivity level, i.e. R_A, the FHWA has sponsored research to determine what levels of sign retroreflectivity are needed by the road user. The results of that research led to the development of recommended minimum retroreflectivity levels below which signs would not provide adequate brightness for motorists' needs.[4] Minimum maintained retroreflectivity R_A values were developed for four groups of signs:

- Black message on yellow or orange background warning signs.
- Black and/or black and red message on white background regulatory signs.
- White message on red background regulatory signs.
- White message on green background guide signs.

The values that were presented in the research report were subsequently revised and are shown in tables 7 through 10.[4] These values are based on the standard of 0.2° observation angle and -4° entrance angle. The values presented in the four tables are based on:

(1) The results from research that utilized a human factors and mathematical modeling approach to consider the wide range of visual, cognitive, and psychomotor

capabilities of the driving population and the complexity of the relationships between the driver, the vehicle, the roadway environment, and the sign.

(2) The results from human factors research to evaluate the percent of drivers that would be accommodated by signs with varying levels of retroreflectivity.

(3) The results from measurements made on over 20,000 inservice signs in over 50 State and local jurisdictions.

(4) Input received from the more than 40 State and local jurisdictions represented at three regional workshops held in Baltimore, MD, Kansas City, MO, and Denver, CO in late 1995.

(5) Input from public agency and private industry representatives received at numerous presentations given at such forums as the Transportation Research Board (TRB) Annual Meeting, the Institute of Transportation Engineers Annual Meeting, the American Traffic Safety Services Annual Meeting, the TRB Visibility Symposium, and State-sponsored Safety and Traffic Engineering Workshops.

The recommended values only apply to yellow and orange warning signs, white and red regulatory signs, and green guide signs (excluding street name signs). They do not apply to parking signs, or brown or blue series signs. Given the many unresolved issues with vehicle headlamp performance specifications and the difficulty in measuring overhead sign retroreflectivity, at this time the FHWA is not recommending that minimum values be established for overhead-mounted signs.

In developing the recommended values, FHWA attempted to balance the desire to accommodate the highest percentage of drivers as practical with considerations of the budgetary constraints facing State and local jurisdictions. These values were developed in recognition of the fact that retroreflectivity is only one factor that contributes to poor nighttime performance of signs.

It should also be recognized that these values provide a guide as to the levels at which signs will become dysfunctional for a significant portion of the driving population under certain driving conditions. This does not mean that they will be dysfunctional for all drivers under all conditions. Signs with retroreflectivity values below these levels should be considered for replacement. These values should be used in connection with sound engineering judgement to determine the motorist's needs at a particular sign installation. Unique geometric situations or areas with complex visual backgrounds may require higher levels of retroreflectivity and/or larger or supplemental signs to provide the motorist with sufficient visibility for sign detection and recognition.

Table 7. Minimum retroreflectivity guidelines for black-on-yellow and black-on-orange warning signs.

Legend Color: Black
Background Color: Yellow or Orange

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

All table values in cd/lx/m^2
1 in = 2.54 cm

* 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		

Source: FHWA

Table 8. Minimum retroreflectivity guidelines for black (and/or red)-on-white regulatory and guide signs.

Legend Color: Black and/or Black and Red
Background Color: White

Traffic	45 mi/h or greater			40 mi/h or less		
Sign Size:	>=48-in	30-36-in	<=24-in	>=48-in	30-36-in	<=24-in
Material						
I	25	35	45	20	25	30
II	30	45	55	25	30	35
III	40	55	70	30	40	45
IV & VII	50	70	90	40	50	60
All table values in $cd/lx/m^2$ 1 mi/h = 1.6 km/h 1 in = 2.54 cm						

Source: FHWA

Table 9. Minimum retroreflectivity guidelines for white-on-red regulatory signs.

Legend Color: White
Background Color: Red

Traffic Speed:	45 mi/h or greater						40 mi/h or less					
Sign Size:	>=48-in		36-in		<=30-in		>=48-in		36-in		<=30-in	
Color:	W	R	W	R	W	R	W	R	W	R	W	R
All Signs:	35	8	45	8	50	8	25	5	30	5	35	5
All table values in $cd/lx/m^2$ 1 mi/h = 1.6 km/h 1 in = 2.54 cm												
Note: Since both the legend and the background of these signs is retrorefletorized 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 retrereflectivity of the white material divided by the retroreflectivity of the red material is less than four, the sign should be replaced.												

Source: FHWA

Table 10. Minimum retroreflectivity guidelines for white-on-green guide signs.

Legend Color: White
Background Color: Green

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

Source: FHWA

To ensure that agencies replace signs that no longer provide the retroreflectivity levels prescribed by these tables, or their replacement, a program for timely sign inspection and replacement will be needed; hence, the need for a sign management system.

SIGN MANAGEMENT SYSTEM

A management system can be defined as an integrated and coordinated set of policies, procedures, methods, and tools that assist decision makers in providing a product in a serviceable condition in the most cost-effective manner. In the highway field, management systems have been created for pavements, bridges, traffic safety, and traffic congestion. An obvious extension of these management systems is in the area of traffic control devices and signing in particular. In this context then a Sign Management System (SMS) can be defined as a coordinated program of policies and procedures which ensure that the highway agency provides a sign system that meets the needs of the user most cost-effectively within available budgets and constraints. When fully developed, a comprehensive Sign Management System can effectively manage various activities that take place during the life cycle of highway signs from purchasing of materials or fabricated signs through the sign's service life and eventual replacement and recycling. As illustrated in figure 4 the activities throughout the life cycle of signs can be coordinated through series of programs within a computer environment.

A comprehensive sign management system consists of the following elements for various stages of the life-cycle of signs:

- Sign materials (sheeting, substrate, bracing, etc.) should conform to specifications of the agency, and selection of the appropriate material should consider cost, service life, and motorists' needs. The ability to track the cost and service life of various materials through a SMS will ensure that the agency is using the most cost-effective material for the specific user requirement.

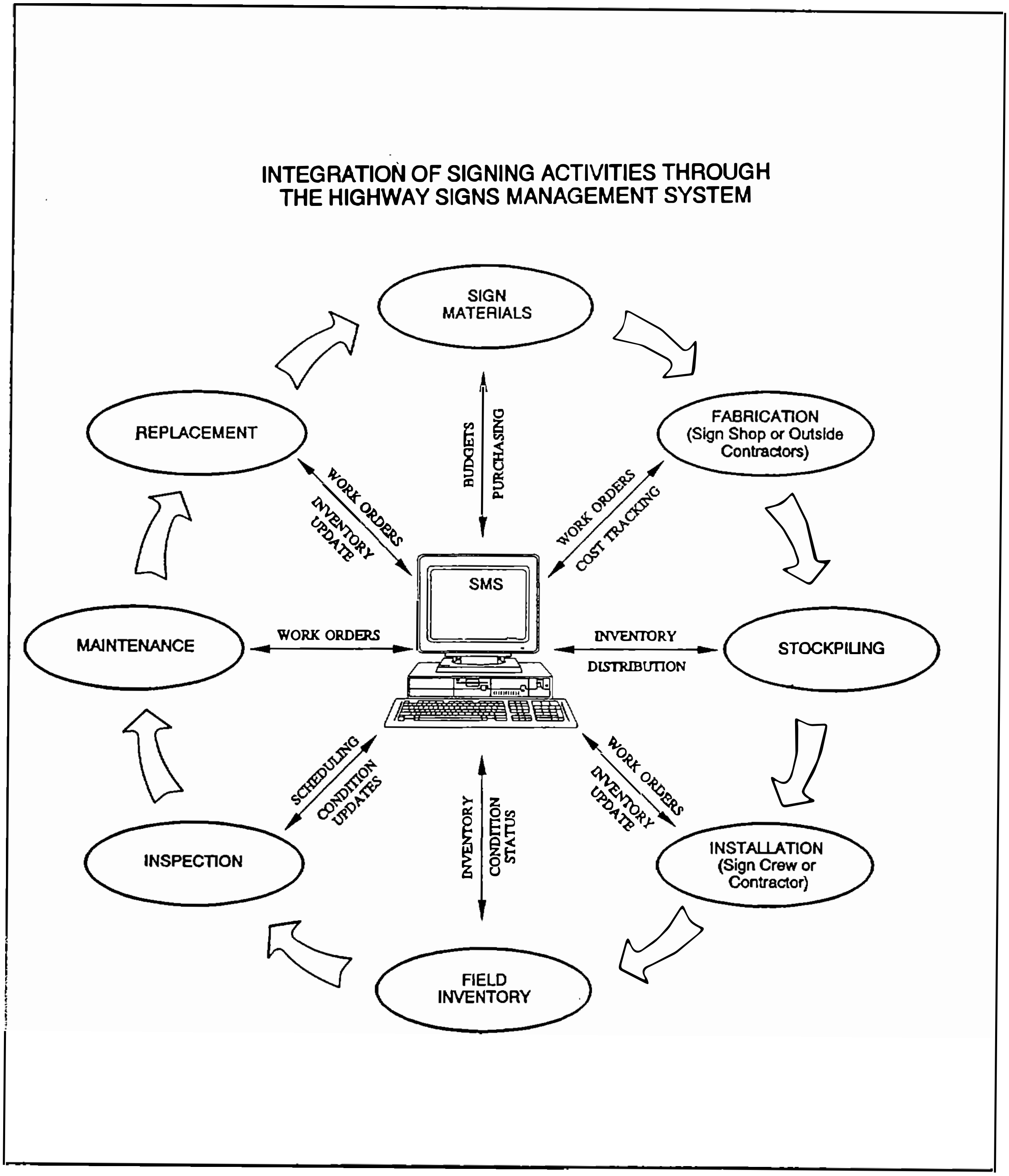

Figure 4. Integrated traffic sign management system.

- An effective SMS would provide the ability to forecast sign replacements, which would facilitate budgeting and scheduling of sign material or fabricated sign replacements.

- An inventory of stockpiled fabricated signs will allow managers to ensure timely replacement of signs.

- An SMS can generate work orders for new sign installation by in-house sign crews or by contractors.

- The nucleus of an SMS would be the inventory of the signs on the road network. That inventory is maintained through the computer and a work order system that ensures updating whenever sign activities occur.

- Periodic inspections of signs is necessary to insure that they are maintained at a serviceable level and continue to meet the users' needs. An SMS can be effective in scheduling inspections, recording the results, and determining when signs may need to be replaced.

- Inspections will identify maintenance needs, such as sign cleaning, straightening of sign posts, removal of graffiti, clearing of view-obstructing foliage, etc. These maintenance activities can be scheduled through the SMS and the work accomplished including costs can be recorded with the SMS.

- The replacement of ineffective signs can be scheduled and the inventory can be updated through an SMS using work orders.

- Certain sign materials especially aluminum substrate and metal supports can be recycled and used for future sign requirements.

These sign activities, some of which will be discussed in detail in this guide, can be effectively coordinated using a computer and a series of interrelated software program modules.

SIGN INVENTORY[4]

Part and parcel of a sign management system is a sign inventory. One has to know what one has in order to manage it effectively. This general axiom applies especially to highway signing. While it is beneficial to know what the agencies inventory of signs and/or sign material is in the sign shop, it is highly desirable to know what is out on the road.

[4] This section, except for minor editing, was originally prepared by Jeff Paniati of FHWA.

is in the sign shop, it is highly desirable to know what is out on the road.

A comprehensive inventory can serve many purposes including:

- **Targeting Signs for Replacement** — tracking the installation dates of traffic signs allows the user to easily identify those signs that are most likely in need of replacement. When combined with an effective inspection program this allows the removal of signs that have reached the end of their useful life.

- **Identification of Problems** — maintaining records of maintenance activity allows the user to identify problem locations. Physical countermeasures can be utilized at high vandalism sites, while safety studies can be conducted at locations with frequent knockdowns. A well-maintained inventory is also important for identifying and quickly replacing missing signs.

- **Minimizing Tort Liability** — an inventory is an essential tool for use in tort liability cases. It can provide evidence of the existence of a particular sign at a particular location and document the inspection or maintenance activity associated with the sign. An inventory can also be an effective tool for identifying non-conforming signs as standards are changed. Some insurers have recognized the value of sign inventories in reducing liability. For example, the Utah Risk Management Association offers a 3 percent discount on insurance premiums to jurisdictions with a sign inventory.[5]

- **Planning and Budgeting for Sign Replacement** — knowledge of the numbers and ages of signs allows the manager to establish a regular program of sign replacement. This can include identification of signs to be replaced, estimation of material quantities, routing and scheduling of replacements, etc. The inventory allows the manager to make informed decisions and to allocate limited resources in a cost-effective manner.

- **Maximizing Productivity** — combining work orders with a sign inventory allows the manager to monitor the productivity of signing activities and to effectively schedule both emergency and regular maintenance activities.

If the inventory is to be successful in providing these functions and meeting the needs of the user, then it must be well designed. The following is a seven-step process for the planning and development of an effective sign inventory.

Step 1: Involving Key Personnel

The development and maintenance of an effective sign inventory is a significant undertaking. It can involve a substantial investment on the part of the jurisdiction. Reaping the benefits of this investment requires the commitment and participation of individual responsible for:

- Collecting Data
- Entering Data
- Installing Signs
- Maintaining Signs
- Inspecting Signs
- Using the Inventory

The success or failure of the inventory depends on the communication between the personnel involved more than any other aspect. The best planned system, using the latest in computer hardware and software will not be successful if those responsible for collecting and maintaining the data do not see the value of the sign inventory. It is essential that individuals responsible from each of the areas listed above actively participate in the planning, development and implementation of the inventory. In small jurisdictions this may involve only a few individuals, in larger jurisdictions it may require a steering committee with representatives from each area. Regardless of the size of the group, they should be consulted throughout the process and their input used to guide the development and refinement of the inventory.

Step 2: Selecting a Location Reference System

The establishment of the location reference system provides the foundation on which the inventory will be built. In many jurisdictions, one or more location reference systems may already exist. If a standard location reference system has been established for the jurisdiction, then clearly the sign inventory should utilize this same system. Use of a common location reference system brings about many efficiencies (utilization of measurement tools, training of personnel, linking of data bases, etc.) and is highly desirable. If multiple reference systems exist or in the absence of any established location reference system, the user group must select the system that will be most effective in meeting the needs for signing. Alternative location reference systems include:

- **Route/Milepost/Distance** — this system is primarily used by larger jurisdictions that have physical markers at regular intervals [usually 1-mi (1.61-km) spacing] along the roadway. Signs are located by the distance from the nearest milepost. Distances are recorded as positive if they are in the direction of increasing mileposts and negative if in the direction of decreasing mileposts. A variation on this approach is the reference post system. With this approach sequentially numbered reference posts are placed at irregular intervals along the roadway. Signs are located by the distance plus or minus from the nearest reference post. The advantage of the reference post approach occurs when alignment changes are made to the roadway. With the milepost system all of the markers and data along the route within and after the change must be reassigned. With the reference post system only data within the changed section is affected.

- **Route/Milepoint** — with this system signs are located at a milepoint (normally specified to the hundreds or thousandths of a mile) along a route. This system may be used with or without markers on major physical features such as bridges. Where physical markers do not exist, roadway features such as intersections, bridges, etc. are given a milepoint (and milepoint maps, straight-line diagrams, or listings of roadway features and their milepoints are used for reference). This system is the most common for rural locations. Use of vehicle-mounted electronic distance measurement devices can significantly increase the quality and efficiency of measuring distances in the field.

- **Link/Node/Distance** — with this system, intersections (and often other physical features) are given node numbers and the roadway sections between the nodes are designated as links. Links are numbered using the node numbers at either end of the link. For example, the link between nodes 1 and 2 would be known as link 1-2 if you were traveling from node 1 to node 2, and link 2-1 if your were traveling from node 2 to node 1. Signs are located by a distance (either in miles or feet) from the beginning of the link. Reference point and control section systems are variations of the link/node approach. With these systems, roadway sections are numbered (similar to links) and signs are located by a distance from the beginning of the control section or from the last reference point. As with the milepoint system, maps or listings are used in the field for reference. The advantage of the link/node system (and the reference point and control section systems) is similar to that for the reference post method. If construction is done lengthening or shortening a route, only the affected links have to be changed, not the entire route. One disadvantage of this system is that the link and node numbers by themselves are meaningless to the field user and must be tied back to a route name.

- **Route/Intersection/Direction/Distance** — with this system, signs are tied to specific intersections and are located by their distance away from the intersection in a particular cardinal direction. This system is typically used in urban areas with closely spaced intersections. In rural areas with long distances between intersections this system is very inefficient due to the need to find an intersection to use as a reference. To be effective, this system requires that consistent cardinal directions be established for each intersection. Without this consistency, one user may identify a particular leg of the intersection as west, while another would call it northwest or southwest. A variation of this system is to locate signs by their distance from one intersection toward another intersection (sometimes referred to as the "from/to" or " A street/B street" method). For example, a sign might be located on Main Street, 50 ft (15.2 km) from the intersection with Elm Street toward the intersection of Maple Street. A disadvantage of either approach is the need for a map to identify adjacent intersections.

- **Latitude/Longitude** — with the advent of Geographic Information Systems (GIS) for the integration and display of data and the Global Positioning System (GPS) for the location of data, latitude/longitude coordinates have become another option for establishing sign locations. With a hand-held GPS receiver (or a GPS card in a portable computer) the user can obtain latitude and longitude coordinates for a location on the ground. While GPS is not affected by cloud cover or electrical interference, it can be blocked by tall buildings in urban areas or tree cover in rural areas. Effective use of GPS data also requires the availability of GIS base-maps on which to display the data and relate the data to other reference systems that can be used to locate signs in the field. GPS and GIS applications are still in their infancy in the highway community, but if well-developed they clearly offer the potential to significantly increase the accuracy and efficiency of locating and displaying sign data.

More detail on location reference systems can be found in a National Cooperative Highway Research Program synthesis study on highway location reference systems.[(6)]

In addition to the longitudinal location reference systems described above, the user must decide whether to reference individual signs or sign supports. Some inventories treat each sign as a unique record while others use the sign support as the basic record and then reference signs to the support (a one support to many signs relationship). Both systems have their advantages and disadvantages.

The referencing of individual signs is the most commonly used approach. This is especially true in smaller jurisdictions with relatively few supports with multiple signs mountings. The selection of the sign support as a referencing method may be advantageous for jurisdictions with a large number of supports with multiple signs. It eliminates some of the data redundancy by requiring the user to only enter the support information one time and then referencing a number of signs to that support. It does require the development of a system for identifying the sign location on the support (often a sequential numbering system starting from the top left and proceeding clockwise is used).

The selection of the longitudinal and sign reference systems should be made in conjunction with the selection of the inventory software (see Step 4), since many off-the-shelf software programs will support only one (or a limited number) of these reference systems.

Step 3: Choosing Data Elements

Having selected a location reference system, the next step in the process is to determine what data elements will be collected. There are a wide range of data elements that can be collected and used in the management of signs. Each individual user must weight the usefulness of the data versus the costs required to maintain the data. The major expenses of data collection are often associated with the travel time required to get to the signs in the field and the costs required to make field measurements. Once in the field the incremental cost of collecting additional data elements is relatively small. For most data elements, the decision whether or not to collect the data will be based on the usefulness of the data for managing the inventory and the ability of the agency to maintain the data.

The following listings provide the data elements that should be considered when developing an inventory. The data elements have been categorized into three groups based on the importance of the elements: core, critical, and desirable. They are described below.

Core Elements — these data elements are essential for effective sign management and should be included in every inventory. An inventory containing these elements will provide information on the location of signs, their condition, and any maintenance activity that has been conducted. This will allow for a basic inventory that can identify signs needing replacement, be used for tort liability defense and provide some limited management and budgeting capability. Table 11 provides a listing of the core data elements.

Critical Elements — these data elements significantly increase the value of the sign inventory and should be given serious consideration. The addition of details of the installation date and the characteristics of the sign and supports provide a much greater ability to target signs for replacement and develop cost-effective sign replacement plans and budgets. Table 12 provides a listing of the critical data elements.

Desirable Elements — these data elements may add value to the inventory depending on the needs of the individual user. They provide more detail on the sign installation. Table 13 provides a listing of the desirable data elements.

The user group identified in Step 1 should be used as a resource in selecting the desired data elements. The selection process should not be comprised by the data elements that users "want," but rather the data elements they "need." Surveying users wants can result in unrealistic "wish lists" of data elements. It is important that the final selection only include those elements that will serve a well-defined need and for which there is a commitment to maintain.

Table 11. Core data elements.

DATA ELEMENT	DESCRIPTION
Location	Includes several variables (such as route name, distance, etc.) depending on the location reference system that is selected.
Position	Location of the sign relative to the road (e.g. left, right, overhead, median).
Sign Code	Usually based on the MUTCD designations, may be supplemented or modified based on State or local sign designations.
Sign Condition	An assessment of the quality of the sign based on daytime and nighttime visual inspections.
Maintenance Activity	Maintenance activity associated with a particular sign.
Inspection/Maintenance Date	Date when the sign was inspected or maintained.

Table 12. Critical data elements.

DATA ELEMENT	DESCRIPTION
Installation Date	Date when the sign face was installed.
Sign Size	The width and height of the sign.
Sheeting Type	Grade of retroreflective sheeting.
Backing Type	Type of sign blank material.
Post/Support Type	Type of sign support used, may include breakaway characteristics.
Post/Support Condition	An assessment of the quality of the sign support.
Sign Orientation	Cardinal direction the sign is facing.
Traffic Speed	Speed limit on the roadway where the sign is located.

Table 13. Desirable data elements.

DATA ELEMENT	DESCRIPTION
Offset	Distance from the edge of pavement.
Height	Height of sign above the level of the road at the edge of the pavement.
Retroreflectivity	Objective measure of the nighttime quality of the sign.
Inspector	Name or initials of the individual who inspected or maintained the sign.
Sign Identification Number	A unique number identifying the sign.
Images	Visual images of the sign, either digitally captured or linked to a videodisc-based photolog.
Comments	Supplementary notes about the sign installation.
Other Reference Numbers	Could include maintenance district, plan or contract numbers, etc.

Step 4: Selecting Inventory Software

In the past, small jurisdictions used paper-based methods for maintaining sign inventories, while large jurisdictions that could afford computer systems had to resort to mainframe-based applications. Neither was very effective in meeting user needs. Paper-based systems were difficult to maintain and severely limited access to the data. While some excellent mainframe computer-based systems were developed, the majority were expensive to maintain, not user-friendly, and required sophisticated programming to make any changes to the system. The introduction of the microcomputer opened up a whole new range of options for developing inventories. The cost of hardware dropped dramatically and a range of software approaches including spreadsheet and data base software packages could be used to develop inventory systems.

Today, even the smallest of jurisdictions have access to microcomputer hardware and a wide range of public and private domain off-the-shelf software packages have become available to the user. The options include:

- **Customized Programs** — If a primary objective is to have a system that exactly matches the user's needs, then a customized sign inventory software application may be appropriate. As more and more jurisdictions move toward Geographic Information Systems, the sign inventory may be just one of a series of data management applications that are developed. If experienced software development capabilities are not available in-house they can be contracted for. While this approach allows the software to be tailored to fit the jurisdiction's needs, it often comes at a significant cost. These costs include initial development of the software and ongoing maintenance and support. For most smaller jurisdictions, the costs of this approach are prohibitive. For State highway departments, customized programs likely will be required due to the need to integrate the sign management system with other information systems and to the large number of potential users at both control and district levels.

- **Off-the-Shelf Software** — For users with limited budgets or those who are willing to be more flexible, a number of off-the-shelf packages have been developed in recent years. These include both public domain software available from local technology transfer centers, and the MCTRANS and PCTRANS transportation software clearinghouses at very nominal costs. These public domain packages range from rudimentary to very sophisticated. Similarly, there is a wide range of proprietary software packages available. These packages can be found in both MCTRANS and PCTRANS and through advertisements in magazines such as the *ITE Journal*. Costs for these software packages range from several hundred dollars into the thousands of dollars. For additional fees, some of the vendors will make minor changes to customize the software to better match the needs of an individual jurisdiction. While most of the software packages available were developed strictly for sign inventories, several larger packages that include additional modules for the management of markings, lighting, traffic signals, etc. are available as well.

  While there are many more off-the-shelf products available that could be discussed here, some offer unique capabilities. One of these is the FHWA Sign Management System which includes sign deterioration models that predict when a sign is likely to need replacement. These models allow the user to estimate future budget requirements for sign replacement. Appendix A provides a summary description of the SMS program, which is fully explained in the User's Guide.[7] Figure 5 shows the data elements, the predicted R_A value and the estimated replacement data for a typical sign.

At least one commercial program offers the capability to record and store digitized color images of the sign as illustrated in figure 6. While the hardware necessary to collect the data and store the images is significantly more expensive than most inventory systems, the availability of the image can be advantageous especially for unique message signs such as guide signs.

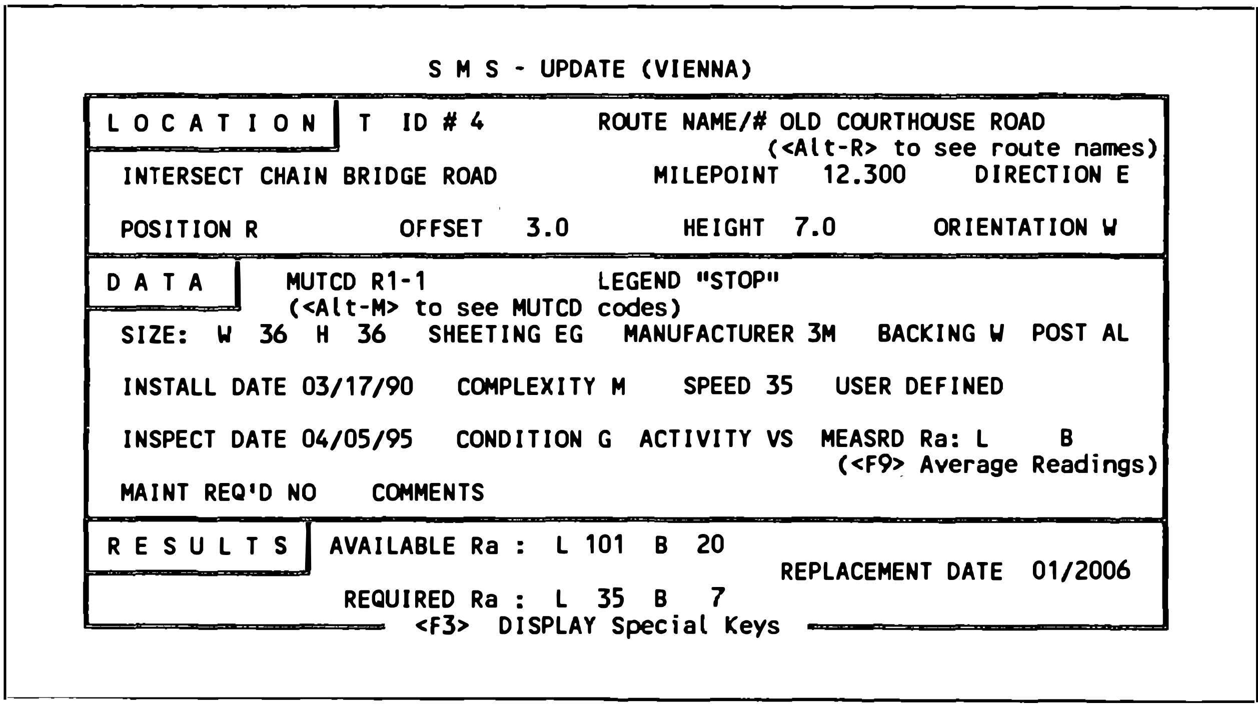

Figure 5. FHWA sign management system.

- **Turn-Key Systems** — A third option that is available, are turn-key systems, There are a number of consultants who have developed sign inventory software packages, that market the software along with their data collection services. These firms are skilled in data collection and for a fee (either a flat fee or a per sign cost) will collect the data and provide the user with a complete operational inventory that includes both the software and the inventory data. Firms offering such services can be found through advertisements in magazines such as the *ITE Journal*. This type of approach can be useful for jurisdictions with limited manpower to collect the initial inventory data.

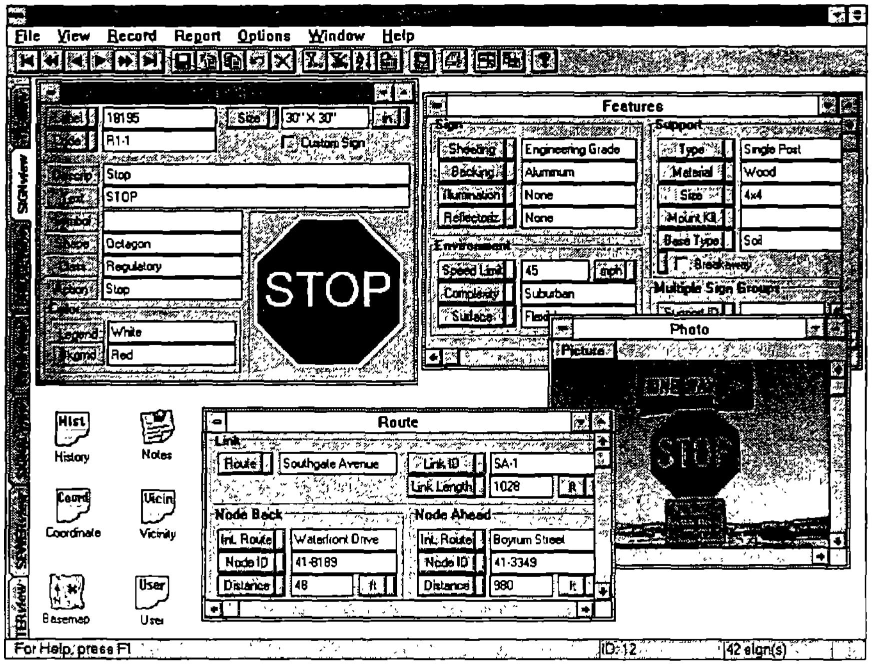

Figure 6. Example of an inventory program that includes sign picture.

Step 5: Preparing for Data Collection

Having selected a location reference system, defined the data elements to be collected, and selected a software package, the inventory administrator must now make the final preparations for the actual data collection. This preparation is a two-part process. The first part involves establishing definitions, conventions, etc. Some of the issues that should be addressed prior to beginning full-scale data collection are:

- **Route Names/Numbers** — The inventory administrator must select a standard approach to naming routes. Will route names or numbers be used? For routes with multiple names, which name will be selected. It is important to define the route names initially to avoid multiple names for the same route. Software that includes look-up tables for route names can assist in this process. If this capability does not exist in the software, then a standard route name list should be developed.

- **Ramps/Service Roads** — Larger jurisdictions with grade-separated interchanges will have signs on ramps, unnamed service roads, or rest areas. A naming convention must be developed for these sections of road so that the signs can be properly located. One approach that can be used is to assign them names or numbers based on their location relative to the mainline of the roadway. For example, ramps may be designated by the milepost of the interchange and sequentially numbered.

- **What signs to include?** — Will the inventory include just regulatory and warning signs or will it also include street name signs, parking signs, post-mounted delineators, etc.?

- **Whose sign is it?** — Often the development of a sign inventory forces jurisdictions to determine who is responsible for signs at jurisdictional boundaries. The most frequent point of confusion are signs at intersections of routes maintained by two different jurisdictions. The inventory administrator should determine if an agency policy exists. If not, one should be defined.

For most of these issues there is no right or wrong answer. The important thing is that a consistent policy be established, recorded, and communicated to all users.

The second part of the preparation process is training of the data collectors, which is key to the success of the collection effort. This training should include not only the individuals who will be building the inventory, but also those who will be responsible for maintaining the data. The policies established in the first part of the preparation will from the core of this training. In addition, the inventory administrator may need to develop data collection forms and instructions, inspection guides, etc.

Step 6: Initial Data Collection

The initial data collection effort to establish a sign inventory requires a significant effort. Many jurisdictions will not be in a position to hire an outside consultant or devote a large amount of staff to collect the data in a short period of time. Normally, the initial data collection will be conducted over a period of months or even several years. As a result, it is critical that the data collection be organized in a way to allow a subset of the inventory to become operational as quickly as possible. The type of subset selected depends on the jurisdiction, but could involve breaking up the inventory by roadway class (Interstates, U.S. routes, State routes, local routes, etc.), by townships, by maintenance districts, or by sign types (regulatory, warning, street name, parking). Another option is to quickly collect a few core and critical data elements (location, sign type, condition, etc.) and gradually collect other data elements as time allows. The key is to pick a cohesive group that will result in a useful inventory.

The benefit of this approach is that it will quickly produce a working inventory that can be used and maintained. This allows the agency to begin accruing the benefits from the inventory and demonstrating its usefulness. This can be important in obtaining continued support for the full development. Starting with a small piece of the entire system also allows the inventory collection and management procedures to be tested and refined.

Three basic methods are available for collecting sign inventory data:

1) **Manual Field Data Collection** — Manual field data collection is the most widely used method to gather the initial data for a sign inventory. Using this approach one or more persons equipped with data entry forms and measurement tools collect the data. Depending on the location reference system and the size of the jurisdiction, various methods can be used to establish the location of the sign. These methods range from the use of a measuring wheel to a vehicle-mounted distance measuring device to a hand-held GPS receiver. Establishing the location of the sign is often the most difficult and time consuming part of the data collection. One recent study, found that use of GPS receivers for obtaining location reference information for urban signs was approximately 20 percent faster than data collected manually using traditional measurement techniques.[9]

   Once the location is established, a combination of visual observations and measurements are used to gather the inventory information. The amount of time required for this task will be dependent on the data elements selected for inclusion in the inventory. The manual approach is labor intensive, but relatively simple. With minimal training and a well designed data collection form, the data can be quickly gathered in the field and entered into the computer system back at the office.

2) **Microcomputer-Based Field Data Collection** — With the decrease in the cost, size, and weight of portable microcomputers, direct entry of field data is now a viable option. Many jurisdictions and sign inventory consultants now use this approach. The location of the sign may be established as with the manual approach described above or may be recorded directly into the computer. Distance-measuring devices and GPS receivers that can be integrated into the computer allow the data to be stored directly into the sign record eliminating data entry errors and reducing data entry time. Other sign inventory data can be keyed directly into the computer, eliminating the need for data reduction back at the office.

   Another recent advance in the microcomputer area has been the development of pen-based computers. These computers allow the user to enter data by touching the screen with a pen. This can speed the data entry process by minimizing or eliminating keyboard entry. This technology is being widely investigated for a variety of transportation-related applications including maintenance management, accident data collection, etc. This approach was successfully used in the development of a sign inventory for the New Jersey Department of Transportation. This inventory covers 16,000 mi (25,744 km) of roadway and includes over 150,000 signs.[10]

   More details on emerging technologies for data acquisition can be found in recent reports by the Federal Highway Administration and the Transportation Research Board.[11,12]

3). **Photologs/Videolog-Assisted Data Collection** — If available, photologs or videologs can be used as a starting point for the sign inventory. Photologs consist of sequential images of the highway taken from an instrumented vehicle. Traditionally, photologs are taken using a 35-mm motion picture camera modified to take individual frames of film at preset distances (normally one picture every 59 ft [18 m] or every 26.2 ft [8 m]). Videologging is similar to photologging, however, continuous images of the roadway are taken instead of individual pictures at preset distances. In recent years jurisdictions have begun to use videodisc-based photolog systems instead of the traditional film-based systems. In this system, the film images are transferred to videodisc or a shuttered video camera is used to record directly to the videodisc. Videodisc-based systems offer the advantage of reduced storage costs and increased accessibility.

Using this technique basic information such as the location of the sign, sign type, support type, etc. can be gathered through visual observation of the photolog images in the office. The collection of measurements such as the offset, height and size of the sign can be estimated by overlaying a grid on the screen. Precise measurement of these elements and determination of the elements such as the sheeting type or backing type must be made in the field, however.

An important issue that must be addressed when using this approach is the ability to read the legend on the photolog image. The Connecticut DOT (ConnDOT) recently completed a pilot study to develop a videodisc-based inventory system.(13) One of the problems they encountered was the ability to read the sign legend on the photolog image. In this effort they found that 45 to 70 percent of the signs, depending on sign location, were not legible using normal inventory images taken every 59 ft (18 m). However, using a second, close-up image of the right side of the roadway, they were able to increase the legibility to approximately 90 percent.

The data collection costs for the inventory will vary depending on the data collection approach used and the number and type of data elements collected. ConnDOT estimates that the costs of developing a base inventory for the estimated 170,000 signs on the 8,000 mi (12,872 km) of State system using a manual field data collection method would be approximately $163 per mile ($100 per km) or $7.65 per sign. Using the videodisc-based inventory, supplemented with field data collection, ConnDOT estimates their collection costs at $58 per mile ($35.90 per km) or $2.72 per sign. Based on the estimated costs for alternative road inventory procedures from earlier work by Datta and Herf and cost information provided by various jurisdictions, it is estimated that the cost of manual data collection ranges from $4 to $9 per sign, microcomputer-based data collection from $3 to $7 per sign, and photolog-assisted data collection from $2 to $5 per sign depending on the data elements collected, size of the inventory, etc.(14,13,15,16)

Step 7: Maintaining the Inventory

As is evident from the previous discussion of costs, the development of a sign inventory is a significant investment. This investment can easily be wasted if the groundwork for maintaining the inventory has not been laid early on in the development of the inventory. The inventory administrator must identify all installation and maintenance activities (including those done under contract by private forces) that affect the data elements selected in Step 4 and develop a process for ensuring that these activities are reflected in the inventory.

Since most jurisdictions already have some work order system in place for assigning work and accounting for labor and materials, integration of the collection of the necessary sign inventory data with the work order is usually the most effective approach. Depending on the data elements selected and the information already being collected as part of the work order, only minor modifications to the form itself may be necessary. The National Cooperative Highway Research Program Synthesis "Maintenance Management of Street and Highway Signs" contains several examples of work order forms.[17]

As critical as the design of the form, is the timely processing of the data collected. In developing the process for maintaining the inventory, a defined sequence should be identified for routing copies of the completed work orders to the individual responsible for data entry. While in small jurisdictions, this person may have numerous other responsibilities, time must be set aside to allow regular data entry. If changes to the system are not entered in a timely manner, the inventory can become out of date and unreliable as a daily working tool. Users will quickly lose faith in the system if this is allowed to happen.

As with the initial data collection, microcomputer-based data collection can be used to directly record the data in the field. The field data can then be uploaded to the complete inventory, in the office, at the end of the day. This eliminates the need for data entry and puts the inventory, out in the field, in the hands of the end-user. If this approach is used, it is important that the software include good edit checking to spot data entry errors and regular quality control checks by the inventory administrator to ensure accurate data is being entered.

SIGN INSPECTION

The routine inspection of traffic signs to ensure their effectiveness is a critical component of a comprehensive sign management system. Periodic inspection of signs should be a standard operating procedure of the agency responsible for motorist safety. Signs can be deficient in any number of ways; hence, items that should be checked include:

- Condition of sign face — indications of major cracking, delamination or peeling or blistering of the retroreflective sheeting materials, missing message, etc.

- Discoloration, streaking, or fading of the sign face.

- Visibility of the sign — roadside vegetation or a new structure may be blocking the motorists' view of the sign.

- Dirt or other substance on the sign.

- Vandalism.

- Orientation and structural stability of the sign support system.

- Usefulness or appropriateness — some signs may no longer be needed and should be removed.

- Poor retroreflectivity level.

To detect and then resolve any and all of these deficiencies, a comprehensive sign inspection program is required. This would include formal scheduled inspections by trained sign crews and even staff engineers as well as informal observations by personnel of various agencies including the highway and police department and even postal carriers or other public agencies that travel the routes frequently. The department responsible for signing should solicit the assistance of all appropriate departments and establish a procedure for receiving notices of a potential signing problem.

Most of the problems listed above can be identified by a visual inspection during the day by trained personnel. If the personnel are adequately trained and sensitive to observing these deficiencies, problems can be identified on a daily basis as they travel along the routes. However, it will still be necessary to conduct a formal inspection at least annually. Programs and procedures for conducting sign inspections can be found in "Maintenance Management of Street and Highway Signs" and in the Institute of Transportation Engineers' publication *Traffic Sign Handbook*.(17,18) This guide will focus on the methods for inspecting for retroreflectivity condition.

One of the deficiencies which can not be detected by a daytime visual inspection is the sign's level of retroreflectivity. Over time all signs will experience diminishing retroreflectivity levels. This deterioration will result from the ultraviolet portion of sunlight, moisture, high daytime/low nighttime temperature cycling, pollutants, and even chemical reactions between the sheeting and the substrate (i.e. aluminum panel). Also, loss of retroreflectivity can occur from vandalism (i.e. gun shots, spray paints, etc.).

Inspection for loss of retroreflectivity can range in sophistication and involve either subjective visual inspections or instrument inspections. The selection among the alternatives is dependent upon the resources (funds, personnel and equipment) of the agency. The location (overhead vs. ground mounted), number of signs, and other logistical factors may also influence the inspection method.

Visual Inspection Methods

There are a number of alternative visual inspection procedures that can be employed to determine if a sign has lost its effective luminance and may be near or below the minimum maintained R_A values. The most simple is to drive along at night and observe for obviously deficient retroreflective signs. This procedure can be very efficient if the inspector is experienced enough to know when a sign is ineffective and specifically when it is at or below the minimum R_A values. Research conducted for the State of Washington has demonstrated that inspectors can be trained to visually detect signs within certain levels of retroreflectivity.(19)

The key to relying purely on a subjective visual assessment is to select the most appropriate inspectors and train them to relate a visual assessment of luminance to an actual R_A value. If possible, the inspector(s) should be older than 50 because research has shown that older drivers have impaired nighttime vision and require brighter signs. Training of new inspectors would involve having them view signs of different colors at various levels of retroreflectivity. To do this, the agency should keep a supply of signs at the maintenance yard for this purpose. Even after suitable training, it is a good idea that each inspector view the test signs, especially those at or near the minimum values, just before the night inspection run.

As an aid to this visual inspection, a sign inspection pamphlet has been published by FHWA.(22) The pamphlet includes night photographs of signs at different levels of retroreflectivity. While photographic images are not totally reliable and do not replicate exactly what a person sees, they can provide the inspector another aid in judging the retroreflectivity adequacy.

Another aid to the visual inspection procedure is to use a test panel — a small (no greater than 12 in [0.3 m] square) panel of sheeting that has a retroreflectivity level equal to (or nearly so) the minimum value for that color. The test panel can be attached to the "questionable" sign using either masking tape or a clamp. Stepping back about 30 ft (9.1 m), the observer should hold a flashlight about 2 in (50.8 mm) from his/her eyes and shine it at the sign. If the inspection guide is brighter than the sign, the sign should be replaced.

Nighttime inspection is often not feasible for administrative reasons; for example, the inability to pay overtime if that would be necessary. If this is the case a daytime visual inspection procedure using a hand-held high-intensity light beam may be used. When a high-intensity q-beam of about 200,000 candlepower is flickered across the face of a sign during the day, it will show a "glow" of returned light if the retroreflectivity level is still adequate. The effectiveness of this procedure is affected by the ambient light conditions and, therefore, is not very precise. However, with some training an inspector can detect obviously inferior and failing signs with this method. The Mississippi Department of Transportation has used this inspection method for a number of years; their traffic engineering department can provide guidance on how to perform this procedure.

Inspection by R_A Measurement

The best method to determine if a sign has reached its minimum R_A level is to measure the signs retroreflectivity in the field. This can be accomplished by using a commercially available retroreflectometer, such as manufactured by Advanced RetroTechnology, Inc. Figure 7 shows an inspection being performed using their Model 920 Field Retroreflectometer and figure 8 shows the apparatus in more detail. (As this document was being completed Flint Trading, Inc. announced the availability of another hand-held retroreflectometer know as the Retro Sign®. Information was not available on this product.) This device can be used during the daytime. However, as is evident from figure 7, it requires that the inspector be at the sign to make the measurement.

The retroreflectometer will come with instructions on how to use the instrument. In addition to those instructions, the following is recommended:

1) Make sure the instrument is properly calibrated as found in the instructions; a faulty reading will occur if this is not done.

2) Take a reading from at least four areas of each color, which can then be averaged for recording purposes. Black areas do not require measurements because they are not intended to be retroreflective.

3) An extension pole can be purchased which will allow access to nearly all roadside mounted signs. A bucket truck will be required for overhead signs.

4) Follow standard traffic control procedures for maintenance activities prescribed by your agency and as found in Part VI of the MUTCD.

Figure 7. Sign inspection using model 920 retroreflectometer.


Figure 8. Components of the model 920 retroreflectometer.

Measurements using a retroreflectometer will take considerable time and therefore, it is not necessary that every sign be measured each inspection period. Measurements could be limited to those signs that were identified during a nighttime visual inspection or the daytime inspection with the q-beam. Also, if the inventory system has the capability similar to that of the FHWA's SMS program, it could be limited to signs that have been identified as requiring inspection by the program.

It would be highly desirable to be able to measure the retroreflectivity level of a sign during the day from a moving vehicle. Such a device has already been developed. Initially developed under a contract with the National Cooperative Highway Research Program, a second generation has been developed by the FHWA. Figures 9 and 10 are inside- and outside-vehicle photographs of the system which has been named the Sign Management and Retroreflectivity Tracking System (SMARTS). While the vehicle is moving the operator aims the tracking/video system at the desired sign. The system will automatically track the sign and at 200 ft (61 m) will flash the sign with a powerful flash tube. The recording system captures the retroreflectivity levels of all colors within the image and a picture of the sign (image). This information along with the GPS coordinates the other data associated with the sign and are stored in the systems data base. This data can be used to evaluate the quality of the sign and can be used for establishing and modifying the sign inventory data base. When fully developed a mobile system will allow periodic inspection of retroreflectivity levels of all traffic signs to be performed fairly efficiently. However, since the apparatus is likely to be expensive, approximately $100,000, it is likely that only a few local agencies, outside the State highway department, could afford to have their own. It is much more likely that either private enterprise will purchase these and provide the inspection service on a per distance or per sign basis or that the State highway department will "loan" the apparatus to the various local agencies.

SIGN MAINTENANCE

In the context of a sign management system, sign maintenance involves all activities, short of replacing a worn-out sign, that keep the sign effective. Typically these activities could involve:

1) Cleaning of the sign face due to normal dirt accumulation.

2) Removal of spray paint and other markings from vandalism.

3) Maintaining adequate visibility to the sign by cutting back or removing foliage.

4) Reorientation of the sign.

5) Replacement of the sign post damaged by a knock down.

Figure 9. Exterior view of FHWA's SMARTS.

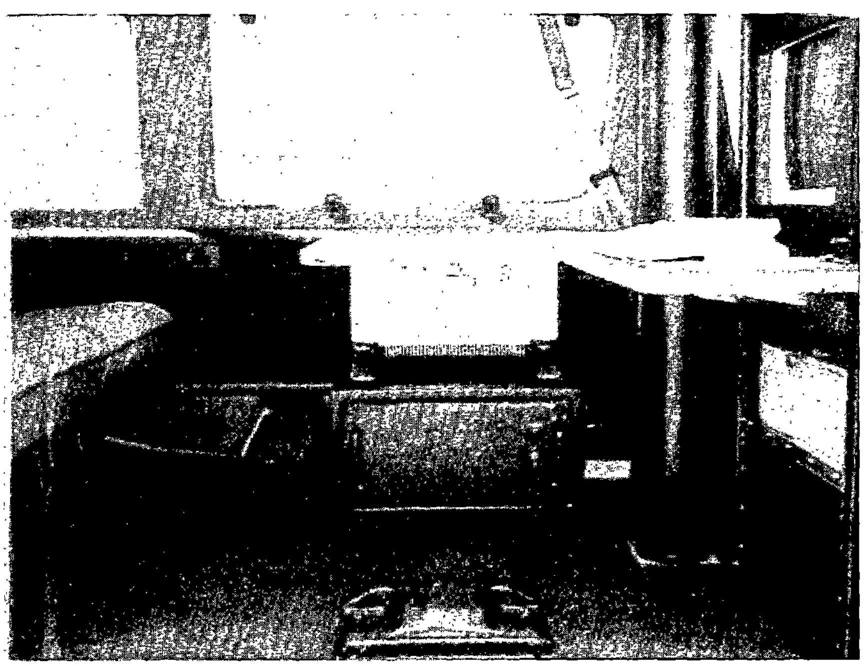

Figure 10. Interior view of FHWA's SMARTS.

With regard to sign cleaning, most agencies, State and local, do not, as a standard practice, clean their signs on a regular schedule, annual or otherwise. In most cases, the "washing" of the sign by normal rain will remove most accumulation of residue from various sources. At least one State agency that evaluated this practice determined that while some signs benefitted from washing, in general it was not worthwhile to do so.[17] However, there are many instances and situations where periodic washing is necessary to ensure that the normal life of the sign is attained. Signs that are vulnerable to excessive residue build-up that may not be washed away by rain include:

- Signs on heavily traveled truck routes especially at locations where trucks must stop. Over time the diesel fumes will significantly discolor the sign and render it ineffective.

- Signs directly under certain trees which exude resins. Signs placed under the canopy of trees such as oaks and pines are often discolored from this phenomenon. The discoloration is not easily removed by normal rainfall.

- Geographic areas with little annual rainfall.

- Signs within tunnels and under structures.

The effect that washing will have on an individual sign will likely vary by its age, type of material, and the environmental conditions. For a study on the retroreflectivity service life of signs conducted for the FHWA in 1991, the researchers found that washing signs increased the R_A value by an average of nearly 12 percent for engineering grade (Type I) sheeting (sample size of 336 signs of varying years of exposure and varying geographical locations) and nearly 8 percent for high intensity grade (Type III and IV) sheetings (sample size of 251 signs).[18] The newer encapsulated sheeting materials are apparently less affected by dirt accumulation.

Before replacing a sign, the agency may want to consider washing the sign. However, this extra maintenance activity may not be worth the additional effort, unless it is obvious that the sign has a significant dirt accumulation which is masking its retroreflectivity condition.

The washing of signs can be accomplished by using either a high pressure sprayer mounted on the back of a truck or by a standard cloth or squeegee attached to a long pole. Just water or a mild detergent is usually sufficient to remove most dirt buildup. However, it is best to consult with the supplier or manufacturer of the material, especially if a warranty is being provided.

The retroreflectivity of signs that have been vandalized by spray painting will certainly be adversely affected. Some manufacturers claim to provide retroreflective sheeting materials for which spray painting can easily be removed with normal washing.

Maintaining unobstructed line of sight to the sign is extremely important. Vegetation of all types can quickly block the motorists' view of the sign, making it ineffective both day and night. In areas where this is a problem, agencies should have a routine maintenance program whereby vegetation is cut back or removed as appropriate.

It is a good idea that a record of any and all of these maintenance activities be kept. Many of the computer inventory programs have the capability of recording the date and type of maintenance activity performed for each sign and keeping an historical record.

Additional information and procedural guidance for all aspects of sign maintenance can be found in Maintenance Management of Street and Highway Signs.[16]

SIGN REPLACEMENT OPTIONS FOR MEETING MINIMUM RETROREFLECTIVITY LEVELS

As noted earlier in this guide, minimum R_A values have been established for four groups of signs. These guidelines should be considered as values that marginally meet the retroreflectivity needs of most drivers. In many situations, and for some drivers especially those who have diminished night acuity, significantly brighter signs are needed. However; nor does it mean that if the R_A is just slightly lower than the minimum that it is totally ineffective. However, the minimum values do indicate the sign should be replaced soon.

All agencies have a limited maintenance budget, and therefore, must have a cost-efficient sign replacement program. To replace signs much sooner than when they reach their minimum R_A value will have the benefit of providing brighter signs to motorist, but it will likely increase the agency's cost for signing. On the other hand, replacing signs after they have reached their minimum R_A value may have several repercussions, including:

- Increased nighttime accidents due to deficient retroreflectivity levels.
- Increased motorist delay due to motorists not seeing or being able to read guide signs and thereby missing a turn.
- Increase motorist irritation due to their inability to read signs at night.
- Increased potential for tort claims because the sign's low R_A is considered a factor in an accident.

The last issue will have a direct negative financial impact on the agency. One large monetary judgement against the agency can far outweigh the agency's budget for sign maintenance.

It would seem, then, that the goal for an agency is to have a sign replacement program that *cost-effectively* identifies and replaces those signs that are approaching or at the minimum R_A requirements. This can be accomplished through a sign management system with varying levels of sophistication commensurate with the agency's sign budget.

Table 14 shows four options that an agency can follow to ensure that its signs will meet the minimum R_A requirements. The table also shows, in the middle column, the key components of a sign management system that will be required, and in the third column appropriate comments are provided. It is emphasized that these replacement options consider only the retroreflectivity condition of the sign. However, signs will need to be replaced due to the other observed deficiencies mentioned earlier. These replacement options are discussed below.

Table 14. Sign replacement options[1]

OPTION	SMS REQUIREMENTS	COMMENT
1. Visual Assessment Only	* Nighttime Inspection * Minimum R_A Reference Sign or Panel * With or Without Inventory * No Special Equipment	- Marginally Acceptable - May Err - May Not Be Cost-Effective
2. Maximum Sign Life	* Sign Dating * Inventory w/Date of Installation * Relationship of Sign Life to R_A Value * No Special Equipment	- Acceptable - Eliminates Night Inspections - May Err - May Not Be Cost-Effective
3. Maximum Sign Life with Visual Assessment Verification	* Same as # 2 * Additional Nighttime Inspection	- Acceptable - Will Increase Cost Inspection - May be More Cost-Effective than # 2
3. Measured R_A Compared to Required R_A	* Inventory * Sign Dating * Reflectometer	- Desirable - Higher Inspection Cost - Highest Assurance that Signs Replaced when Required - Maximum Life of Sign

[1]Based on Retroreflectivity condition only.

1. Replace Based on Visual Assessment

The simplest, but less precise, method for replacing signs due to their low retroreflectivity level is to identify such signs through a visual nighttime inspection. The procedures for conducting such an inspection were discussed previously. This method is described as less precise, because without the use of a retroreflectivity measuring device, or at least a minimum R_A reference panel, the decision to replace will be based on a subjective opinion of the inspector. To avoid the error of rating a sign satisfactory, when in fact its actual R_A is at or below the required minimum, the inspector will need to be conservative in his/her subjective rating. Without any verification by a retroreflectometer, this will result in signs being replaced before they have reached their full effective life. However, if the inspector is sufficiently trained and experienced, then the agency may feel comfortable with this method, recognizing that some signs may be replaced too soon if the inspector is conservative in his/her appraisal or some signs may remain that should be replaced based on their actual R_A value.

Although an inventory can facilitate this simple approach, an agency does not necessarily have to have an inventory. The inspection, which should be accomplished at least annually, can be scheduled by a number of criteria, for example by:

- Sign types, e.g. all STOP signs one period, all warning signs another period, etc.
- Road types, e.g. all freeways one period, all residential streets another period, etc.
- Districts, e.g. all signs on all roads in a maintenance district or area for one inspection period, etc.

The decision on scheduling and routing for the sign inspection is best determined by the agency.

2. Replace Based on Maximum Sign Life

Another option is to replace signs simply by their age. As of now there is no definitive data on the service life of various types of sign materials. The various manufacturers claim their material will last a certain number of years and some will provide a warranty for that period. However, there has yet to be a definitive study that indicates that certain materials will reach the minimum R_A value in a certain number of years. (One of the advantages of the FHWA SMS program that was discussed in this Guide is that it includes a program for monitoring the service life of different materials and establishing the expected life of a sign.)

Based on the literature it appears that the minimum service life for two major groups of signs is as follows:

- Types I and II — 7 years
- Types III and IV — 10 years.

These values or others that the agency has based on its experience could be used as a replacement threshold in lieu of the actual R_A value.

To implement this option the agency must have a sign dating program whereby each sign is marked in some way with the date the sign was installed. There are a variety of ways to mark the installation date on the sign, such as non-washable ink, embossing and even bar coding. Although as with the first option it would not be necessary to have a sign inventory, this method would be facilitated if the agency did have a sign inventory which included the date when the sign was installed. With a computerized sign inventory, which included date of installation, those signs of a certain age or greater could be identified easily by sorting through the data base.

Within this option the replacement decision would simply be the age of the sign regardless of its retroreflectivity condition. An advantage of this option is that the agency would not have to perform a periodic nighttime inspection for retroreflectivity, relying solely on the age of the sign as a indicator for replacement. However, under this option, the agency may be replacing signs too soon especially if they are using a conservative service life threshold, or conversely, may not be replacing them soon enough if the service life threshold is set too high. Over time as more data becomes available on the effective service life of signs by sheeting material type and/or manufacturer, then this may be less of an issue.

3. Replace Based on Maximum Sign Life With Visual Assessment Verification

The third option is to make a nighttime visual assessment of those signs that have reached or exceeded the maximum service life value used for option 2. Under this option signs would not be replaced until they fail the visual inspection as followed under the first option. In essence this option combines the procedures for options 1 and 2. It is more efficient than either of the two options because it limits the costly nighttime inspection to those signs which are of a certain age and it avoids replacing signs of certain age which may still be effective.

As with options 1 and 2, a computerized inventory is not necessary. However, a computerized inventory, which included the date of sign installation, would greatly facilitate this option. Signs that are a certain age or older could be sorted from the inventory and the list provided to the inspectors.

4. Replace Based on Measured R_A

The third, and most desirable, is to replace the sign when its measured R_A is at or close to the minimum required R_A. For this option it will be necessary for an agency to own or have access to a retroreflectometer, or when it becomes available, the previously discussed mobile SMARTS. Essentially, this option entails the agency to measure those signs suspected of being close to the minimum R_A values. Identification of suspected signs could be through the visual inspection process, the age of the sign, or, if the computer program being used for the inventory allows, the predicted R_A value based on a retroreflectivity deterioration model. (Currently the FHWA SMS program includes a module that predicts the retroreflectivity level, R_A, for two types of sheeting materials, Type I and IV. This prediction is based on a model developed from research and considers the sheeting color, age, and geographical and environmental factors.)[20]

Again, as with the other options, a sign inventory is not absolutely required, but it is highly desirable. If the sign inventory includes the date of installation, sheeting type, and other key parameters, then signs suspected of being close to the minimum required R_A value can be easily sorted from the data base. Sign inspectors can then be directed to those questionable signs and retroreflectivity readings can be made.

Although this option *may* increase the agency's cost for sign inspection, it should prove to be cost-effective for the overall sign program. The maximum effective service life of the sign would be realized and signs would not be replaced prematurely.

MINIMUM RETROREFLECTIVITY IMPLEMENTATION GUIDELINES

In consideration of the options discussed above, a minimum and desirable program for meeting the minimum retroreflectivity guidelines is recommended. These are discussed below.

Minimum Program

The minimum program consists of the following elements:

1. **Computerized Inventory** — Although it has been stated that it is not necessary to have a computerized inventory, the advantages are such that it is recommended for all agencies, regardless of size. Numerous computer programs exist which can be used off-the-shelf or customized programs can be developed fairly inexpensively. Computers and data base management systems are becoming commonplace and this situation should extend to sign inventory.

   The data elements should be those listed under the **core** and **critical** listing (tables 11 and 12) in the Sign Inventory section. Of particular importance is to have a sign dating program whereby the sign is dated when installed and recorded in the computer inventory.

2. **Inspection** — Inspection of signs for retroreflectivity levels should be done at least annually. (It is emphasized that signs can be deficient for reasons other than poor retroreflectivity and this can and should be identified through normal daytime inspections and maintenance programs.) This can be a simple visual nighttime

inspection. In addition, an agency may obtain a retroreflectometer that can be used either for confirming the adequacy of signs detected by the visual method, and/or just be used at the sign shop in connection in training inspectors and "calibrating" the visual inspection process. Smaller agencies can "share" a retroflectometer (it costs about $3,000) since it is not needed all the time.

Although a "through-the-window-while-driving" nighttime inspection should be performed for all signs, more time could be devoted to signs that are suspected to be deficient. A computerized inventory with sign dating will allow the identification of potentially deficient signs due to age. At these signs, the visual inspection can be augmented by measuring with the retoreflectometer.

3. **Replacement** — The replacement strategy under this program is either based on the inspector's opinion as to the condition of each sign inspected, or, if the retroreflectometer is used, the actual R_A compared to the required R_A.

Desirable Program

The most desirable program is to implement an integrated computerized sign management system. Under such a program nearly all activities related to signing would be integrated through a system of computer modules as was illustrated earlier in figure 2. The key components of the program are described below.

1. **Computerized Inventory** — A computer program would be acquired or developed that would include all the data elements described in the Inventory section. Furthermore, the program would have the capabilities of integrating several components including stockpile inventory, field inventory, inspection histories, work orders, costing and budgeting. It would also have the capability of tracking sign deterioration for the purpose of developing better predictors of sign service life for the different material types. Programs already exist, including the FHWA Sign Management System, that perform many of these functions.

2. **Inspection** — Retroreflectivity inspections would be performed during the day using a hand-held retroreflectometer or, when it becomes available, the mobile traffic sign evaluator. This measurement technique would be only for those signs that are expected to be deficient either because of age or, more preferably, because of an estimated R_A that is derived from a prediction model within the program.

3. **Replacement** — For the purpose of insufficient retroreflectivity condition, signs would be replaced only when they reach the minimum R_A required. (Agencies that prefer to establish higher standards for retroreflectivity can simply increase the minimum requirements.) This is established by comparing the measured value

obtained by either the hand-held retroreflectometer or the Traffic Sign Evaluator against the minimum R_A required for the particular sign.

There are, of course, variations or graduations within these two suggested levels of implementation guidelines. Also, there are specific procedures that each agency will want to adopt to meet their individual needs and existing maintenance procedures.

Agency Level Considerations

Initially it was assumed that the program to be followed for meeting minimum R_A requirements would vary by agency type, that is, State vs. county vs. city vs. town or township. Presumably, the larger the agency, the more sophisticated the program. However, this is not necessarily so. While the amount of funds available for the total sign program in proportion to the number of signs that need to be maintained is certainly a key factor, the most important factor affecting the level of sophistication is the commitment of the personnel who would administer and operate the program. The smallest of agencies can have a fully integrated sign management system for a relatively low cost even considering the need for computer hardware and software and peripheral equipment. On the other hand, State highway departments may find it disproportionally more expensive to implement a full program because of the large network of roads. This situation may also occur with large cities and counties, especially if they have limited budgets for signing. This problem can be overcome, somewhat, if sign management systems are established for separate districts or sections, if appropriate.

The key to the successful implementation of any level of sign management system will, as with all other programs, lie with the commitment and dedication of the staff. This starts with management who provides the tools, direction, and supervision. It continues when there is a person responsible for the continuous operation of the program. And finally, it requires a conscientious sign crew of inspectors and maintenance personnel who understand the merits of the program and ensure that the information they provide is accurate and timely.

APPENDIX A. FHWA SIGN MANAGEMENT SYSTEM (SMS) SUMMARY DESCRIPTION

OVERVIEW OF SMS

The Sign Management System (SMS) has been developed by the Federal Highway Administration (FHWA) Office of Safety and Traffic Operations Research and Development to provide State and local highway agencies with a tool for assembling a sign inventory and to assist them in maintaining their signs in accordance with the anticipated national guidelines on minimum retroreflectivity levels.

To do so, the SMS integrates three basic elements for comprehensive sign management - inventory, inspection and maintenance/replacement. These basic elements help determine the retroreflectivity condition of a sign, which is the key determinant of a sign's effectiveness. To allow for compliance of minimum retroreflective levels, the SMS program estimates when a sign may need replacement based on key data elements such as type of sign, its color, age of sign, etc. The SMS uses initial retroreflectivity (R_A) measurements taken when a sign is installed and a series of deterioration equations to estimate when a sign's retroreflectivity will drop below the minimum guidelines. This way, signs can be scheduled for replacement before their condition becomes substandard.

The SMS program is divided into three sections: Sign Inventory, Sign Dictionary and Utilities.

SIGN INVENTORY

Data Elements

The SMS program requires the identification of certain data elements that are needed for each sign in order to calculate the sign's R_A. Each sign in the inventory is a separate sign record. Each sign record should contain as much information as possible about the sign's age, location, type, manufacturer, color, etc. The data elements are used in the calculation of the R_A and the replacement date. The required data elements are as follows:

- Route name/# — up to 25 characters, where the sign is located.
- Location — three possible methods of measurement (described below).
- Direction — compass direction of travel on the road.
- Position — location of sign relative to the road.

- Orientation — direction the sign is facing.
- MUTCD — codes of sign types.
- Sheeting — type of sheeting used.
- Install date — date of installation of sign.

Several other data elements are not required but can be entered into the sign record to help determine a more accurate R_A level and replacement date.

Location Measurement

There are three methods of sign location measurement available in the SMS. The first type of location measurement is the milepoint location method which may be used if the road is referenced by milepoints. The location of the sign along the road can be entered to the nearest 1/1000 of a mi (0.00161 km). The second type of measurement is the intersection/distance location method. This method may be used to reference the sign location to the nearest intersection or to any other prominent feature (e.g., a bridge). The distance from the intersection is entered in feet. In this location method, the name of the intersection route must be entered in the required "INTERSECT" field. The third location measurement method, the milepost method, may be used when there are markers on the roadside every mile. Distance can be measured to as small as every 0.1 mi (0.161 km). The closest milepost marker to the sign is entered into the record. The distance in feet from the closest milepost marker is recorded with a plus (+) sign for after the milepost marker and a minus (-) sign for before the marker.

History File

A history file is created to track the inspections of each sign record in an inventory file. A history file is specific to the inventory file because it keeps track of all of the inspection data for the signs in that specific file. The sign history file is automatically updated each time a new inspection date for a sign is entered. Additionally, the condition of the sign at the time of inspection can be entered and the measured R_A from field measurements can be recorded. The history file is important in tracking a sign's deterioration through its existence which is used in the Utilities section of the SMS program. It also helps keep track of sign maintenance activity.

Archive Records

An archive file is built when the user creates an active inventory file. Each active file contains all of the current active sign records. An archive file is a storage file used when active signs are removed from service. To archive a record, the user moves it from the active file to the archive file. All of the data previously entered into the active sign record will remain as it is in the archive file because archive files may be accessed, but cannot be modified. An archive record stores the removal date and reason for the removal of the sign.

UTILITIES

Test Sign Program

The purpose of the Test Sign Program within the SMS is to refine deterioration equations so that the equations better model the conditions in a particular geographic area. The user is able to tag sample signs for testing, and track their retroreflectivity levels over several years. These levels are then input into the SMS and are used to develop a specific set of equations relative to the geographic area for the test signs. The SMS program default equations would not be used to determine deterioration rates in the test sign program. Rather, a predictive set of equations using conditions related to the geographic area would be utilized. Therefore, more accurate results could be determined for the test signs as well as the remainder of the sign inventory. In this way, the test sign program will permit users to more accurately predict sign service life and replacement needs in their specific geographic location.

There are six essential activities involved in the test sign program:

- Sign selection — The program needs to include a large enough selection of test signs to make the sample statistically accurate.
- Identification of signs in the SMS — Tag signs picked for the test program so they can be tracked.
- Periodic measurements of sign retroreflectivity — Conduct periodic measurements of the test signs' R_A using either a hand-held retroreflectometer or a traffic sign evaluator. Readings will be averaged by the SMS to yield a single background reading and single legend reading.
- Data analysis — Test sign data should be analyzed for consistency.
- Modification of equations — Deterioration equations in the SMS program can be modified with the results of the test sign program.
- Verification of results — Accuracy of updated equations can be tested by inspection of the available R_A of non-test signs in the inventory.

R_A Measurements and Calculation of Sign Results

The R_A is the measure of a sign's retroreflectivity level. As a sign ages, its retroreflectivity deteriorates more and more causing the sign to become increasingly difficult to read. The SMS has the ability to estimate when a sign may need to be replaced based on the comparison of different R_A measurements. FHWA has developed minimum retroreflectivity standards which have been programmed into the SMS as the required R_A. The required R_A considers elements such as sign background color, legend color, sign size and roadway speed in its calculations.

A second type of R_A measurement is calculated from the SMS programs and equations by using data from the sign inventory database. Estimates of available R_A are prepared using data elements, such as the sign type, sign color, age of sign, and sheeting material of the sign, which are entered into each individual sign record. Additionally, the SMS equations use the amount of heating degree days, the annual precipitation and the elevation appropriate to the region, which must be entered into the system to allow it to calculate the available R_A. The SMS does not require field measurements to calculate available R_A, rather the SMS calculates the R_A from the data in each sign record. The SMS compares a sign's available R_A to the required R_A and determines the remaining retroreflectivity of the sign to calculate the sign's remaining service life. From this, the replacement date is determined by adding the remaining service life to the current date. The maximum life of a sign has been established as 20 years, regardless of the replacement date calculated.

Deterioration Model for EG and HP Sign Types

The capability of predicting the replacement date of a sign is limited to signs made of sheeting Type I (engineering grade) and sheeting Type IV (high-intensity). There are eight possible sheeting/color combinations derived from four possible sign colors (red, yellow, green and white) and the two sheeting types. Depending upon the color and sheeting combination, the SMS calculates the deterioration rate of the sign using the regression equation for that particular combination. These equations are only used to estimate the available R_A. From this calculation, the SMS can estimate the proper replacement date for the sign.

SIGN DICTIONARY

The Sign Dictionary contains the information of all of the signs in the Manual on Uniform Traffic Control Devices (MUTCD). These signs are referenced from the sign inventory records. The sign dictionary accepts custom signs from a particular jurisdiction.

Cost Estimator

Most of the sign records in the MUTCD sign dictionary provide replacement costs per square foot for each particular sign. In the case when the replacement cost is not provided for a sign, a user may enter a particular screen to enter or modify an average cost per square foot for sign replacement materials. Each sign record will have its own replacement costs associated with it depending upon the type of sign, and the type of sheeting and backing of the sign. A sign inventory report summarizes all of the costs for each sign in the entire inventory file.

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