Maintaining Traffic Sign Retroreflectivity: Impacts on State and Local Agencies

PUBLICATION NO. FHWA-HRT-07-042 APRIL 2007

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Federal Highway Administration

Research, Development, and Technology
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FOREWORD

In 1992, the Congress directed the Secretary of Transportation to revise the Manual on Unifrom Traffic Control Decives to include a standard for minimum levels of retroreflectivity that must be maintained for traffic signs. The FHWA already had an active research program investigating the nighttime visibility of traffic signs, and responded to the congressional mandate by publishing a set of recommendations for minimum maintained sign retroreflectivity levels in October 1993. An analysis of the impacts of the proposed minimum maintained traffic sign retroreflectivity levels was published in April 1998.

The following document updates the 1998 report on the national impact of minimum maintained traffic sign retroreflectivity levels, and addresses concerns expressed in four FHWA-sponsored workshops that were held in 2002. The primary sources of information for this effort are previous studies related to the benefits of improved signage and the impacts of implementing sign system upgrades.

This report will be of interest to State and local agencies with responsibility for traffic signs and people involved in traffic sign maintenance.

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TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-HRT-07-042		

4. Title and Subtitle Maintaining Traffic Sign Retroreflectivity: Impacts on State and Local Agencies	**5. Report Date** April 2007 **6. Performing Organization Code** FHWA HRDS-05
7. Author(s) Kenneth S. Opiela, PE, PhD Carl K. Andersen	**8. Performing Organization Report No.**
9. Performing Organization Name and Address Turner-Fairbank Highway Research Center 6300 Georgetown Pike McLean, VA 22101-2296	**10. Work Unit No.** **11. Contract or Grant No.**
12. Sponsoring Agency Name and Address Office of Safety R&D Federal Highway Administration 6300 Georgetown Pike McLean, VA 22101-2296	**13. Type of Report and Period Covered** **14. Sponsoring Agency Code**

15. Supplementary Notes

16. Abstract

This report analyzes the impacts that might be expected from the adoption of proposed minimum maintained retroreflectivity levels for traffic signs to improve night visibility. The report evaluates the broad spectrum of concerns expressed by State and local agency staff at four workshops held during the summer of 2002. These include administrative, fiscal, implementation, and tort liability concerns.

The report includes a summary of previous studies, including those of several State agencies, to determine the impacts of the proposed new minimum maintained levels for traffic sign retroreflectivity. The various sign cost elements are identified and changes attributable to the new minimum levels of retroreflectivity are isolated. The cost of sign face materials is seen as the major source of increased costs. The cost impact is determined to be a function of the condition of existing signs, State and local agency practices on the use of sign materials, and current procedures for sign management.

The report provides estimates of the National impact of the proposed minimum levels generated by the models previously developed using updated inputs for sign material costs and road mileage. It was assumed that the distribution of non-compliant signs has remained the same. Estimates of the costs for upgrading street name and overhead guide signs were also generated to cover the full spectrum of signs covered by the proposed minimum levels. National sign replacement costs incurred as a result of proposed minimum maintained retroreflectivity levels are estimated to be $37.5 million. Using a 7-year implementation period for regulatory, warning, and guide signs and a 10-year implementation period for street name and overhead guide signs, the annual impacts are estimated to be $4.5 million for years 1 through 7 and $2.1 million for years 8 through 10. The estimates are based upon the added cost of higher performance sign materials, with the majority of sign replacements conducted as part of normal sign maintenance cycles. The labor, equipment, and mileage costs for sign replacement were excluded under the assumption that the proposed implementation period was long enough to allow replacement of non-compliant signs under reasonable maintenance cycles.

The report concludes that there will be increases in the costs to agencies resulting from the need to use more expensive sign face materials to increase retroreflective performance, but there should be no impacts on the costs of other sign elements. Agencies may experience a reduction in service life costs because of the longer service life of the improved sign face materials.

17. Key Words	18. Distribution Statement
retroreflectivity, maintained retroreflectivity, minimum maintained retroreflectivity, impact, impact assessment, impacts analysis, national impact assessment	No restrictions

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No of Pages	22. Price
Unclassified	Unclassified	38	

Form DOT F 1700.7 (8-72) **Reproduction of completed pages authorized**

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 yard	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 degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		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	35.314	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 degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		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 March 2003)

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PREFACE

This report addresses the impacts of the implementation of proposed changes to the Manual on Uniform Traffic Control Devices (MUTCD) that would set minimum levels of retroreflectivity for in-place traffic signs. The proposed change seeks to improve the night visibility of traffic signs by requiring agencies to replace signs that fall below a minimum level of retroreflectivity. The need to replace signs that do not satisfy the minimum levels will have impacts on State and local agencies. The degree of impact will be influenced by the specific values of the minimum levels as well as by the current state of an agency's sign system. The impacts will be further influenced by the methods used to assess and maintain an agency's sign system.[1]

An important test of the practicality or viability of the proposed changes can be found in an analysis of the impacts they will have on State and local agencies. These agencies have the day-to-day responsibility to design, place, and maintain the traffic signs in the U.S. While State and local agency personnel recognize the critical importance of their role to maintain the retroreflectivity of traffic signs on the roads in their jurisdictions, the resources available for this role are limited. This report takes a broad view of impacts, as reflected in the concerns expressed by agency personnel, and studies the extent of impact associated with those concerns.

This report assumes that rulemaking efforts will lead to minimum maintained levels of traffic sign retroreflectivity and that State and local agencies will be primarily responsible for bringing their sign systems into compliance, if they are not already doing so.

Assessing the impacts is difficult for many reasons. First, while it is possible to isolate the important cost elements associated with signs, differences in agency accounting practices and prices make it difficult to establish average costs. Second, it is difficult to identify the scope of direct and indirect impacts. Third, it must be recognized that specific information on the numbers and condition of in-place signs is limited, making it difficult to generate definite overall cost impacts. Last, it must be recognized that there is a measure of uncertainty and variability in the costs and performance (e.g., service life), making it hard for any agency to know the specific degree of impact they will face.

Recognizing the difficulties described above, it is still important to analyze and quantify the expected impacts on public agencies. Therefore, this report takes the best information available on the subject and develops an estimate of those impacts.

1. INTRODUCTION

1.1. System of Traffic Signs

Traffic signs are the principle medium by which highway agencies communicate regulatory, warning, guidance, or other information to road users. This means that traffic signs must be detectable, legible, and comprehensible to users at a distance commensurate with their purpose. Traffic signs are designed to satisfy these requirements by selection of sign size and color, the size and style of letters and numerals and application of symbols, and the retroreflective materials used for the background and legend. It is through the appropriate selection of the design parameters that State and local agencies develop signs intended to meet drivers' needs under both day and night conditions.

The FHWA has promoted efforts to design and implement improved traffic control devices (TCDs) that meet the needs of drivers under both day and night conditions. There has been considerable research to 1) understand driver needs, 2) develop improved TCDs (e.g., designs, materials, and technology) to meet those driver needs, and 3) establish sound practices for TCD application and management. The underlying motivation for these efforts has been the interest in promoting safety and efficient flow of traffic during all time periods. Crash data indicate, however, that about 50 percent of the traffic fatalities occur at night despite significantly lower volumes of traffic. This over-representation of night fatalities has persisted for more than 20 years. The nighttime crash rate has been estimated to be three times that during the day.[2] The FHWA is, therefore, focusing more attention on the nighttime crash problem and reviewing the influences of highway design and control.

1.2. Night Visibility of Traffic Signs

The night visibility of traffic control devices (e.g., signs, pavement markings, and signals) is critical to the safe and efficient operation of roadways at night. TCDs also represent one area where immediate night visibility improvements are considered possible to enhance the delineation of the roadway, warn drivers aware of unexpected conditions, and facilitate their abilities to navigate the road system.

Every version of the Manual on Uniform Traffic Control Devices (MUTCD)[3] has included requirements for nighttime sign visibility, since the first edition in 1935. Over that time, a variety of sign materials have evolved to provide options in meeting detectability and legibility objectives, but there have been no specific design or maintenance thresholds. The available materials vary in cost and performance, particularly relative to night visibility, complicating decisions for traffic sign design and budgets for sign programs.

1.3. Purpose of Retroreflectivity

Retroreflectivity, one of the factors associated with night visibility, is the property of a material to redirect light back towards its source. In the case of a traffic sign, light is redirected back from the sign face toward the vehicle's headlights, making the sign visibile to the driver. The American Society for Testing Materials (ASTM) has established testing procedures and manufacturing requirements for retroreflective materials and measurement equipment. These measures can be used in varying ways to support the different methods and procedures by which agencies assess and manage the retroreflectivity of traffic signs.

1.4. Traffic Sign Degradation

The retroreflectivity of signs gradually deteriorates over time, thus making signs progressively less visibile at night. While deterioration can occur in a number of ways, the primary mechanisms are the loss of retroreflectivity and the fading of the color portions. As the retroreflective properties deteriorate, the sign becomes less detectable and legible at night. When the colors fade, the sign loses a distinguishing feature and the contrast between legend and background is reduced. For critical signs, such as STOP signs, fading of the red background may make the sign less detectable and legible even during the daytime. Deterioration can occur for a variety of reasons, ranging from the environment in which the sign exists to poor workmanship during fabrication or improper installation of the sign. Highway agencies are faced with the challenge of determining when the deterioration has reached levels that warrant replacement of the sign while at the same time avoiding replacing a sign before its true useful life is reached. The useful life of a traffic sign is a critical factor in assessing sign maintenance costs for a highway agency.

1.5. Minimum Maintained Retroreflectivity

In 1992, the Congress directed the Secretary of Transportation to revise the MUTCD to include a standard for minimum levels of retroreflectivity that must be maintained for traffic signs.[4] The FHWA already had an active research program investigating the nighttime visibility of TCDs to meet driver needs. In 1993, the FHWA responded to the congressional mandate by publishing a set of research recommendations for minimum maintained sign retroreflectivity levels.[5] A series of tables was presented in the research report to establish minimum maintained retroreflectivity levels for regulartory, warning, and guide signs. Based on comments received in workshops with practitioners, revised recommended minimum levels were published in 1998 in a report entitled “An Implementation Guide for Minimum Retroreflectivity Requirements for Traffic Signs.”[6] Because of changes to U.S. headlight standards, the FHWA conducted additional research to develop minimum maintained retroreflectivity levels for overhead guide signs and street name signs, which were not included in the minimum levels published in 1998. The research was published in 2003,[7] and culminated in the proposed minimum maintained retroreflectivity levels for traffic signs in July 2004.

1.6. Impacts of Proposed Rule

About 75 percent of the public roads in the United States are maintained by local agencies, 21 percent are maintained by State agencies, and the remainder are maintained by Federal agencies.[8] Therefore, it is imperative that the impacts on State and local agencies resulting from the proposed addition to the MUTCD of minimum maintained traffic sign retroreflectivity levels be carefully assessed.

Impacts take many forms and can be considered positive or negative. For this analysis, the concerns identified by participants in four workshops on nighttime sign visibility conducted for the FHWA at locations across the country in 2002 were used as a starting point.[9] About 100 State and local officials participated in these workshops, which were organized to present updated information on the FHWA’s plans to implement new minimum maintained sign retroreflectivity levels through changes to the MUTCD. During these workshops, the participants cited numerous perceived impacts that the new levels would have on their agencies, which are outlined in Table 1. It needs to be stressed that many of these items were perceptual, as many of the agencies had not begun thinking about how they would determine their degree of compliance or how they would implement more rigorous sign management processes to address night visibility needs.

It should be noted that most of the participant discussion in the workshops focused upon the negative impacts of implementing minimum levels of traffic sign retroreflectivity. The extent of those negative impacts will vary from agency to agency, depending upon current sign replacement practices. Negative impacts are expected to be smaller for agencies that currently have proactive sign management practices. There is also the potential for positive impacts from improved signing, including lower overall sign costs due to more effective sign replacement strategies and improved safety and mobility for the driving public due to better sign visibility. Participants recognized their agency roles and noted that adoption of minimum levels could be useful in obtaining increased funding for sign improvements**.** The workshop participants suggested that the new minimum levels should not be imposed without Federal funding assistance. However, the means to offset the costs of sign inspection, replacement, and long-term maintenance of adequate night visibility is not a topic that is covered in this report.

The concerns presented in Table 1 cover a broad spectrum, some of which can be readily translated into dollar amounts. However, it is difficult to generate reliable financial estimates for many of the concerns, and for some concerns it is not considered necessary.

1.7. Benefits of Improved Visibility of Traffic Signs

The FHWA believes that although improving sign retroreflectivity will be especially beneficial to older drivers, all drivers, including younger drivers, will find that improved sign retroreflectivity will be beneficial for their nighttime driving experience. All drivers need legible signs in order to make important decisions at key locations, such as intersections and exit ramps on high-speed facilities. This is particularly true for regulatory and warning signs. This is fundamental to safe driving, and the lack of uniform retroreflectivity standards has led to wide variations in maintenance levels of these critical signs. As discussed in the Supplemental Notice of Proposed Amendments (SNPA),[10] there have been some investigations that demonstrate potential safety benefits of upgrading sign materials. More importantly, maintaining sign retroreflectivity is consistent with one of the FHWA's primary goals, which is to improve safety on the nation's streets and highways. Improvements in sign visibility will also support the FHWA's efforts to be responsive to the needs of older drivers, which is important because the number of older drivers is expected to increase significantly in the next 30 years.

1.8. Organization of Report

This report is organized to address questions associated with the concerns at increasingly higher degrees of detail. Chapter 2 addresses questions about the cost impact at the individual sign level, such as how much will need to be spent on sign face materials. Chapter 3 addresses questions at the agency level, such as the number of in-place signs that do not meet the proposed minimum levels, and the impacts of procedures to implement and administer management practices to comply with the proposed new rule. Previous impact analyses are reviewed in

Chapter 4, including one State report that addressed tort liability concerns. All of this information is then used to develop the National Impact Assessment that is presented in Chapter 5. Finally, the conclusions are provided in Chapter 6.

Table 1. Summary of Participant Concerns from FHWA Sign Workshops in 2002

- Administrative Impacts
  - New guidelines may require agencies to devote more personnel to signing activities.
  - Personnel will need training to conduct various functions needed to assess or manage the nighttime visibility of traffic signs.
  - Training activities may need to be coordinated with requirements at a national or State level for certification to assure that staff members are qualified.
  - Many agencies will need to increase their sign documentation efforts to have the records that show evaluations were conducted and that signs met the evaluation criteria. Agencies will also need to keep these records over a longer period of time.
  - It will be difficult for transportation management to support requests to elected officials for additional funding unless a documented safety benefit can be linked to the expenditures.
- Fiscal Impacts
  - The assertion of the 1998 FHWA report that many agencies "will not likely feel any additional impact of implementing the minimum retroreflectivity guidelines" has not been ascertained.
  - The guidelines may lead to a higher sign replacement rate than presently exists. This will increase the signing costs for an agency.
  - Even if sign replacement rates remain the same, the use of more expensive sheeting may increase costs.
  - Factors that are expected to increase the fiscal burden on agencies include (not all impacts will apply to all agencies):
    - Cost of training personnel.
    - Cost of overtime pay for nighttime inspections.
    - Cost of acquiring evaluation equipment (for example, retroreflectometers or inspection panels).
    - Cost of additional documentation activities and longer retention of the information.
  - The fiscal resources required to meet the minimum visibility/retroreflectivity guidelines may have to be diverted from other transportation responsibilities.
  - Implementing processes to manage sign replacement has been shown in some agencies to reduce overall sign costs, although the start-up costs can be large.
- Implementation Impacts
  - Some participants felt that conducting nighttime visual inspections were beyond the capabilities of their agency, primarily due to the overtime pay that would be required.
  - A few participants expressed the opinion that they felt that daytime sign inspections would be just as good as nighttime inspections. However, most participants agreed that daytime inspections couldn't be used to reliably assess nighttime sign visibility.
  - Guidelines that eliminate the use of Type III (high intensity) sheeting for the legend of overhead signs will be a large burden to agencies with many overhead signs. Most of these signs currently use Type III sheeting and the replacement intervals for these signs are typically longer than post-mounted signs.
  - A long time period to implement the changes will reduce the impacts on agencies. This will help agencies to make the necessary changes in policies, practices, procedures, staffing, and training, as well as replacing existing signs that don't meet the requirements.
  - The evaluation methods should be implemented in a manner that recognizes the potential for changes in sign visibility that can occur between evaluation periods. There are many different events and occurrences that may lead to a decrease in sign visibility. Examples include:
    - Sign removal due to vandalism or crash impact.
    - Physical damage to the sign face (which may or may not be visible in daytime conditions).
    - Sign sheeting deterioration.
    - Growth of brush or vegetation.
- Tort Impacts
  - The specifics of the MUTCD language will have a significant impact on the extent of the tort liability impacts on agencies. The greater the level of detail in the MUTCD language, the greater the expected tort exposure for agencies.
  - Sign visibility and/or sign retroreflectivity has not generally been a significant tort issue in the past.
  - There is a need to recognize that the minimum levels in the guidelines are a rough benchmark that is dependent upon a number of factors.

1.9. Background and Assumptions

This analysis of the impacts of the proposed minimum maintained traffic sign retroreflectivity levels updates FHWA-RD-97-053, "Impacts on State and Local Agencies for Maintaining Traffic Signs within Minimum Retroreflectivity Guidelines," April 1998. In addition to updating the 1998 report, this report addresses concerns expressed by the 2002 workshop participants. The primary sources of information for this effort are previous studies related to the benefits of improved signage and the impacts of implementing sign system upgrades. No new or better data were discovered, necessitating a reliance on previously gathered data. More detailed information on retroreflectivity and the research efforts that have led to the proposed minimum maintained retroreflectivity requirements for traffic signs can be found in the 1998 report.

It is important to emphasize that the proposed minimum retroreflectivity levels for traffic signs presented in Appendix A represent a minimum threshold needed to accommodate older drivers in dark rural conditions. There are uncertainties associated with the minimum levels due to assumptions about viewing position and surrounding conditions, modeling weathered retroreflective sheeting materials, and aggregation. Furthermore, there are conditions when agencies may choose to use higher minimum maintained retroreflective levels. The MUTCD does not restrict agencies from using higher levels of retroreflectivity if, based on engineering judgment or studies, the agencies determine that higher levels are warranted. The presence of the minimum retroreflectivity levels in the MUTCD does not imply that all pertinent signs must meet the minimum retroreflectivity levels at all times. The FHWA understands that there will be cases where issues such as weather, vandalism, or damage influence the visibility of a sign.

Because many factors influence the visibility of a particular traffic sign under actual nighttime driving conditions, efforts to schedule sign upgrading or replacement actions should be triggered as a sign approaches the threshold so that it never reaches a level that is inadequate to meet drivers' needs.

This impacts analysis was conducted with the following assumptions:

- The proposed minimum maintained traffic sign retroreflectivity levels cited in Appendix A will be established as a requirement in the MUTCD;
- Agencies will be provided a 7-year time frame to bring regulatory, warning, and guide signs into compliance, and a 10-year time frame for street name and overhead guide signs;
- Agencies will have flexibility to use one or more methods for assessment and management of their sign systems; and
- Some categories of signs (e.g., parking series) will be excluded from the requirements.

Under these assumptions, the analysis indicates that impacts are distributed over a long enough period of time to allow most sign replacements to occur under normal maintenance cycles.

2. TRAFFIC SIGN COSTS

The most basic way to look at the impacts on State and local agencies imposed by establishment of minimum maintained traffic sign retroreflectivity levels is to analyze the change in cost for an individual sign. The sections below isolate the various elements of sign cost, provide some estimates of the cost differences between various materials, discuss the effect of service life, and summarize other influences on sign cost.

2.1. Elements of Sign Cost

There are costs associated with the design, fabrication, installation, and maintenance of a traffic sign as a result of the materials, labor, and equipment needed. The major elements include.

Sign Materials
- Substrate
- Post or structure
- Sign face materials
- Hardware
- Sign protection treatments (e.g., anti-vandalism parts)

Sign Fabrication
- Legend cutting devices
- Fabrication devices
- Inventory costs

Sign Inventory Control
- Inventory control labeling and logging
- Procurement certification
- Stock labeling and control

Sign Maintenance
- Periodic cleaning
- Replacement or repair of vandalized or damaged signs
- Maintenance equipment (e.g., retroreflectometers)
- Sign material recycling equipment and programs

Sign Crew Wages and Benefits
- Wages and overtime
- Benefits
- Lost/down time
- Deadheading time
- Contractor costs (where the tasks are privatized)

Illumination
- Power costs
- Lighting hardware and wiring
- Maintenance of lighting equipment

Training
- Initial training
- Incremental training
- Certification

In analyzing the impacts, it is necessary to isolate those cost elements that are truly affected by the proposed minimum levels of retroreflectivity. On the assumption that agencies will be able to spread the efforts to upgrade non-compliant signs over a 7-year or 10-year implementation period, the most significant additional cost becomes that of the sign face materials. Associated with the above assumption is that most replacements will take place under planned maintenance cycles. Thus, there should be no additional costs to the agencies for labor and time required to physically replace signs. An assumption is also made that agencies are currently following the MUTCD guidance in Section 2A.22 which recommends night-time inspections. There may be additional costs to agencies for equipment modifications to work with alternative sheeting materials, for conducting training for staff on working with these materials, and for labor and equipment related to new sign management processes and procedures. It is difficult to estimate the magnitude of the additional costs on a per sign basis, but they are considered to be a small percentage of the total cost of a sign.

2.2. Sign Cost Updates

The most significant impact associated with improving the night visibility of a sign is the difference in the cost of the sign sheeting material selected. There are limited data available on the types of materials currently being used by State and local agencies, so a general analysis of cost impacts was undertaken. Table 2 provides a rough approximation of unit cost differences, in dollars per square foot ($\$/ft^2$) of sign face, for available materials by ASTM designation.[11] These numbers reflect the upward side of the various reported costs for available sign materials.

Table 2. Comparison of Sign Face Upgrading Costs (additional cost per square foot / percentage change)

Material	Cost per Foot^2	Type II	Type III & IV	Type VII, VIII, IX, & X
Type I	$0.75	$0.50 (67%)	$0.75 (100%)	$2.75 (367%)
Type II	$1.25	------	$0.25 (20%)	$2.25 (180%)
Type III & IV	$1.50	------	------	$2.00 (133%)
Type VII, VIII, IX, & X	$3.50	------	------	------

Upgrading sign sheeting materials from Type I to Type III or Type IV, which is the most likely change that would result from establishment of minimum maintained retroreflectivity levels, will result in an increase of approximately $\$0.75/ft^2$. For a typical 36" x 36" sign, that would translate to a $6.75 increase in the cost of the sign sheeting material. While this is a 100 percent increase in the cost of the sheeting (from $6.75 to $13.50), the total cost for an installed sign is estimated to be $100-200, (based on average reported costs in Reference 6, updated for inflation) which implies that the $6.75 increase in sheeting cost translates to a 3 to 7 percent increase in installed cost. All other costs for the sign and the replacement activities would remain unchanged. The overall costs to an agency would be dependent upon the total number of signs in their inventory and the degree of change made.

2.3. Sign Life Cycle Costs

The best measure of the cost of a sign to an agency is its life-cycle cost, under which the total cost is distributed over the years of useful life that the sign will provide. Generally, signs are expected to provide adequate detectability and legibility for 7 to 15 years, depending on the sign sheeting, but there are currently no specific criteria or models that can definitively predict service life. Estimates of the life-cycle cost of a sign are difficult to establish, but important to consider for long-term budgeting.

To illustrate the influence of service life, assume that an agency plans to upgrade 1,000 yellow 36" x 36" warning signs. Three materials are considered for these signs: Type X, Type Y, and Type Z. These materials vary in cost and expected service life as shown in Table 3. Over a 30-year period, it would be necessary to replace Type X signs five times after initial installation. The Type Y materials would require two replacements and the Type Z material only one replacement during the 30 years. The cumulative sign sheeting costs indicate that it might actually save the agency money to select a higher cost material with a longer service life. The most dramatic outcome occurs when total installation costs are added to the sign sheeting costs. Assume an average cost of $150 to install or replace a 36" x 36" warning sign. This includes labor, hardware, administrative expenses, and other costs, and is incurred each time the sign reaches the end of its useful life. In this example, signs manufactured with Type X material must be installed six times, but only three times for Type Y and twice for Type Z. The total costs of the sign and replacement operations clearly illustrate that what appears in the beginning to be the more expensive option is the less expensive option in the end. In reality, the costs in this example would increase due to inflation and other external changes that might affect the service life or unit costs of the materials. Table 4 illustrates how an annual increase of 3.5 percent in sign material, fabrication, and installation costs would affect the live cycle costs of the example.

Table 3. Example of Life Cycle Costs for Various Materials (Fixed Cost)

Example Sheeting Material	Cost (per ft^2)	Expected Sign Life (years)	Year 0	Year 5	Year 10	Year 15	Year 20	Year 25	Sign Sheeting Costs	Total Cost (including installation)
Type X	$0.75	5	$6,750	$6,750	$6,750	$6,750	$6,750	$6,750	$40,500	$940,500
Type Y	$1.50	10	$13,500		$13,500		$13,500		$40,500	$490,500
Type Z	$3.50	15	$31,500			$31,500			$63,000	$363,000

Table 4. Example of Life Cycle Costs for Various Materials (Net Present Cost)*

Example Sheeting Material	Cost (per ft^2)	Expected Sign Life (years)	Year 0	Year 5	Year 10	Year 15	Year 20	Year 25	Sign Sheeting Costs	Total Cost (including installation)
Type X	$0.75	5	$6,750	$8,017	$9,522	$11,309	$13,431	$15,952	$64,980	$1,508,980
Type Y	$1.50	10	$13,500		$19,043		$26,862		$59,405	$719,463
Type Z	$3.50	15	$31,500			$52,773			$84,273	$485,576

*Net Present Cost estimates based on 3.5% inflation per annum.

2.4. Factors Influencing Sign Costs

Agencies that have historically used Type I sheeting for the majority of their signs are likely to experience higher implementation costs than will agencies that have historically used Type II, or III sheeting. Initial cost increases may even be higher if agencies opt to use microprismatic sheeting (Types IV, VII, VIII, IX and X). In addition to the cost differences between sheeting types, there are other factors that can influence the implementation costs incurred by an agency, including:

- The number and size of large signs and overhead guide signs in a jurisdiction;
- The initial condition of the signs in the agency's system;
- The degree of sign face material upgrade that is chosen;
- Future changes in sign material costs, including competition-induced changes in prices;
- Contract prices for sign materials;
- Decisions to fabricate signs or buy pre-fabricated signs;
- Strategic alliances between agencies to procure materials and services;
- Using larger signs to offset the need for higher retroreflectivity levels;
- Reducing the number of signs;
- Applying the minimum requirements to fewer categories of signs; and
- Development of new sign materials and technologies.

It is the responsibility of highway agencies under the MUTCD to maintain acceptable levels of night visibility for in-place traffic signs. The minimum maintained retroreflectivity levels for traffic signs provides only the starting point for processes that will lead to improved night visibility over the road network. An agency may choose to define "acceptable" as some level above the minimum levels to better serve the needs of the driving public. For example, retirement communities may wish to use brighter signs to better accommodate older drivers. It is hoped that agencies will adopt retroreflectivity levels for traffic signs that are commensurate with the visual requirements of roadway users based on actual local conditions.

3. SIGN MANAGEMENT COSTS

In addition to the direct costs of a sign, an agency will also incur costs for the processes they have developed to procure, deploy, maintain, monitor, and upgrade traffic signs. The information below reflects some of this diversity and indicates the difficulty in establishing specific agency-level cost impact estimates.

3.1. Sign Management Processes

Each State or local highway agency has a sign management process that is used to add, remove, modify, and maintain the full spectrum of signs that are placed on the streets and highways within their jurisdiction. These processes vary by 1) the size of the agency, 2) the nature of the highway system under an agency's jurisdiction, 3) agreements with other internal departments, external agencies, private sector manufacturers, suppliers, contractors, and consultants, 4) the history of sign practices in the area, and 5) other factors. These processes vary from information-driven systems that allow field staff to generate work orders on laptop computers or personal data assistant (PDA) devices to arrangements that designate a member of the local council to install, fix, or replace signs with materials carried in his/her pick-up truck.

Clearly, the nature of the process, the age and adequacy of the existing sign inventory, and the resources of an agency imply that the cost impacts of implementing new MUTCD provisions will be greater for those agencies that do not have a formal sign management system already in place. Additionally, an agency that has freeway or expressway segments is likely to have responsibility for overhead guide signs, with a higher system cost than an agency responsible for a roadway network comprised primarily of residential streets.

There are various methods that an agency may use to maintain minimum levels of traffic sign retroreflectivity in its jurisdiction. These methods can be loosely categorized as assessment-based or managed replacement. Under assessment-based replacements, scheduled evaluations provide a direct measurement of the adequacy of the retroreflectivity of in-place traffic signs. Signs not in compliance with minimum levels, or likely to fall out of compliance before the next assessment, are scheduled for replacement. Managed replacement relies on information about each sign to determine when a given sign should be replaced. Varying levels of detail may be incorporated into a managed replacement system, ranging from manufacturers' warranty periods to complex lifetime models incorporating environmental conditions, traffic volumes, etc.

3.2. Sign Management Methods

The methods associated with assessment-based and managed-replacement processes are not always distinct and may be used in combination. These include:

- Visual nighttime inspections: trained personnel assess traffic signs from a moving vehicle of a specific type.
- Measured sign retroreflectivity: retroreflectometer readings are taken for each sign and compared to the table of minimum levels to determine whether the sign is adequate. This may be done with direct or indirect measurement devices that are appropriately calibrated.

- Expected sign life: signs are scheduled for replacement when experience, control signs, material warranties, or other attributes dictate replacement.
- Blanket replacement: all signs of a certain type or in a specific area are changed at specified intervals, eliminating the need to track the life of individual signs. Replacement cycles are based upon the shortest expected lifetime for the signs within the replacement group.
- Control signs: a set of control signs is monitored to determine when signs of a specific type or group approach the minimum levels to trigger sign replacements.

These methods vary in their initial implementation costs and annual operating costs. The nature of sign management processes in an agency and the current status of the sign system will dictate the degree of need for initial assessments and replacements.

3.3. Sign Management Cost Elements

The cost elements for sign management vary by the specifics of the process. Major cost elements include:

- Inventory assessment costs
  - Field equipment – including vehicles, retroreflectometers, safety apparel, data forms or data-logging equipment, etc.
  - Crew deployment
  - Logistics management
  - Inventory updates
- Data processing
  - Data entry and verification
  - Linking data to a location referencing system
  - Material inventory control labeling and support systems
  - Data back-up, archiving, and recovery costs
- Software systems
  - Sign inventory/management software
  - Software upgrades and maintenance
  - Staff training
  - Server and work stations
  - Field devices
- Work order processing and tracking
- Warranty monitoring
- Salvage and recycling

These costs are a function of the size of the agency, the ability to link with other systems, the availability of support staff, and a host of other factors.

The use of sign inventory and management software is not strictly necessary for an agency to bring a sign system into compliance. However, inventories and management tools (e.g., software to schedule sign replacements for the next funding cycle) may be beneficial in making a sign management system more cost-effective. For example, an inventory of signs along a given corridor allows a simple check-off of performance during a visual nighttime inspection and permits identification of any missing signs.

Note that it is assumed that State and local highway agencies already design and install signs in compliance with the MUTCD, which includes provisions for day and night inspections and maintenance of traffic signs.

There are a number of factors that can influence the sign management costs of an agency. These include:

- The nature of the existing sign management process and the amount of process enhancement required or desired;
- Methods selected for enhancing a sign management process (e.g., developing a sign inventory);
- Labor rates and work rules (e.g., nighttime inspections may add an overtime increment to the hourly wage rate);
- Methods used to procure sign materials;
- Decisions to fabricate signs or buy pre-fabricated signs;
- Degree of privatization of the traffic sign system;
- Strategic alliances between agencies to procure materials and services;
- Using larger signs to offset the need for higher retroreflectivity levels;
- Reducing the number of signs;
- Applying the minimum requirements to fewer categories of signs;
- Development of new sign materials and technologies;
- Competition induced drops in sign material prices; and
- Using the proposed minimums as a tool to understand driver's needs and allow some signs to remain in place longer than done previously.

Many of the above items were also identified in Section 2.4 as factors influencing the cost of individual signs. It is recognized that these factors will vary by agency, and that some of the factors will reduce the overall cost of a sign management program and other factors will increase the cost. The impacts to an agency by the factors listed above will be directly tied to the decisions of each agency to address or not address each factor. By electing to utilize cost-saving factors, the combined negative impacts of these factors may not be significant, especially when considering the assumption that all agencies are currently following the recommendations in the MUTCD.

4. PREVIOUS IMPACT ANALYSES

There have been two previous reports on the national impact of implementing minimum maintained levels of traffic sign retroreflectivity: an effort by the National Cooperative Highway Research Program (NCHRP) focused on determining how stringent the requirements could be; and a study undertaken by the FHWA to evaluate the impact on State and local agencies that would be incurred to establish the minimum levels proposed in FHWA-RD-97-052.[12] In addition, there are some documented efforts by State Departments of Transportation (DOTs) to assess the impacts of the proposed new minimum levels on their agencies. These studies and reports have taken different approaches, and all provide information on possible impacts. The findings of these efforts are described below. Since the specific proposed minimum levels have not varied greatly, the findings of these previous efforts are believed to be relevant.

4.1. NCHRP Report 346

NCHRP Report 346, "Implementation Strategies for Sign Retroreflectivity Standards," [13] investigated the impacts of alternative implementation strategies for compliance with minimum maintained traffic sign retroreflectivity levels. Two sets of acceptance criteria were considered, with implementation time frames ranging from 1 to 10 years. A cost impacts model was formulated that considered sign, transportation, and labor costs. As part of this effort, field measurements of retroreflectivity were made for more than 8,000 signs (with red, green, white, and yellow sheeting) in 28 counties in 26 States. Associated with this sample were data related to the agency having jurisdiction over the sign and the area type. The sign data indicated similar trends in the distribution of signs by retroreflectivity levels across State, county, city, and town classifications. The data also provided estimates of the distribution of signs by area and the number of signs, by type, per road mile (sign densities).

This research effort also included a large-scale survey of highway agencies regarding their sign management practices. The 1990 survey was distributed to over 900 State, county, and city highway agencies, with a 30 percent response rate. A review of the responses found that, at that time:

- Approximately 33 percent of the States had sign inventories, as did many county and city agencies;
- Over 90 percent of the inventory systems included information on sign type;
- More than 75 percent of the inventories included installation or replacement date information;
- More than 50 percent of the inventories had data on the sign sheeting material; and
- Sign fabrication and maintenance costs were captured, and reasons for sign replacement were isolated.

The methodology used for the economic analysis involved expanding the sample for each of the jurisdictions based upon the area type, roadway mileage, and estimated sign densities. The percentage of signs at each retroreflectivity level was applied to the count by type, with those not meeting the criteria scheduled for replacement. All signs were degraded using algorithms from other FHWA research for the next analysis year. This process was repeated annually for the five alternative implementation periods. The replacement costs were summed for each type of agency to assess the impacts by type of agency.

The NCHRP study considered two sets of criteria for nighttime sign visibility (based on retroreflectivity) as shown in Table 5. The values for minimum maintained sign retroreflectivity levels that are currently proposed for inclusion in the MUTCD are also provided for the corresponding categories. The current proposed values are comparable, even though they span a broader range of materials than was considered in the NCHRP study.

Table 5. Comparison of Minimum Levels Used in NCHRP Analyses and Updated Minimum Levels

Sheeting Color	NCHRP Report 346 –Lower Value–	NCHRP Report 346 –Upper Value–	MinimumValues Proposed for MUTCD
Red	8	21	7
Yellow	20	60	50/75
Green	8	10	15
White	35	70	50

NCHRP Report 346 concluded that, at the lower criteria and with a ten-year implementation schedule, the projected annual sign maintenance costs "were in the same range" as existing sign maintenance costs. Thus, the lower criteria should have relatively minor economic impacts on jurisdictions. The report went on to say, "this finding suggests that current sign maintenance standards are adequately maintaining signs above the lower standard." The report noted that the findings were based upon a sample of signs in the various jurisdictions, that overhead and street name signs were not included, and that averaged estimates of the various costs elements for sign maintenance were used. Thus, the impacts for any particular jurisdiction may vary. It was noted that sign inspection costs were estimated to be less than 5 percent of the annual sign maintenance budget. The report further noted the need for additional research on the deterioration of retroreflective properties, the development of field methods for evaluating sign retroreflectivity, and an analysis of the potential liability of agencies due to inadequate signing.

The findings of this study were limited to Type I and Type III sheeting materials which were the most widely used at the time. It can be inferred that since the newer microprismatic materials (i.e., Types VII, VIII, IX, and X) have higher costs (see Table 2) the resultant cost impacts on agencies would be higher. The results, however, indicate that the impacts on an agency should be small, if conducted over an extended implementation period.

4.2. FHWA Impact Analysis

The publication FHWA-RD-97-053 summarized the findings of a survey of 19 State and local agencies relative to their sign management processes and the potential impacts of proposed minimum maintained traffic sign retroreflectivity levels outlined in Reference 12. The surveys distributed to these agencies solicited information on the types of sign materials used, the unit costs for materials, typical replacement costs, and perceived impacts of the new requirements. The survey results indicated that there were significant variations in sign upgrade needs and management costs. For example, the estimates for the percentage of signs needing replacement ranged from 1 to 61 percent based upon specific types of signs. The highest percentage related to the special needs of the red color used for STOP signs. The degree of sign maintenance performed by an agency was a factor, with some agencies facing higher costs to bring sign systems into compliance than others. Similarly, some agencies cited that there would be little or no impact on their sign management operations while others cited the need to hire new staff (one State agency estimated the need for 76 additional persons), purchase retroreflectometers and new vehicles, and conduct a large initial sign replacement effort.

Seven of the agencies contacted were able to provide retroreflectivity data for a sample of their signs. The retroreflectivity data was compared with the proposed minimum levels to determine the percentage of signs that would need to be replaced. Aggregate estimates of sign replacement costs were generated by applying equivalent percentages of replacement by highway type for the other parts of each of these seven jurisdictions. The data gathered for this analysis found only limited application of sign materials other than Types I, II, and III. Since microprismatic materials (i.e., Types VII, VIII, IX, and X) have higher costs, the degree of impact would be higher where these materials are substituted for previously used materials.

Table 6 presents the information in Table 10 from Reference 6. It was concluded from the analysis of the data gathered for sign conditions in 1994 that about 5 percent of the signs under State jurisdiction and 8 percent of the signs under local jurisdiction would not meet the proposed minimum requirements. Based upon the estimated sign replacement costs, the report calculated that bringing all signs in the U.S. into compliance would cost agencies $176 million, in 1994 dollars ($32 million for State agencies and $144 million for local agencies). The study did not analyze annual costs over varying implementation periods, but noted that replacement over a longer period of time would be the best approach. Furthermore, the report calculated the total cost of sign replacement, but did not itemize the marginal cost of upgrading the sign face material.

Table 6. Percentage of Signs Not Meeting Proposed Minimum Retroreflectivity Levels

Sign Group	Sheeting Color	State Jurisdiction	Local Jurisdiction	Combined
Group 1	Black Legend on Yellow or Orange Background	3.01%	9.51%	8.77%
Group 2	Black or Black-and-Red Legend on White Background	3.68%	6.86%	4.40%
Group 3	White Legend	1.67%	3.44%	2.11%
	Red Background	4.31%	7.81%	5.15%
Group 4	White Legend	3.77%	5.81%	4.13%
	Green Background	9.61%	2.90%	8.46%
All Signs	Legend	2.31%	3.98%	2.69%
	Background	4.48%	8.00%	5.48%

The impacts reported in the FHWA study are consistent with NCHRP Report 346. The estimate of 5 to 8 percent of signs requiring replacement is lower than the basic replacement rate that would be assumed if the agency had a 10-year replacement program (i.e., 10 percent of the signs would be replaced each year). Furthermore, an agency can accelerate the compliance process by upgrading the retroreflectivity of those signs needing replacement due to vandalism, knock downs, or changing traffic control schemes.

4.3. State Agency Impacts Analyses

4.3.1. Texas DOT

A study conducted by the Texas Transportation Institute[14] compared the results of nighttime visual inspections with proposed minimum maintained sign retroreflectivity levels. In this effort, Texas DOT sign crews were asked to conduct inspections of 50 signs set up by the research team on a closed course in College Station, TX. The measured retroreflectivity value was known for each sign in this sample of regulatory, warning, and guide signs. More than 200 Texas DOT sign crew members participated in these inspections.

This study concluded that more signs were rated "unacceptable" in the visual inspections than would have been rejected by comparing the measured values with the proposed FHWA minimum sign retroreflectivity values. This is because observers consider factors that are not captured by using retroreflectometers. In this effort, the luminance uniformity of the sign face was a focus of attention. Other damage and the influence of the environment on sign visibility were also noted.

This study confirmed that there are often clearly obvious problems with the visibility of signs at night. It further confirmed that non-measurement approaches for assessing signs are effective and that a sign management system using visual nighttime inspections may result in a sign system that has higher minimum maintained sign retroreflectivity levels than are currently proposed.

4.3.2. Indiana DOT

The Indiana DOT contracted with Purdue University to help them determine the likely cost impacts of new FHWA regulations on their sign management program.[15] At that time, the State only used Type III sign sheeting material, relied on manufacturer's warranties, and had a ten-year replacement cycle for their signs. The Purdue research team developed a sampling scheme to assess signs in different parts of the State and to measure the average retroreflectivity for each sign. They ultimately sampled 1,613 signs of various types between June 2001 and May 2002. Attribute information about each sign was also captured. The retroreflectivity measurements were compared to the minimum levels proposed in the FHWA's 1998 report that corresponded to the type and size of sign (Reference 12). Based upon the sample, it was concluded that:

- Approximately 98 percent of the signs in the field should not only meet, but exceed, the proposed FHWA minimum retroreflectivity levels for any speed or any size of sign.
- Sign retroreflectivity degrades over time at different rates based on the color of the sign. The red signs showed the quickest degradation in retroreflectivity.
- There is no statistically significant difference in the retroreflectivity values for cleaned versus un-cleaned signs.

- There was no statistically significant difference in sign retroreflectivity in districts where there is believed to be higher levels of environmental pollution.
- There is limited effect of the sun on degradation related to the direction a sign faces.

The researchers recommended that the State alter its replacement policy to add two years to the replacement cycle for all signs, except STOP signs (i.e., use a 12-year replacement cycle).

The report concluded that there would be a negligible impact of the proposed minimum retroreflectivity levels, but cautioned that the conclusions were based upon a small sample. It is not clear to what extent the signs on local roads were considered. The study did demonstrate the value of monitoring sign retroreflectivity performance over time to get the fullest use of sign life.

4.3.3. North Carolina DOT

In 2000, the North Carolina DOT contracted with the North Carolina State University to investigate the impacts of the proposed minimum levels for traffic sign retroreflectivity.[16] The researchers conducted numerous interviews, observed current sign management processes, and reviewed related literature from other agencies. They generated a long list of possible alternatives that the State could pursue and then evaluated the impacts of each. They estimated that North Carolina had over three million signs on their 78,000+ miles of streets and highways under State, county, and local jurisdiction.

The report documented in detail many aspects of sign management. For example, they conducted a rigorous review of sign inventory and management software packages. They reviewed the implications of decisions related to the selection of sign sheeting materials over a 50-year life cycle. In this analysis, the costs of upgrading the State's 51,000 STOP signs from Type I to high-intensity sheeting (Types III and IV) and from Type I to microprismatic sheeting (Types VII, VIII, IX, and X) were explored. They showed that due to the longer life of higher-end retroreflective materials, an agency can actually save money through fewer replacement cycles over time. This was shown to be true to a point, as the option of using microprismatic sheeting costs more than the option of using high-intensity sheeting over time.

The report included estimates of the number of signs in the State by color group and generated estimates of the number of signs in each group that would not meet the proposed minimum levels, based on the data in Reference 6 (see Table 6). Although there are an estimated 74,639 non-compliant signs, this represents less than 3% of the total number of signs in North Carolina. Assuming that the non-compliant signs are replaced during normal sign maintenance activities, over a seven-year implementation period there would likely be very little impact on the agency.

The report identified a wide range of approaches for agencies to follow to improve night visibility of traffic signs. The various elements were packaged into strategies and cost estimates for each strategy were developed. The report recommended that the State implement a comprehensive sign management system that would incorporate an inventory of all signs. Further, a tort tracking system was proposed to monitor any claims against the State associated with inadequate signs. Several million dollars in costs would be associated with these recommendations.

This report concluded that the proposed minimum maintained sign retroreflectivity levels would have a significant cost impact on the State. But, when components of the implementation are evaluated, it is noted that the impacts included not only the cost of sign replacements, but also establishment of a state-of-the-art GIS-based sign inventory and management system and a tort claims tracking system. Since these systems are not required to meet minimum retroreflectivity levels, they should not be considered as a direct impact of this rulemaking.

4.4. Tort Liability

The North Carolina report attempted to address the concern of tort liability, which has often been cited by agencies as a primary concern, through a review of the legal liability of the State and its local communities under the North Carolina Tort Claims Act. The report noted that, for the thousands of tort claims against the State annually, only 45 claims were issued against the North Carolina DOT from November 2000 to October 2001, of which only eight directly cited sign maintenance or sign management issues. Of these eight claims, six were dismissed for various reasons. The report cited the need for the agency to maintain a formal sign maintenance and inspection system to prevent lawsuits and provide a sound defense.

It is not possible from this limited analysis to make any inferences about whether the proposed minimum maintained retroreflectivity levels for traffic signs will lead to increased tort liability. Further, each State has different laws related to State liability and limitations to claims, which affect tort impacts.

5. NATIONAL IMPACTS ASSESSMENT

5.1. Approach to Update the 1998 National Impact Assessment

The 1998 national impact assessment (Reference 6) described efforts to estimate the cost of bringing traffic signs into compliance with the proposed minimum maintained retroreflectivity levels across the nation, and developed a model to predict the costs to State and local agencies. The 1998 impact model has the following features:

- The density of various sign types per road mile, and their retroreflective condition, were compiled from data from two States and seven local agencies;
- Sign density distributions were translated to national levels by expanding the mileage in the study to the national mileage for similar roadways;
- Costs for sign face upgrading and replacement were derived from data on sign management processes gathered from 19 State and local agencies;
- Average values for sign size were used to estimate sign replacement costs;
- Data on sign retroreflectivity conditions were used to estimate the percentage of signs that did not meet the minimum levels specified in the 1993 tables; and
- Costs for sign replacement were based upon results of an agency survey (these results were noted to have a high degree of variability due to differences in agency practices and accounting methods).

The model was limited to signs manufactured with Type I and Type III sheeting. It was assumed that 50 percent of Type I signs would be upgraded to Type III, and all Type III signs that required replacement would be replaced with new Type III signs.

The model is considered fundamentally sound, but uses total sign replacement costs, and not the marginal cost of upgrading sign sheeting, to generate an estimated impact. These costs are believed to be an over-estimate of the impacts on State and local agencies since they are based upon full sign replacement costs outside of planned maintenance cycles for traffic signs.

Since there are no known recent studies that have led to new information on sign performance or the compilation of data on the retroreflectivity of existing signs, it was decided to use the same model to update the national impact assessment, with the following assumptions and revisions:

- It was assumed that the distribution of signs by type has remained essentially the same and that the sign density along State and local roads is similar to the conditions that existed when the 1998 impact assessment was conducted;
- Updated State and local mileage were obtained from Highway Statistics 2005;
- The assumption was made that Type III materials can be used to meet the minimum maintained retroreflectivity levels for the majority of signs; and
- Although proposed minimum maintained retroreflectivity levels have been updated, the current values are similar to the 1993 proposal, and thus it was assumed that there is no appreciable difference in the percentage of signs that need replacement.

5.2. Updated National Impact Assessment

The updated National Impact Assessment is intended to generate an improved estimate of the cost to State and local agencies of bringing the national sign system into compliance with the proposed minimum maintained retroreflectivity levels. This assessment includes an analysis of the marginal cost difference between sheeting materials in the sign face material costs for each subset of traffic signs. First, the model was used with weighted sign replacement cost factors that were scaled to reflect only the differential costs for higher performance sign face materials. This provides national impact estimates for regulatory, warning, and guide signs. Second, an estimate of the number of street name signs was generated and the costs associated with upgrading the sign faces for this subset of signs was computed. Last, the number of overhead guide signs was estimated and associated sign face upgrade costs were used to determine the cost impacts. The three estimates were then combined to determine the overall cost impacts. The methodologies, assumptions, inputs, and resulting estimates for each sign group are described below.

It is understood that there are several factors that affect the accuracy of the impact assessment. The most important are the actual number of signs that need to be replaced, and the distribution of signs by type along the roads. The numbers of signs that need to be replaced are based on agency reported data. These may represent proactive agencies, with lower than average percentages of non-compliant signs. The distribution of signs by type was also based on a relatively small sample set, which did not include every sign type. The 1998 study consolidated the sign types in large groups, as a means of reducing the possible errors due to missing sign types, but the data are still limited.

5.2.1. Regulatory, Warning, and Guide Signs

Previous estimates of the impact to bring sign systems into compliance with proposed minimum retroreflectivity requirements were based on total sign replacement costs, which included the costs for sign face materials, sign substrate, sign supports, and other elements. Since a key facet of the proposed rule is that agencies will be allowed to bring their signs into compliance over time, with a significant portion of sign replacements conducted during normal sign maintenance activities, the impact of the proposed rule is primarily due to the difference in cost of sign face materials. It is assumed that the most fundamental upgrade that agencies will select is to replace Type I sheeting with either Type III or Type IV sheeting. An additional impact is the conversion of the white legends and borders on post-mounted guide signs from Type III to Type VII, VIII, IX, or X sheeting. The total impact to State agencies is calculated using data on the four sign groups from Reference 6 (specifically the calculation of average sign size and the number of signs that need to be upgraded) and the current cost difference in sign face materials, plus the cost of upgrading sign legends. The results for State agencies are shown in and the results for local agencies in Table 8.

Table 7. Impact on State Agencies for Improvement of Sign Face Materials for Regulatory, Warning, and Post-Mounted Guide Signs

Sign Group*	Sign Size (ft^2)	Number of Signs Requiring Upgrade	$/$ft^2$	Upgrade Cost
Group 1	7	130,000	0.75	$682,500
Group 2	7	200,000	0.75	$1,050,000
Group 3	7	100,000	0.75	$525,000
Group 4	96	30,000	0.75	$2,160,000
Legends	9.6	30,000	2.00	$576,000
TOTAL				**~$5,000,000**

*Group designations are described in Table 6.

Table 8. Impact on Local Agencies for Improvement of Sign Face Materials for Regulatory, Warning, and Post-Mounted Guide Signs

Sign Group*	Sign Size (ft^2)	Number of Signs Requiring Upgrade	$/$ft^2$	Upgrade Cost
Group 1	7	1,000,000	0.75	$5,250,000
Group 2	7	440,000	0.75	$2,310,000
Group 3	7	580,000	0.75	$3,045,000
Group 4	96	10,000	0.75	$720,000
Legends	9.6	10,000	2.00	$192,000
TOTAL				**~$11,500,000**

*Group designations are described in Table 6.

Therefore, the cost impact for State highway authorities to upgrade all regulatory, warning, and post-mounted guide signs to meet proposed minimum maintained retroreflectivity levels will be approximately $5 million, and for local highway agencies will be slightly under $12 million.

An agency's past attention to signs will influence how many signs will need to be replaced. There will be costs in future years as currently acceptable signs age to the point that they need replacement.

5.2.2. Street Name Signs

The 1998 model did not include street name signs and there is no known source of data about the number and condition of these signs on the road network. To address this shortcoming, an analysis was undertaken using an estimate of 3 million intersections in the country, with approximately 10 percent of those signalized (estimate obtained from the FHWA's Office of Transportation Operations). This estimate has been regularly used in their analyses of traffic control needs. For this analysis, street name signage was considered to be different for signalized and unsignalized intersections with an average of eight large overhead sign panels assumed for signalized intersections and an average of six smaller signs assumed for unsignalized intersections.

It was assumed that 20 percent of all street name signs would need to be replaced, which is more than twice the percentage required for regulatory, warning, and guide signs. In addition, signs at signalized intersections will be upgraded from Type I to microprismatic sheeting, while signs at unsignalized intersections will use Type III or Type IV sheeting. The resulting estimate is provided in Table 9.

Table 9. Estimated Costs for Street Name Sign Improvements

Element	**Signalized**	**Unsignalized**
Number of intersections	300,000	2,700,000
Number of signs per intersection	8	6
Total number of signs	2,400,000	16,200,000
Number of signs requiring upgrade (at 20%)	480,000	3,240,000
Average sign size (feet)	8.0 x 1.5	2.5 x 0.75
Sign area (square feet)	12	1.88
Cost of upgrade (per square foot)	$2.00	$0.75
Total estimated sign upgrade cost	$11,500,000	$4,600,000
Approximate Estimated Total	**$16,100,000**	

The impact to upgrade street name signs at all intersections to meet the minimum maintained retroreflectivity levels is estimated to be approximately $16 million, with a $1.6 million cost per year under a ten year implementation period. Lacking any specific information on the distribution by agency type, it was assumed that the impact would be proportional to road mileage. Thus, the impact to upgrade street name signs would be approximately $3.3 million for States and $12.3 million for local agencies, with the remainder under Federal jurisdiction.

5.2.3. Overhead Guide Signs

The numbers of overhead signs are estimated in two manners: using data received from 16 States, and using the sign densities for post-mounted guide signs found in Reference 6. The States that responded to an inquiry through the various FHWA Division Offices represented approximately 30 percent of the State-maintained highway mileage. The overall sign density for overhead signs was just over 0.11 signs per mile. The sign densities for post-mounted signs for State and local highways, with values of 0.38 and 0.06 signs per mile, respectively, provided a much higher estimate of the number of overhead guide signs. Averaging the two numbers resulted in a national estimate of 280,000 overhead guide signs.

The impact of upgrading the legends on overhead guide signs was determined using an average overhead sign panel size of 12 by 8 feet, with the legend accounting for no more than 10 percent of the sign face. The estimate assumed that the sign background would remain Type III or Type IV sheeting, while legends are upgraded to Type VII, VIII, IX, or X sheeting. The impact of upgrading all overhead guide signs with microprismatic legends is described in Table 10.

Table 10. Estimated Costs for Overhead Guide Sign Legend Improvements

Element	Value
Number of Overhead Signs	280,000
Average Sign Size (feet)	12 x 8
Sign Area (square feet)	96
Legend Area (square feet)	9.6
Cost of upgrade (per square foot)	$2.00
Approximate Estimated Total	**$5,400,000**

The impact to upgrade the legends on all overhead guide signs to meet the proposed minimum maintained retroreflectivity levels is approximately $5.4 million, which would be spread over a ten-year implementation period. The distribution by agency type was assumed to be the same as for post-mounted guide signs, as discussed in Reference 6, which is approximately 65 percent State and 35 percent local agencies. Thus, the impact to upgrade overhead guide signs would be approximately $3.5 million for States and $1.9 million for local agencies.

5.3. Overall Costs

The overall impacts to State and local agencies can be estimated by adding the sign face improvement costs for each subset of signs – regulatory signs, warning signs, post-mounted guide signs, street name signs, and legends on overhead guide signs. Table 11 provides the individual and consolidated estimates.

Table 11. National Impact Assessment to Comply with Minimum Maintained Retroreflectivity Levels for Traffic Signs, by Sign Type and Agency Type

	Cost in Millions of Dollars		
Sign Types	**State**	**Local**	**Total**
Regulatory, Warning, & Guide Signs (7-Year Implementation Period)	5.0	11.5	16.5
Street Name Signs (10-Year Implementation Period)	3.3	12.3	15.6
Overhead Sign Legends (10-Year Implementation Period)	3.5	1.9	5.4
TOTAL	11.8	25.7	37.5
Annual Cost (Years 1-7)	1.4	3.1	4.5
Annual Cost (Years 8-10)	0.7	1.4	2.1

With implementation periods of seven years for regulatory, warning, and guide signs and ten years for street name signs and overhead guide signs, the annual impacts will be $4.5 million for years 1 though 7, and $2.1 million for years 8 though 10. There will be additional expenses in later years, as existing signs fall out of compliance and are replaced. However, many of these signs will likely not require upgrade, but will be replaced in kind during their normal servicing intervals. Also, the impact for the upgrade of overhead guide signs assumes that the legends on 100 percent of overhead guide signs need to be replaced, even though many States already use microprismatic sheeting for the legends. Thus, the estimated $37.5 million in costs that are directly attributable to the proposed rule are likely to be an over-estimation.

A 1992 survey conducted by the American Traffic Safety Services Association (ATSSA) reported that the total combined sign budgets for 37 State DOTs was $138 million per year; an average of $3.7 million per year per State. This implies a national total for the States alone of $185 million per year in 1992. Inflating this cost using the change in consumer price index from December 1992 to December 2006 (42.2 percent) results in an estimate of the total combined sign budget for the States of $263 million per year. The $1.4 million estimated additional annual costs for years 1-7 for State agencies would represent only a 0.5 percent increase in costs. Similar data are not available for local agencies. While their budgets may not provide as much funding per sign as is available to the States, the cumulative local agency budgets should still be commensurate with the greater number of signs under local jurisdiction. Thus, while it is not possible to generate a specific estimate of the percent increase in annual cost of signs for local agencies, it should be a relatively small percentage of the overall budget

6. CONCLUSIONS

The analysis described in this report provides an estimate for the national impact of the proposed rule for minimum maintained traffic sign retroreflectivity at approximately $37.5 million, which will be incurred over a period of several years. Using a 7-year implementation period for regulatory, warning, and post-mounted guide signs and a 10-year implementation period for street name and overhead guide signs, the annual impacts are estimated to be $4.5 million for years 1 through 7 and $2.1 million for years 8 through 10.

The single direct impact of the proposed rule is the increased cost to agencies of using sign face materials with higher retroreflective properties. While that difference is 100 to 133 percent of the present cost of sign face materials, it only represents a 3 to 7 percent increase in the total sign cost.

If agencies are allowed to bring their sign systems into compliance over multi-year implementation periods, as is proposed, there are many cost elements that were included in previous estimates that are not directly attributed to the proposed rule. Elimination of these cost elements results in a significant reduction in the impact of the proposed rule.

Improved retroreflective sheeting materials provide longer service life than some sheeting materials used in the past, which may result in agencies experiencing reduced sign maintenance costs over time.

Agencies that develop new or improved sign assessment and management programs may realize reduced service life costs as they fully utilize the service life of installed signs.

Existing nighttime visual inspection programs typically identify signs in need of replacement well before they reach a level of retroreflectivity that is below the proposed minimum maintained retroreflectivity levels. The minimum levels were based on research substantially conducted under dark rural conditions with no glare. The human observer will evaluate the sign in its actual surroundings, which are complex and usually different than those conditions under which the proposed minimum maintained retroreflectivity levels were developed.

Research has not yet been able to provide a quantitative estimate of the safety and operational benefits attributed to improved retroreflectivity of traffic signs. Due to the complexity of the driving environment, and a limited ability to understand how drivers acquire, process, and react to information, it is doubtful that the impact of any single traffic sign can be quantified. However, good signage for both day and night conditions is believed to promote improved safety and traffic flow.

Tort liability regarding sign visibility at night does not historically appear to have been a problem. While the proposed rule will give potential litigators “numbers” to use, improved assessment and management programs, if followed by the agency, usually provide an adequate defense.

Appendix A - Proposed Minimum Maintained Levels of Traffic Sign Retroreflectivity

Background:

In 1985, the USDOT was petitioned to require minimum levels of retroreflectivity for signs and pavement markings. In 1992, Congress directed the US DOT to "revise the MUTCD to include a standard for a minimum level of retroreflectivity that must be maintained for pavement markings and signs, which shall apply to all roads open to public travel." Since that time significant strides have been made in developing sound practical minimum requirements, as well as in means to facilitate their implementation. The information provided in this report represents one of the latest products of the FHWA's efforts**.**

Recent Research:

The FHWA has been involved in research investigating driver night visibility needs since the early 1980s. This research led to the publication of a report entitled "Minimum Retroreflectivity Requirements for Traffic Signs" (FHWA-RD-93-152, October 1993) which translated driver's needs for sign luminance for various types of signs and applications into minimum levels of retroreflectivity. Retroreflectivity was selected as the evaluation criterion since it could be conveniently measured in the field. The minimum retroreflectivity values recommended in the 1993 report were modified somewhat after workshops with practitioners in 1995. These requirements were published in 1998 in a report entitled "An Implementation Guide for Minimum Retroreflectivity Requirements for Traffic Signs" (FHWA-RD-97-052). In 1999, the FHWA initiated further research to define minimum requirements for sign types not covered in the 1993 report with a project entitled "Minimum Retroreflectivity Values for Overhead Guide Signs and Street Name Signs" (publication pending). This project developed a new analysis tool, incorporated newly acquired field luminance requirements data gathered from older driver subjects, and calculated minimum retroreflectivity requirements for overhead and street name signs.

In efforts to combine the results from the two research efforts, it became apparent that there was a need to revisit both research efforts to incorporate data that reflected current conditions. In 2000, the FHWA funded a project entitled "Updated Minimum Retroreflectivity Levels for Traffic Signs," (draft report December 2002). In this project, the basic inputs for the analytical derivation of driver luminance needs (translated to retroreflectivity measures) were updated. This included changes to reflect the characteristics of newer headlights, the capabilities of older drivers, the influences of larger-sized vehicles in the current fleet, the properties of sign materials that did not exist when the earlier research was undertaken, and other factors. A more powerful computer analysis tool was used to determine minimum driver retroreflectivity requirements. The project generated numerous detailed tables that reflected various sign positions, traffic speeds, and other factors. These tables were collapsed and consolidated to provide an easier-to-use benchmark. Table 1 provides the most recent version of the minimum requirements for traffic sign retroreflectivity. This single table combines the requirements for all color and sign applications, except for signs with blue or brown backgrounds.

Application:

Why have these minimums at all? Hasn't the FHWA indicated that they are really interested in better night visibility for drivers? It is believed that the minimum requirements that have evolved from the recent research provide useful benchmarks that are needed to support efforts by agencies to assess the night visibility of their in-place signs, determine those needing replacement, and apply more rigorous sign management programs.

Table 12. Minimum Maintained Retroreflectivity Levels

Sign Color	Sheeting Type①				Additional Criteria
	Beaded Sheeting			Prismatic Sheeting	
	I	II	III	III, IV, VI, VII, VIII, IX, X	
White on Green	W*; G ≥ 7	W*; G ≥ 15	W*; G ≥ 25	W ≥ 250: G ≥ 25	**Overhead**
	W*; G ≥ 7	W ≥ 120: G ≥ 15			**Ground-mounted**
Black on Yellow or Black on Orange	Y*; O*	Y ≥ 50: O ≥ 50			②
	Y*; O*	Y ≥ 75: O ≥ 75			③
White on Red	W ≥ 35: R ≥ 7				④
Black on White	W ≥ 50				—

① The minimum maintained retroreflectivity levels shown in this table are in units of $cd/lx/m^2$ measured at an observation angle of 0.2° and an entrance angle of -4.0°.
② For text and fine symbol signs measuring at least 1200 mm (48 in) and for all sizes of bold symbol signs.
③ For text and fine symbol signs measuring less than 1200 mm (48).
④ Minimum Sign Contrast Ratio ≥ 3:1 (white retroreflectivity ÷ red retroreflectivity).
* This sheeting type should not be used for this color for this application.

Bold Symbol Signs

- W1-1, -2 – Turn and Curve
- W1-3, -4 – Reverse Turn and Curve
- W1-5 – Winding Road
- W1-6, -7 – Large Arrow
- W1-8 – Chevron
- W1-10 – Intersection in Curve
- W1-11 – Hairpin Curve
- W1-15 – 270 Degree Loop
- W2-1 – Cross Road
- W2-2, -3 – Side Road
- W2-4, -5 – T and Y Intersection
- W2-6 – Circular Intersection
- W3-1 – Stop Ahead
- W3-2 – Yield Ahead
- W3-3 – Signal Ahead
- W4-1 – Merge
- W4-2 – Lane Ends
- W4-3 – Added Lane
- W4-5 – Entering Roadway Merge
- W4-6 – Entering Roadway Added Lane
- W6-1, -2 – Divided Highway Begins and Ends
- W6-3 – Two-Way Traffic
- W10-1, -2, -3, -4, -11, -12 – Highway-Railroad Advance Warning
- W11-2 – Pedestrian Crossing
- W11-3 – Deer Crossing
- W11-4 – Cattle Crossing
- W11-5 – Farm Equipment
- W11-6 – Snowmobile Crossing
- W11-7 – Equestrian Crossing
- W11-8 – Fire Station
- W11-10 – Truck Crossing
- W12-1 – Double Arrow
- W16-5p, -6p, -7p – Pointing Arrow Plaques
- W20-7a – Flagger
- W21-1a – Worker

Fine Symbol Signs – Symbol signs not listed as Bold Symbol Signs

Special Cases

- W3-1a – Stop Ahead: Red retroreflectivity ≥ 7
- W3-2a – Yield Ahead: Red retroreflectivity ≥ 7, White retroreflectivity ≥ 35
- W3-3 – Signal Ahead: Red retroreflectivity ≥ 7, Green retroreflectivity ≥ 7
- W3-5 – Speed Reduction: White retroreflectivity ≥ 50
- For non-diamond shaped signs such as W14-3 (No Passing Zone), W4-4p (Cross Traffic Does Not Stop), or W13-1, -2, -3, -5 (Speed Advisory Plaques), use largest sign dimension to determine proper minimum retroreflectivity level.

Appendix B – Summary of Reported Impacts

Agency/Location	Reported Impacts	Comments	Implications
NCHRP 346 (7)	• Low level criteria will have minor impact over a 10 year implementation • Many agencies have implemented sign management processes • Cost model can be useful to assess impacts over differing sign system conditions	• The low level criteria evaluated used values similar to those most recently proposed • The cost factors used in the analysis reflect costs for that time period • Some costs have gone down, few materials included • Based upon a broadly gathered sample of signs. • Overhead and street name signs not addressed	• Minor impact conclusion • Concluded that impact costs should not include process improvement costs • Supports long term implementation to minimize costs to agencies • Cites need for research on field methods, degradation rates, and liability issues
USDOT Highway Safety Evaluations (14)	• Sign projects are among the highest payoff safety projects based upon evaluation reports submitted between 1978 and 1996. • B/C ratio for sign projects 22.4 to 1	• Conclusions based upon several years of data, but reporting process was not uniform. • The data does not isolate the nature of sign improvements, so the relation to nighttime visibility cannot be determined.	• Evidence that improved signing reduces crashes leading to a highly positive safety benefit.
Texas DOT (8)	• Texas DOT sign crews reviewing 50 signs in training program suggested replacement of more signs than might be necessary under the proposed FHWA minimum requirements. • Findings raised questions about the appropriateness of the contrast ratio aspect of the requirements.	• The AASHTO Task Force participated in these exercises and similarly found the need to replace about three times more signs than would needed to satisfy the minimum levels. • Usefulness of the visual inspections method led to the proposal that agencies be allowed to use it instead of measurement methods. • TF agreed that it may be appropriate to alter the contrast criteria.	• The results suggest that the minimum values will not affect agencies as much as might be expected. • The field exercises demonstrated the value of night inspections to find a multitude of possible problems that adversely affect night visibility.
FHWA Impacts Report (5)	• Nineteen agencies provided feedback on survey about sign management efforts in State & local agencies. • They provided feedback on the expected impacts of the new requirements. • Seven of these agencies provided data for a sample of their signs that was used to estimate overall impacts. • Estimates of the impact led to the conclusion that the requirement would not have major impacts if implemented over a long period.	• Impacts analyses based upon estimates of the number of signs based on a small sample. • The sample was obtained from agencies who volunteered to provide the data leading to possible bias. • The minimum levels considered were similar to the most recently proposed levels. • Survey feedback indicated a widespread range of perceived impacts and highly variable costs.	• This study added evidence that the impacts of the requirements would be minor. • The range of perceived costs is great. Efforts may be needed to assist agencies in estimating more specifically their costs.

Indiana DOT (9)	• Retroreflectivity was field measured for a sample of signs in five parts of the State. • Data indicated that more than 90% of the signs met or exceeded the minimum levels proposed by FHWA in 1998. • Data analysis found no effect for cleaning of signs before measurement and no effect associated with differences in environmental factors in different parts of the State. • Recommendation to the State to increase the replacement cycle for all but stop signs to 12 years.	• The data collection did follow ASTM procedures, but it is not believed that this had an impact on the conclusions. • The agency only uses Type II material, so the results are less generally applicable.	• Impacts of new requirements considered low. • Good example of how data can be used to justify extending replacement cycle. • Useful insights on wiping effects that can be included in the procedures.
Mendocino, CA (15)	• Road safety reviews which focused on sign and markings led to crash reductions savings in excess of $11 million. • B/C ratio of 1:159 reported. • Program cost were approximately $160,000, but calculated crash savings ranged from $12.8 to $23.7 million.	• This study relied on CHP data which covered a ten year period. • There was a limited number of sections, but the safety experience of State roads in the area were used as a control. • The effects of signing and marking improvements was not isolated.	• Some skepticism is needed relative to the order of magnitude of the benefits, but it there would seem to be ample evidence of the value of good delineation and signing. • Detailed of the review process and reasons for 3 year frequency should be pursued.
North Carolina DOT (11)	• The agency undertook an extensive analysis of current sign practices and options available. • It was estimated that there are over 3.2 million signs on the streets and highways in the States. • Estimates of sign condition were generated from sample studies. Less than 10% of the State's signs were believed to be below the minimum levels. • The State already conducts regular night sign inspections. • After considering a broad range of alternatives, it was recommended that the State undertake a comprehensive sign inventory and develop a full-function SIMS. Price over $4 million.	• The report contains a good summary of information on sign inventory and management systems. • A lot of options considered in the development of NCDOT strategy. • Useful critiques of estimating tools. • Good long-term life-cycle cost analyses.	• Recommendations suggest a large impact on the State, but the bulk of the costs are associated with putting a comprehensive SIMS in place. • Less than 10% of their signs estimated to need replacement.

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