Maintaining Traffic Sign Retroreflectivity: Impacts on State and Local Agencies (Draft)

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16. Abstract

This report analyzes the impacts that might be expected from the adoption of proposed minimum maintained levels for the retroreflectivity of traffic signs to improve their night visibility. The report attempts to study 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. In addition, the report attempts to determine if there are quantitative safety and operational benefits associated with sign improvements to enhance night visibility.

The report is primarily a summary of other 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 was seen as the major source of increased costs. The degree of cost impact to state and local agencies would be a function of the condition the existing signs, sign material use practices, and processes 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, since no better data exists, that the distribution of non-compliant signs (i.e., signs having retroreflectivity levels below the proposed minimum levels) on the nation's roads would remain 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 cost estimates updating those generated in 1998 indicate that state and local agencies would be likely to incur impacts of $51.1 to $73.3 million per year for 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 estimates are based upon the added cost of higher performance sign materials and replacement as part of normal sign maintenance cycles. Low and high cost estimates where generated to reflect the options state and local agencies have in selecting sign materials.

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. 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 currently planned maintenance cycles. Slight additional costs for personnel and training might be incurred initially.

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Preface

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 traffic control devices (e.g., designs, materials, and technology) to meet 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 fifty percent of the traffic fatalities occur at night despite lower volumes of traffic. This over-representation of night fatalities has persisted for more than twenty years. The nighttime crash rate has been estimated to be three times that during the day [1]. The FHWA is, therefore, focusing more attention on the nighttime crash problem and reviewing the influences of highway design and control on it.

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, make drivers aware of the hazards, and facilitate their abilities to navigate the road system.

Over the past five decades, means to enhance the night visibility of traffic signs have evolved. The concept of minimum maintained levels of traffic sign retroreflectivity was advanced to provide a threshold that represented a basic level of driver need. Retroreflectivity, the property of a material to redirect light back toward the source of the light (and hence the driver), represents a convenient measure of night visibility. It is a measure that is well developed and supported by the American Society for Testing Materials (ASTM) which has established both testing procedures and manufacturing requirements for retroreflective materials and measurement equipment. This measure can be used in varying ways to support the different methods and procedures an agency may choose to employ to assess and manage the retroreflectivity of traffic signs. The FHWA is developing guidelines for methods and procedures that can be used by highway agencies to maintain in-place traffic signs above the minimum levels. It is hoped that these initiatives will be useful in bringing inadequate (e.g., low night visibility) traffic signs to a level of retroreflectivity that meets the needs of drivers and leads to greater attention by agencies on maintaining the retroreflectivity of traffic signs.

An important test of the practicality or viability of new guidelines 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 millions of signs. Many 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, but often the resources available for this role are limited. This impacts analysis takes a broad view of impacts as reflected in the concerns recently expressed by agency personnel and studies the extent of impact associated with the concerns.

This impacts analysis assumes that rulemaking efforts will lead to minimum maintained levels of traffic sign retroreflectivity for traffic signs and that state and local agencies will be responsible for bringing their sign systems (in-place signs) into compliance.

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 hard to establish average costs. Second, it is hard 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 impacts they will face.

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1.0. INTRODUCTION

1.1. Night Visibility of Traffic Signs

Traffic signing is a critical component of any road because it is the medium by which the highway agency communicates regulatory, warning, guidance, or other information to road users (e.g., motorists, bicyclists, and pedestrians). This means that traffic signs must be detectable and legible to the users at a sufficient distance commensurate with their purpose. Traffic signs are designed to satisfy detectability and legibilty objectives by their basic size, color, size and style of letters and numerals, application of symbols, and the materials used for the background and legend (e.g., retroreflective sheeting). These critical features of any sign must meet the driver's needs under both day and night conditions.

For over 40 years MUTCD has required that signs be retroreflective or illuminated to make signs visible at night [2]. A variety of sign materials have evolved to provide options for sign designers 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.

It is well understood that traffic signs deteriorate over time. 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 the STOP sign, fading of the red background may make the sign less detectable and legible, even during daytime. Deterioration can occur for a variety of reasons ranging from the environment in which the sign exists to poor workmanship in the fabrication and 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 without 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.

This document addresses the impacts of the implementation of proposed changes to the MUTCD that would set minimum levels of retroreflectivity for in-place traffic signs that agencies would be expected to maintain. This proposed change seeks to improve the night visibility of traffic signs by requiring agencies to replace all signs (in designated groups) that do not meet driver needs. Obviously, 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 the current state of an agency's sign system. The impacts on an agency will be further influenced by the methods used to assess the existing sign system as well as maintain it over time.

1.2. Agency Concerns about Impacts

About 75 percent of the public roads in the United States are maintained by local agencies (municipalities, counties, parishes and highway districts), 21 percent by state agencies, and the remainder by Federal agencies [3]. Therefore, it is imperative that the impacts of the proposed changes to the MUTCD to set minimum maintained levels of traffic sign retroreflectivity on state and local agencies be carefully assessed.

Impacts can take many forms and they can be considered positive or negative. For this analysis, the concerns identified by participants in a series of four workshops on nighttime sign visibility conducted for the FHWA at locations across the country in 2002 were used as a starting point (2). About 100 state and local officials participated in these workshops that 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 the new levels would have on their agencies. It needs to be stressed here that many of the impacts cited were perceived. Most agencies had not initiated thinking about how they would determine their degree of compliance and/or implement more rigorous sign management processes to address night visibility needs. The major concerns expressed by the participants are listed in Table 1 [4].

It should be noted that most of the participant discussion in the workshops focused upon the negative impacts of implementing new provisions (minimum levels) for retroreflectivity of traffic signs. The extent of negative impacts (if any) will vary from agency to agency, depending upon the current sign replacement practices in individual agencies. The negative impacts are expected to be smaller for those agencies that currently have proactive sign replacement 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 the new minimum levels would be useful in getting their agencies to increase funding for sign improvements. The workshop participants suggested that the new minimum levels should not be imposed without Federal funding assistance. The impacts analysis did not consider this or other means to offset the costs of sign inspection, replacements, and long-term maintenance of adequate night visibility.

A broad spectrum of concerns is summarized in Table 1. While these can all be translated into dollar figures, it is not easy to generate reliable estimates for some factors and others for which it is unnecessary. The report is organized to address questions associated with the concerns at increasingly higher degrees of detail. Chapter 2 addresses questions about the costs impact for individual signs. For example, how much will need to be spent on sign face materials? Chapter 3 addresses questions at the agency level. For example, how many in-place signs do not meet the minimum levels? And, what will be the impacts on agencies relative to implementing and administering processes and practices to comply with the proposed new rule? The national impacts and tort liability concerns are addressed. Chapter 4 attempts to

Table 1 – Summary of Participant Concerns from FHWA Sign Workshops in 2002 [4]

- 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 (3) 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.

determine if there are quantifiable safety and operational benefits that can be attributed to improving the night visibility of traffic signs? Through these chapters the participant's concerns will be addressed. Chapter 5 then provides a summary and conclusions.

1.3. Background and Assumptions

This analysis of the impacts of proposed new levels for minimum maintained retroreflectivity for traffic signs follows an earlier FHWA effort on the same topic completed in 1998 entitled "Impacts on State and Local Agencies for Maintaining Traffic Signs within Minimum Retroreflectivity Guidelines" [5]. This effort updates the 1998 report and expands it to address concerns expressed by the 2002 workshops participants. The primary source of information for this effort was 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 a TRB paper by Carlson, et al [6].

It is important to emphasize that the proposed minimum retroreflectivity levels for traffic signs presented in Appendix A may best be considered a "rough threshold." There is variance associated with each minimum value that results from the assumptions about viewing position and conditions, modeling, and aggregation. 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 driver needs. It must be remembered that there are many factors that may influence the visibility of a particular traffic sign at night to a driver.

The impacts analysis was conducted under the assumption that (following feedback received from the recent workshops, inputs from AASHTO, and internal staff discussions) the rulemaking would:

- Use the minimum maintained levels of traffic sign retroreflectivity cited in Appendix A.
- Provide State and local agencies a 7 year time frame for regulatory, warning, and guide signs and a 10 year time frame for street name and overhead guide signs to bring their sign systems into compliance.
- Give agencies the flexibility to use one or more of the various methods for assessment and management.
- Allow some signs or sign categories (e.g., parking series) to be excluded from the provisions.

Under these assumptions, the impacts are distributed over a long-enough period of time to allow most sign replacements to take place under normal maintenance cycles.

2.0. Impacts on the Costs of Traffic Signs

The most basic way to look at the impacts of the proposed minimum maintained levels for traffic sign retroreflectivity is to analyze the changes in costs 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 each sign as a result of the materials, labor, and equipment needed. The major elements include.

Sign Materials

- Substrate
- Post or structure
- Sign face materials
- Sign foundation
- Sign hardware
- Sign protection treatments (e.g., anti-vandalism parts)
- Ancillary equipment (e.g., illumination equipment)

Sign Fabrication

- Legend cutting devices
- Pre-fabricated signs
- Ancillary sign labeling
- Fabrication devices

Sign Inventory Control

- Inventory control labeling and logging
- Procurement certification
- Stock labeling & control

Sign Maintenance

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

Sign Crew Wages & Benefits

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

Illumination

- Power costs
- Lighting hardware & wiring
- Maintenance of lighting equipment

Training

- Initial training
- Incremental training
- Certification

In analyzing the impacts, it is necessary to isolate those elements of costs that are truly affected by the new minimum levels for retroreflectivity of traffic signs. On the assumption that agencies will be able to spread the efforts to upgrade non-compliant signs over the 7-year implementation period, the most significant additional cost becomes that of the sign face materials. Associated with the above assumption is that replacements will take place under planned maintenance cycles. Thus, there should be no additional costs to the agencies for the physical replacement of signs. There may be additional costs to agencies for equipment modifications to work with higher type materials, time to spot check retroreflectivity values, and/or conduct incremental training for staff on working with these materials. It is difficult to estimate the magnitude of these 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 cost impacts associated with improving the night visibility of a sign is largely related to the differential in the cost of the sign sheeting material selected. There is only 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 differentials for available materials by ASTM designation. These numbers reflect the upward side of the various reported costs for available sign materials. For example, the increase in unit cost in going from a Type I material to a Type II can be noted to be $0.25. This translates to a cost increase of 25%.

Table 2. Comparison of Sign Face Upgrading Costs (Additional Cost / Percentage Change)

Material	Unit Cost	Type I	Type II	Type III	Type VII	Type VIII	Type IX
Type I	$1.00	------	$0.25 (25%)	$0.95 (95%)	$2.50 (250%)	$3.00 (300 %)	$3.25 (325%)
Type II	$1.25		------	$0.70 (56%)	$2.25 (180%)	$2.75 (220%)	$3.00 (240%)
Type III	$1.95			------	$1.55 (80%)	$2.05 (105%)	$2.30 (118%)
Type VII	$3.50				------	$0.50 (14%)	$0.75 (21%)
Type VIII	$4.00					------	$0.25 (6%)
Type IX	$4.25						------

Upgrades to Type III material with increases of about $0.70-0.95 are more likely. For a typical 36"x 36" sign, that would translate to $8.55 more in cost for the sheeting material. This translates to a 95% increase in the cost of the sheeting materials for the sign (from $9.00 to $17.55). Total costs of $150-200 are reported for each installed sign, which implies that the $8.55 increase in sheeting cost translates to a 4-6% 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 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 is its life-cycle cost under which the total cost is distributed over the years of useful life that the signs will provide. Generally, signs are expected to provide adequate detectability and legibility for 7-15 years, but there are no specific criteria or models that can definitively predict service life at this time. 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-inch warning signs. Three materials are considered for these signs; Type X, Type Y, and Type Z. Assume these materials vary in cost and expected service life as shown in Table 3. For a thirty-year life cycle, it would be necessary to replace Type X signs five times after the initial installation at time "0." The Type Y materials would require two replacements after the initial installation and the Type Z material only one replacement. The cumulative sign sheeting costs shown in the second to last column indicate that it might actually save the agency money to select a higher cost material for long-term savings (i.e., Type Y costs less than Type X). The most dramatic outcome occurs when the sign replacement costs are added to the sign sheeting costs. An average sign replacement cost is about $150. This covers the crew labor, travel time, miscellaneous hardware, administrative expenses, and other costs. It is incurred each time the sign material reaches the end of its useful life. That occurs six times for Type X material in this example, but only three times for Type Y, and twice for the Type Z material. The total costs of the sign and the replacement operation are shown in the last column. Clearly, what appears in the beginning to be the more expensive option is the cheaper option in the end. In reality, the costs in this example would increase due to inflation over time and external changes would be likely to affect the service life or unit costs of the materials, but unless changes in these factors were substantial, it is not likely that the best strategy would change.

Table 3 – Example of Life Cycle Costs for Various Materials

Example Sheeting Material	Unit Cost	Expected Sign Life (years)	Time Periods (years)						Sign Sheeting Costs	Total Sign Costs
			0	5	10	15	20	25		
Type X	$1.00	5	$9,000	$9,000	$9,000	$9,000	$9,000	$9,000	$54,000	$954,000
Type Y	$1.95	10	$17,550		$17,550		$17,550		$52,650	$502,650
Type Z	$3.50	15	$31,500			$31,500			$63,000	$363,000

2.4. Factors Influencing Sign Costs

It is clear that some agencies are likely to experience higher costs for sign sheeting materials. Initial cost increases may even be higher if agencies opt to use the higher performance materials. There are also a number of things that can influence the unit sign costs to an agency. These include:

- The number and size of large and overhead guide signs in a jurisdiction. There is no good estimate of the number of these signs and since they are individually designed it is harder to estimate their costs.
- The initial condition of the sign system in an area. If a large percentage of the signs are over ten years old, it is likely that a massive sign replacement program will be necessary initially.
- Degree of sign upgrading that is chosen.
- Future changes in sign material costs, including competition-induced changes in prices.
- Methods used to procure sign materials. In some states, local agencies can purchase sign materials from the state schedule and take advantage of quantity discounts.
- 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.
- Reducing the number of signs.
- Applying the minimum requirements to fewer categories of signs.
- Development of new sign materials and technologies.

Changes associated with one or more of these factors will influence the cost perspectives.

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 implementing 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 their driving public. For example, retirement communities may wish to use brighter signs to better accommodate older drivers. It is hoped that agencies will continue or adopt higher "desirable" levels to maximize the safety and mobility benefits from traffic signs.

3.0. Impacts on State and Local Agencies to Maintain In-Place Traffic Signs

It is also possible to assess the impacts of the proposed minimum maintained levels for traffic sign retroreflectivity at the agency level. The following sections 1) identify the costs faced by agencies to manage their sign systems, 2) summarize the findings of earlier national analyses of impact, 3) describe the results of different studies conducted recently by state DOTs, 4) update previous estimates of sign replacement cost, and 5) discuss tort liability issues for agencies. The overall costs to an agency to manage their sign system are a function of the number, density, and condition of existing signs in a jurisdiction as well as the processes that 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 Process Costs

Each state or local highway agency has a sign management process that is used to add, maintain, remove, modify, or otherwise take care of 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) the agreements with other internal departments, external agencies, and even private sector manufacturers, suppliers, contractors, and consultants, 4) the history of sign practices in the area, and 5) other factors. These processes may vary from information-driven systems that allow field staff to generate work orders on their 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 signs in-place, and resources of an agency imply that the cost impacts of implementing any new MUTCD provisions will be greater for those agencies that have not paid attention to their sign systems. For example, an agency that has freeway segments is likely to have many large overhead signs to install and maintain. Their costs of doing business are likely to be higher than for an agency responsible for a bedroom community that is comprised primarily of residential streets that does not have to deal with overhead signs.

There are various methods that an agency may use to maintain minimum levels of traffic signs retroreflectivity in its jurisdiction. These methods can be loosely categorized as assessment-based or managed replacement. Under assessment-based replacements, evaluating each sign on a periodic basis assesses the adequacy of the retroreflectivity of in-place traffic signs. Signs not in compliance with minimum levels, or likely to fall out of the compliance range before the next assessment, are scheduled for replacement. Managed replacement may be considered a "no look" approach to sign maintenance. Information about each sign is used to determine when its useful life is over and work orders are generated for sign replacement. Computerized systems are typically used to drive this approach, but they are not required. The methods associated with these approaches 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 - Data on date of installation is labeled on each sign or recorded in a database. 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 life expected for signs in the type-group or area.
- 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 or implementation costs and the annual costs to operate. The nature of sign management processes in an agency and current status of the sign system will dictate the degree of need for initial assessments and replacements.

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

- Inventory / Assessment Costs
  - Field equipment
  - Crew deployment
  - Vehicles
  - Safety apparel and equipment
  - Data forms or logging equipment
  - Logistics management
  - Inventory updates
- Data processing
  - Data entry & verification
  - Linking data to location referencing system
  - Material inventory control labeling and support systems
  - Data back-up, archiving, and recovery costs
- Software systems
  - Sign inventory software
  - Sign management software
  - Software upgrades and maintenance
  - Staff training
  - Server and work stations
  - Field devices
- Work Order Processing & Tracking
- Warranty Monitoring
- Salvage & Recycling

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

It is important to note however, that sign inventories and sign management software is not strictly necessary for an agency to get its sign system into compliance. Inventories and management tools (e.g., software to schedule sign replacements for the next funding cycle) can be very important to a cost-effective sign management process. For example, an inventory summary of all signs on streets in a given corridor allows a simple check-off of reasonable night visibility in drive-by night inspections, but it would also allow missing signs to be readily noted.

It must be assumed that state and local highway agencies are endeavoring to conform to the MUTCD and are therefore designing and installing signs in compliance with its provisions. It is important to note here that the MUTCD already has provisions for the inspection (day and night) and maintenance of traffic signs.

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

- The nature of the sign management process employed by the agency and the amount of process enhancement needed.
- The nature of methods selected for the enhanced sign management process (e.g., developing a sign inventory).
- Labor rates and work rules (e.g., nighttime inspections may require a steep overtime increment to the hourly wage rate).
- Methods used to procure sign materials.
- Decisions to fabricate signs or buy pre-fabricates signs.
- Degree of privatization.
- Strategic alliances between agencies to procure materials and services.
- Using larger signs to offset the need for improved legibility.
- 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.

Changes associated with one or more of these factors will influence the cost perspectives for a given agency, making it impossible to assess impacts.

3.2. Previous Impacts Analyses

In the efforts to develop the concept of minimum levels for traffic sign retroreflectivity there were two attempts to determine the impacts of the implementation of the requirements. In the first case, the effort focused on determining how stringent the requirements could be. In the second effort, the impacts of the minimum levels proposed in 1998 were assessed using data from a sample of state and local agencies. The findings of these efforts are described in the following sections. Since the specific proposed minimum levels have not varied greatly, the findings of these previous efforts are believed to be relevant.

NCHRP Report 346 "Implementation Strategies for Sign Retroreflectivity Standards" [7]

Under NCHRP Project 5-11 "Implementation Strategies for Sign Retroreflectivity Standards," the impacts of alternative implementation strategies were investigated (5). In this

effort, two sets of acceptance criteria were considered over varying 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 8000 signs (red, green, white, and yellow signs) in 28 counties in 26 states. Associated with this sample was 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 their retroreflectivity levels across city, county, state, and town classifications. The data also provided estimates of the distribution of signs by area and associated sign densities.

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

- 33% of the states had sign inventories, as did many city and county agencies,
- Over 90% of the inventory systems included information on sign type,
- More than 75% of the inventories included installation or replacement date information,
- More than 50% of the inventories had sheeting material type data (this may not have been a specific item in many inventories since there were limited types available and agency policy may have dictated blanket use of one type), and
- Sign fabrication and maintenance costs were captured, and reason for sign replacement was isolated.

Various estimates were generated from the survey results for use in the economic analyses.

The economic analyses methodology involved expanding the sample for each of the jurisdictions based upon the area type, mileage of highways, 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 added for each type of agency to assess the impacts by type of agency. Various stratifications were tested to determine the cost impacts.

This study considered two sets of criteria for nighttime sign visibility (based on retroreflectivity) as shown in Table 4. The most recent proposed values are also provided for the corresponding categories. The proposed 2002 values in their final consolidated state are generally higher, but these values span a broader range of materials than was considered in the NCHRP study. The values associated with material Types II and III from the pre-consolidated tables from recent updates are in parenthesis. For most of the color categories, the values are similar.

Table 4 – Comparison of Minimum Levels Used in NCHRP Analyses and Updated Minimum Levels.

Sheeting Color	NCHRP Min.Retroreflectivity Values		2002 Proposed MinimumValues	
	Lower Value	Upper Value	Final	Pre-Consolidated
Red	8	21	7	(7)
Yellow	20	60	50/75	(30-50/45-65)
Green	8	10	15	(7/15)
White	35	70	50	(45)

This research concluded that at the lower criteria on 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 notes that the findings are based upon a "sample" of signs in the various jurisdictions, that overhead and street name signs are not included, and that averaged estimates of the various costs for sign maintenance were used. Thus, the costs (and hence 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. This research further noted the need for research on the deterioration of retroreflective properties, the development of field methods, and analyses of the liability costs to agencies of inadequate signing.

It is important to point out that the findings of this study only relate to Type II and Type III sheeting materials which were the most widely used at the time. It can be inferred that since the newer microprismatic materials have higher costs (see Table 2), the resultant cost impacts on agencies would be higher. The results indicate that for the lower level criterion (which are close to those values most recently proposed) the impacts on an agency for sign replacement over a ten-year period would be small.

FHWA Impacts Analyses [5]

In 1998, the FHWA published a report entitled "Impacts on State and Local Agencies for Maintaining Traffic Signs within Minimum Retroreflectivity Guidelines." This report summarized the findings of a survey of 19 state and local agencies relative to their sign management processes and expectations of the new guidelines for minimum maintained levels traffic sign retroreflectivity. 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, agencies estimated that the percentage of signs needing replacement to range from 1 to 61 percent based upon specific types of signs. The highest percentage related to the special needs of red STOP signs. Certainly, the degree of maintenance by the agency over time was a factor that would imply higher rates of replacement for those agencies that have not done a good job maintaining their sign system. 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), the purchase of retroreflectometers and new vehicles, and 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. It is important to note that the data gathered for this analysis found only limited application of sign materials other than Types I, II, and III. Since higher performance materials (i.e., Types VII, VIII, & IX) have higher costs, the degree of impact would be higher where these materials are used for all other things being equal.

It was concluded from the analysis of the data gathered for sign conditions in 1994 that about 5% of the signs under State jurisdiction and 8% of the signs under local jurisdiction would not meet the minimum requirements. Based upon the estimated sign replacement costs, bringing all signs in the U.S. into compliance would cost agencies $166 million per year in 1994 dollars ($32 million for state agencies and $144 million for local agencies). This effort did not explicitly analyze costs over varying implementation periods, but noted that replacement over a longer period of time would be the best approach.

The minimal impacts reported in the 1998 study are consistent with the previously cited report. The estimated 5-8% of the signs would need to be replaced is lower than the basic replacement rate that would be assumed if the agency had a 10-year replacement program (i.e., 10% of the signs would be replaced each year). Further, night visibility can be enhanced by upgrading the retroreflectivity of those signs needing replacement due to vandalism, knock downs, or changing traffic control schemes.

3.3. State Agency Impacts Analyses

There have been reported efforts by state DOTs to assess the impacts of the proposed new minimum levels on their agencies. These have taken different approaches. A summary of these efforts is provided below.

Texas DOT [8]

A study conducted by the Texas Transportation Institute 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 results from the ability to observe other factors that

are not captured by using retroreflectometers. In this effort, the uniformity of luminance over the sign face was a focus of attention. Other damage and the influence of the sign's environment that may contribute to its visibility at night were also noted.

This study confirms that there are often clearly obvious problems with the visibility of signs at night. It further confirms that non-measurement approaches for assessing signs are effective.

Indiana DOT [9]

The Indiana DOT contracted Purdue University to help them determine the likely cost impacts of new FHWA regulations on their sign management program. Essentially, the state only uses Type III sign sheeting materials. They rely on manufacturer's warranties and have established a ten-year replacement cycle for their signs. The Purdue researchers reviewed the minimum retroreflectivity provisions of the 1998 FHWA report entitled "An Implementation Guide for Minimum Retroreflectivity Requirements for Traffic Signs [10]." The team then 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 1613 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 values corresponding the type and size of sign as published in the 1998 FHWA report. Based upon the sample, it was concluded that:

- 98% of the signs in the field should not only meet, but also exceed the proposed FHWA minimum retroreflectivity levels for any speed or size of sign.
- There is degradation of retroreflectivity (in this case for ASTM Type III materials) as signs age and there are differences by color of the sign. The red signs showed the greatest degradation of retroreflectivity.
- There is no statistically significant difference in the retroreflectivity values for wiped versus un-wiped signs. This would suggest that this step might be deleted from procedures to measure sign retroreflectivity.
- 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., 12 year replacement cycle).

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

North Carolina DOT [11]

In 2000, the North Carolina DOT contracted with the North Carolina State University to investigate the impacts of the proposed FHWA minimum levels for traffic sign retroreflectivity. The researchers conducted numerous interviews, observed sign management processes at work,

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 documents 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 fifty-year life cycle. In this analysis, the cost of upgrading the state's 51,000 STOP signs from engineer grade, to high intensity or diamond grade sheeting is explored. They show that due to longer life of the higher-end retroreflective materials an agency can actually save money through fewer replacements cycles over time. This was shown to be true to a point, as the diamond grade materials option costs more than the high intensity over time.

The report includes estimates of the number of signs in the state by color group and it generated estimates of the percentage of signs in each group which would not meet the proposed FHWA minimum levels. These percentages are shown in Table 5. In no case, does the percent exceed 10 percent. Again, ten percent replacement is seen as a normal level for agencies operating on a ten-year replacement cycle. Assuming that the non-compliant signs were replaced within the implementation period, there would likely be very little impact on the agency.

Table 5 – Summary of the Estimated Replacement Needs for North Carolina by Jurisdiction and Sign Group.

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

The report identifies a wide range of approaches for agencies to improve night visibility of traffic signs. The various elements were packaged into strategies and costs estimated for each strategy. The report recommends that the state implement a comprehensive sign management system that will incorporate an inventory of all signs. Further, a tort tracking system is proposed to monitor any claims against the state associated with inadequate signs. Several million dollars of cost are associated with these recommendations.

This report concluded that the impacts of the proposed minimum maintained levels for sign retroreflectivity would have a very significant cost impact on the state. But, when the components of implementation cost are investigated, it can be noted that all costs for sign replacements through the implementation of a state-of-the-art GIS-based sign inventory and

management system and a tort claims tracking system are included. Since these systems are not required to meet the retroreflectivity minimum levels, these costs should not be included. It was also noted that North Carolina has been conducting night inspections of its signs for some time. It was not clear whether similar inspections are undertaken by the local highway agencies as well.

3.4. Updated National Impacts Analysis

The 1998 FHWA report entitled "Impacts on State and Local Agencies for Maintaining Signs Within Minimum Retroreflectivity Guidelines"[5], described efforts to estimate the costs for bringing traffic signs up to minimum levels across the nation. This report describes a model developed to predict the costs to state and local agencies. The model has the following basis and features:

- A compilation of data from two states and seven local agencies provided distributions for the density of various sign types and their retroreflective condition.
- The distributions were translated to national levels by expanding the mileage in the nine agencies studied 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 available from the participating agencies was used to estimate the percentage of signs that did not meet the minimum criteria specified in the 1993 tables.
- 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.
- There were also assumptions made about the materials that would be used for the upgrades (e.g., half of the replacements would use Type III material).

Applying the model led to an estimate of $33 million in costs to state agencies and $144 million to local agencies for sign replacement per year. The variability in input data or the specific assumptions has the potential to affect these cost estimates.

The model developed in the earlier effort is considered fundamentally sound, but it generates estimates for total sign replacement, not just upgrading sign faces. 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 cost estimates. The following assumptions and updates were made to the model:

- 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 in the mid-1990's.
- The mileage of roads has changed from the 1993 numbers used in the model. Updated state and local mileage was obtained from Highway Statistics 2001 as noted in the table entitled "Public Road Length – 2001" (page V-7) [12].
- The previous study focused on Type I and III materials. While new materials are on the market, the assumption was made that Type III materials can be used to meet the

minimum levels. Agencies may wish to offer higher performance signs, but the higher costs of these materials cannot be attributed to the new provisions.

- The variability of sign costs noted in the previous research continues. While there has not been much change in Type I (EG) materials, the costs of Type III (HI) materials has dropped, with some agencies reporting that Type III materials now costing half of what they did ten years ago.
- The minimum levels of sign retroreflectivity have been updated and simplified. The corresponding new values are considered similar to the previous levels, so it was assumed that there is no appreciable difference in the percentage of signs that need replacement.
- It must be recognized that the earlier cost estimates did not include overhead signs since there were no minimum levels proposed at the time for these signs. While minimum levels now exist, there is no data on the number or condition of this set of signs. Further, as these signs are typically each unique, it is hard to estimate their costs. The costs to upgrade these signs will be higher due to the need to use higher performance materials since less headlight illumination reaches these signs. These costs will mostly be borne by state agencies.

Table 31 in the 1998 impacts report provided the essence of the sign cost model [5]. The total national mileage of state and local roads was multiplied by a weighted cost per mile for sign upgrading. The weighted cost per mile reflected the relative distributions of signs by type and condition and the observed densities on the road. Since, it is assumed (for lack of any new or better information) the distributions of types and condition and the densities are the same, then applying a scalar increase in sign upgrade costs per mile is the only change needed to generate updated estimates. It was decided that the consumer price index would be an appropriate scaling factor for the costs. This index rose 22% from 1993 to 2001. This index change and variable changes by agency in the basic costs for sign materials led to the decision to use both medium and high factors (25% and 40%) to adjust sign costs for inflation.

Therefore, using the previously developed model revised national estimates for traffic sign replacement are given in Table 6. Estimates were generated for 2001, which is the most recent year that road mileage information was available.

Table 6 – Revised Estimates of National Costs for Traffic Sign Replacement

	1993 Estimate		2001 Estimate	
	State	Local	State	Local
National Mileage	791,305	2,924,123	772,270	3,054,535
Sign Upgrade Cost (per mile)	$41.40	$49.26	$57.50 to $64.40	$68.42 to $76.62
Total National Cost	$32,759,673	$144,044,867	$44,405,525 to $49,734,188	$208,991,285 to $234,038,472
Note – The Highway Statistics document altered the structure of the table reporting road mileage by jurisdiction sometime shortly after 1995. The range of cost estimates for 2001 reflect the assumptions of 25% and 40% inflation rates over the 1993 unit costs.				

There are factors that may affect the ultimate accuracy of these estimates. They include:

- The actual number of signs needing to be replaced may be larger. At present, very few agencies monitor the retroreflectivity of their signs. The agencies that provided the data for the model may represent the most proactive agencies and hence have sign systems in the "best" condition.
- The analysis was based upon the observed use of signs in the nine communities. The usage matrix has a number of empty use cells that are not truly representative of all jurisdictions.
- There are new materials on the market that may be selected by agencies despite their higher costs. Costs for sign materials and sign management are continually changing.

Thus, using the higher-level inflation estimates, states could expect to spend about $49.7 million and local agencies about $234.0 million per year (compared to $32.8 and $144.0 million in the 1998 report) to upgrade signs to meet the minimum maintained retroreflectivity levels. 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 planned maintenance cycles for traffic signs. Regular replacement of traffic signs in the future would be necessary to keep the entire sign system at adequate levels of night visibility.

To put these costs in perspective, the impact can be compared to the overall sign budgets for state agencies determined by a 1992 ATSSA survey [13]. Thirty-seven states (not including two very large states - California and Texas) reported spending about $138 million (or an average of $3.7 million per state) as their annual sign budgets. Inflating these budgets to 2001 levels using the consumer price index would imply that the states are now spending around $185 million annually on traffic signs. The $7.1 million estimated additional annual costs would represent about a 4% increase in costs for all state agencies (i.e., $7.1 million divided by $185 million). Similar data is not available to determine the existing sign budgets for local agencies. Therefore, it is not possible to generate a corresponding estimate of the percent increase for local agencies.

3.5. Expanded National Impacts Analysis

In the previous section, the potential cost impacts of implementing the minimum levels for traffic sign retroreflectivity was analyzed by applying the model used to generate the costs reported in the 1998 impacts report with input data for 2001[5]. It should be recalled that this model is built around the only multi-agency data available on regulatory, warning, and guide sign density and condition. This data was used to derive a weighted sign replacement cost factor for each type of sign. The estimates in the previous section were derived by applying a inflation factor for the cost values and updating national road mileage to reflect conditions for 2001. This allowed direct comparisons with the previously reported cost impact estimates.

There are, at least, two problems in relying on the results provided in the previous section. First, they are estimates of total sign replacement costs which overestimate the impact on agencies since the only additional cost they will incur is for a higher performance sign face material. Second, the model was not designed to estimate cost impacts for overhead guide and street name signs that are now covered by the proposed minimum levels. Therefore, additional analyses were undertaken to generate an improved estimate of cost impacts on state and local

agencies. These additional analyses focused on the incremental differences in sign face material costs for each subset of traffic signs. First, the model was used with a weighted sign replacement cost factors that were scaled to reflect only the differential costs for higher performance sign face materials. The model provided 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.

Regulatory, Warning & Guide Signs

Previous estimates of cost impacts for regulatory, warning, and guide signs reflected total sign replacement costs which included the costs for sign face materials, sign substrate, post, and other elements. Since a key facet of the proposed rule is that agencies would be allowed to bring their signs into compliance over time under their planned sign replacement schedule, the only additional costs that can be attributed to the rule is that for the sign face materials. For example, if an agency has been using Engineer Grade sheeting (Type I) and needs to use High Intensity (Type III) the added costs they would incur would be the difference between materials at $1.00 per square foot versus $1.95 per square foot (from Table 2). It was assumed that the most fundamental upgrade that an agency would choose to make was from a Type I material to a Type III and it was considered the "low estimate." A "high estimate" was generated assuming a material upgrade from Type I to Type VII with an associated cost differential of $2.50. These differentials were incorporated in the sign face materials costs that were conservatively assumed to represent about 10% of the total sign replacement costs. The overall cost impacts for state and local agencies using the adjusted sign face material costs are given in Table 7.

Table 7 – Cost Estimates for Improvement of Sign Face Materials for Regulatory, Warning, and Guide Signs by State and Local Agencies

Agency	State	Local
Road Mileage (from Highway Statistics 2001)	772,270	3,054,535
Unit Sign Replacement Cost (from 1998 FHWA report)	$41.40	$49.26
Total Cost (from Table 31 in 1998 FHWA Report)	$32,759,673	$144,044,867
Updated Unit Sign Replacement Cost (Low inflation index)	$57.50	$68.42
Updated Unit Sign Replacement Cost (High inflation index)	$64.40	$76.62
Updated Total Cost (from Table 6 for low inflation)	$44,405,525	$208,991,285
Updated Total Cost (from Table 6 for high inflation)	$49,734,188	$234,038,472
Low Unit Sign Face Cost	$5.75	$6.84
High Unit Sign Face Cost	$6.44	$7.66
Aggregate Sign Face Replacement Costs (Low Estimate)	$4,440,553	$20,899,128
Total	$25,339,681	
Aggregate Sign Face Replacement Costs (High Estimate)	$4,973,419	$23,403,847
Total	$28,377,286	

Therefore, the cost impacts to upgrade all regulatory, warning and guide signs to meet the minimum levels for the States would range from $4.44 to $4.97 million per year while local agency impacts would range from $20.90 to $23.40 million per year. Again, these estimates follow the assumptions that:

- Improvements to the sign face material represent the only cost attributable to the proposed rule.
- Sign density has remained relatively constant.
- The percentage of signs needing replacement has not changed appreciably.
- Signs would be replaced as part of normal replacement cycles over the implementation period for the rule (7 or 10 years).

The significant difference in the national cost estimates based upon "total cost" for the 1998 report and the earlier 2001 estimate can be noted by comparing these rows to the last two rows in the table.

It must be noted that an agency's past attention to signs will influence how many signs will need to be replaced on the roads in their jurisdiction. It must also be noted that there will be costs in future years as signs that are currently acceptable age to the point that they need replacement.

Street Name Signs

The model described above 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 (from FHWA Office of Operations). This estimate has been regularly used in their analyses to traffic control needs. It includes both signalized and unsignalized intersection of various types. About 10% of all intersections were considered signalized. For this analysis, street name signage was considered to be different for signalized and unsignalized intersections. For signalized intersections, eight large overhead sign panel were assumed with a low upgrade (Type I to Type III material) sign cost estimate of $171.20 per intersection. A corresponding high cost estimate of $320.00 was assumed for each intersection. Similarly, six smaller signs were assumed for unsignalized intersections was with low and high cost estimates of $40.69 and $88.13 per intersection. These estimates reflect the costs of sign face materials and a fixed set-up cost to cover the fabrication of signs with specific street names (only limited mass production possible).

A 10-year implementation period was assumed in generating these estimates. It was also assumed that of the signs at the 3 million intersections would need to be replaced over the implementation period for the rule. This corresponds to the worst-case scenario for an agency, namely, that at the outset, none of their street signs met the minimum levels and hence they would all have to be replaced. With a 10-year implementation period, it was assumed that 10% of the street name signs need to be replaced each year. The resulting estimates for low and high improvement costs are provided in Table 8.

Table 8 - Estimated Costs for Street Name Sign Improvements

Element	Signalized	Unsignalized
Number of Intersections	300,000	2,700,000
Number of sign per intersection	8	6
Average Sign Size (feet)	1.5x8.0	0.75x2.5
Sign Area (square feet)	12.00	1.88
Low Estimate (Type 1 to Type III upgrade)		
Sign Face Material Cost	$11.40	$1.78
Sign Fabrication Cost	$10.00	$5.00
Sign Upgrade Costs per Intersection	$171.20	$40.69
National Total Sign Upgrade Cost	$51,360,000	$109,856,250
10 Year Implementation Cost (10% replacement/year)	$5,136,000	$10,985,625
Total for All Intersections	$16,121,625	
High Estimate (Type 1 to Type VII upgrade)		
Sign Face Material Cost	$30.00	$4.69
Sign Fabrication Cost	$10.00	$10.00
Sign Upgrade Costs per Intersection	$320.00	$88.13
National Total Sign Upgrade Cost	$96,000,000	$237,937,500
10 Year Implementation Cost (10% replacement/year)	$9,600,000	$23,793,750
Total for All Intersections	$33,393,750	

Therefore, the cost impacts to upgrade street name signs at all intersections to meet the minimum levels would range from $16.12 million per year under the low estimate to $33.39 million under the high estimate. Using the same a ratio for State (19.6%) to local (77.4%) roads reflected in the road mileage estimates for intersections, this translates to costs for the States ranging from $3.16 to $6.54 million per year and for local agencies ranging from $12.48 to $25.85 million per year under the 10 year implementation period.

Overhead Guide Signs

Last, estimates of the number of overhead signs were estimated from data received from 19 states. The average density per mile of overhead signs for these agencies was used to generate a national total. Lit overhead signs were excluded. It was assumed that most of the overhead signs exist on state roads. Added sign face costs were determined assuming an average overhead sign panel size of 10 by 16 feet. Since these signs are each unique a fabrication cost was added to the estimate. Low and high cost estimates were generated but they reflect the fact that most overhead signs are made using Type III materials since less illumination from headlights reaches these signs. The low estimate assumed transition from Type III to Type VII material while the high estimate assumed a transition from a Type III to a Type VIII material. A worst case scenario (all overhead signs would need to be replaced over the implementation period) was assumed. The cost impacts derived for a 10-year implementation period is described in the Table 9.

Table 9 - Estimated Costs to States for Overhead Guide Sign Improvements

Element	Value
Number of Overhead Signs	160,502
Average Sign Size (feet)	10.0x16.0
Sign Area (square feet)	160.00
Low Estimate (Type III to Type VII upgrade)	
Sign Face Material Cost	$248.00
Sign Fabrication Cost	$350.00
Total Costs per Overhead Sign	$598.00
National Total Sign Upgrade Cost	$95,979,909
10 Year Implementation Cost (10% replacement/year)	$9,597,991
High Estimate (Type III to Type VIII upgrade)	
Sign Face Material Cost	$368.00
Sign Fabrication Cost	$350.00
Sign Upgrade Costs per Intersection	$718.00
National Total Sign Upgrade Cost	$115,240,092
10 Year Implementation Cost (10% replacement/year)	$11,524,009

Therefore, the cost impacts to upgrade all overhead guide signs to meet the minimum levels for the States would range from $9.60 to $11.52 million per year for a 10-year implementation period. Since these overhead guide signs were assumed to be on major routes under state control, no local agency impacts were expected.

Overall Costs

The overall cost impact to state and local agencies can be estimated by adding the sign face improvement costs for each subset of signs – regulatory, warning, and guide signs, street name signs, and overhead guide signs. These estimates of cost impact are provided in Table 10. Both low and high estimates are provided. Table 10 also reflects estimates for an implementation of 7 years for regulatory, warning, and guide signs and a 10-year implementation period for street name and overhead guide signs.

It can be noted that for both the low and high cases that the costs do not exceed $100 million per year. In each case the cost impacts would be reduced if the replacement of street name and overhead signs was assumed to take place over a longer time frame. It can also be noted that the high estimate is based upon the assumption that a two-increment sign material improvement would take place. While this would not be necessary in most cases, it demonstrates that the cost impact to exceed the minimum levels would not be overwhelming.

Table 10 – Added Annual Costs to State and Local Agencies for Upgrading Sign Face Materials (in millions of dollars) for 7 and 10 Year Implementation Period

Sign Types (Implementation Period)	Estimate Level	State	Local	Total
Regulatory, Warning, & Guide Signs (7 years)	Low	$4.44	$20.90	$25.34
	High	$4.97	$23.40	$28.37
Street Name Signs (10 years)	Low	$3.22	$12.90	$16.12
	High	$6.68	$26.71	$33.39
Overhead Signs (10 years)	Low	$9.60	$0	$9.60
	High	$11.52	$0	$11.52
Total Added Costs (7 & 10 Years)	Low	$17.26	$33.80	$51.06
	High	$23.17	$50.11	$73.28

3.6. Tort Liability

The North Carolina report attempted to address the concern of tort liability that has often been cited as a primary concern [11]. Their report reviewed the legal liability status of the state and its local communities under their Tort Claims Act. While the report notes there are thousands of tort claims against the state annually, only 45 claims against the DOT from November 200 to October 2001 only 8 directly cited sign maintenance or sign management issues. Of these eight claims six were dismissed for various reasons. The report cites the need for the agency to maintain and organized 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 levels of maintained retroreflectivity for traffic signs will lead to increased tort liability. Further, each state has different laws related to suing the state, and limiting claims, that will affect the ultimate tort impacts.

4.0. Benefits of Improved Visibility of Traffic Signs

A question asked frequently at the sign workshops was "What are the safety and mobility benefits of improving the night visibility of traffic signs?" Participants noted that they could be far more effective in their dealings with management, elected officials, and public if they could provide some quantitative estimates of benefit. An attempt was made to find such benefit estimates, but with limited success as noted below.

4.1. Expected Benefits

An implicit assumption that represents the fundamental basis for traffic engineering practice and the MUTCD is that appropriate signage with reasonable visibility during both day and night has positive benefits on traffic safety and flow. Proving this and determining the magnitude of benefit is not easy because it is difficult to isolate the influence of a single element or stimuli to a driver. Certainly, the roadway, the markings, the nature of the road environment, prevailing traffic, and other factors also provide guidance, regulatory, and warning information to the driver.

Intuitively, it is easy to generate a list of the various benefits to the driver, safety, mobility, and the community associated with good signage. The benefits associated with improved night visibility of traffic signs include:

- Drivers
    - Older drivers can function better when on the roads at night (the population is aging!)
    - All drivers are more likely to get the regulatory, warning, & guidance information provided by the signs.
    - Better guidance (e.g., reading street name signs at night) improves traffic flow.
    - Upgrade process provides the opportunity to improve entire signage scheme (e.g., "thinning" or reducing the number of signs, install strong yellow-green signs at pedestrian crossings)
    - Upgrade efforts will permit agency response to changing road & traffic conditions and sign policies (e.g., MUTCD)
    - Reinforcement for other systems (e.g., delineation systems).
- Safety
    - Signs play a role in keeping vehicles on the road and reducing roadside crashes.
    - Improved signage can reduce intersection accidents
    - Improved signage can alert motorists to the presence of pedestrians & bicyclists.
    - Sign replacements provide the opportunity to provide upgraded breakaway features for traffic sign supports to reduce crash severity.
- Community
    - Reduced exposure to tort liability.
    - Better sign quality leads to higher levels of respect for TCDs
    - Improves community image
    - Fewer crashes translate to less risk for emergency personnel

Isolating the effects of a particular sign or set of signs can be accomplished in lab studies where there is control of the amount and nature of stimuli, but it is far more difficult to determine in the field. This becomes even more difficult as specific attributes of signs are concerned (e.g., night visibility). Some of the efforts that have attempted to quantify the benefits of good signing are cited below.

4.2. USDOT Highway Safety Evaluations [14]

Under the Highway Safety Improvement Program (see 23 CFR 924) agencies were required to submit safety evaluation reports to the FHWA for all projects that used Federal funds. These reports were expected to describe the elements of the project and provide a benefit cost ratio associated with the improvement. The FHWA compiled a running database of these measures of impact from 1978 to 1996. The benefit cost ratios for the top ten safety improvements from the last in a series of these reports is provided in Table 11 below. It can be noted that sign improvements bad a benefit cost ratio of 22.4, which implies that these improvements yielded a return of more than $22 for every dollar spent.

Table 11 – Benefit Cost Ratios for Top Ten Safety Improvements

Rank	Improvement Description	Benefit-Cost Ratio
1	Illumination	26.8
2	Upgrade Median Barrier	22.6
3	Traffic Signs	22.4
4	Relocated/Breakaway Utility Poles	17.7
5	Remove Obstacles	10.7
6	New Traffic Signals	8.5
7	Impact Attenuators	8.0
8	New Median Barrier	7.6
9	Upgrade Guardrails	7.5
10	Upgrade Traffic Signals	7.4

It is important to note that the validity of these benefit estimates has been questioned. Questions have been raised about the lack of specific reporting procedures in gathering the data, the limited use of control sites to isolate safety effects, the means used to isolate the specific safety contributions of project elements, the dollar values for costs and benefits, the nature of the statistical techniques used, and the quality of the crash, cost, and other data. Despite these questions, the high ranking supports the contention that sign improvements are a highly effective, low-cost means to enhance safety. The data does not allow specific inferences about the relative contributions that sign improvements have on safety and mobility between day and night conditions. Thus, it is not possible to provide estimates of the benefits that would result from agency efforts to meet the proposed night visibility requirements.

4.3. Local Agency Success Story [15]

Local agencies don't often report the results of their efforts to improve the safety and mobility on the roads under their jurisdictions. Recently, Mendocino County, CA reported the

results of their efforts. It is offered here as an example of what agencies might expect from sign improvement efforts associated with the implementation of proposed new minimum levels for traffic sign retroreflectivity.

Mendocino County lies in a rural area of California north of San Francisco. The county has 1000 centerline miles of highway and a population of 87,000. The director reported in 2002 that their road safety review program that focused on maintaining and improving signs and pavements markings led to accident reduction savings in excess of $11 million dollars. They reported benefit cost ratios of 1:159 and 1:299. These conclusions were reached after comparing sections of two-lane county roads that were part of the road safety review process and those that were not. The state roads in the same area served as a control. Crash data was made available from the California Highway Patrol (CHP) for a ten-year period. Estimates of future crashes were derived from extrapolation of crash trends for each of the three groups of roads. Comparing the differences between estimated crashes and actual crashes revealed the following:

- Roads where safety reviews were conducted and low-cost signing and marking improvements were made had a 42% reduction in crashes.
- Roads where safety reviews were NOT conducted and NO low-cost signing and marking improvements made, there was a 26% increases in crashes.
- State roads in the area that were not included in the safety reviews had a 3% reduction in crashes over the same period.

The total costs for the safety review and sign improvements were about $160,000. The crash reduction savings using Caltrans factors was calculated to be $12.58 and $23.73 million.

While this study did not have a large database, use powerful statistical tools, attempt to isolate the effects of signs from markings, or rely on a rigorous statistical comparison approach, it does have validity. The high B/C ratios suggest that there may be other factor contributing to the reduction in crashes, but there is a large positive benefit in terms of the injuries and property damage that was avoided. Most agencies would be more than satisfied to realize even smaller benefits from improvements in signs and markings. This study does not cite whether there were other issues.

4.4. Other Benefits

A TRIS search was conducted in preparing this report. It yielded very few citations of studies addressing the impacts of sign improvement. There were even fewer citations relative to the impacts of sign improvements for night visibility. To some extent, this was not unexpected given the difficulty in isolating the influence of particular signs on driver behavior and the limited amount of cataloging of internal agency reports on safety effectiveness of signs and sign management programs.

The FHWA goals and objectives promote consideration of safety and mobility. In this impacts analysis, no explicit evaluation of mobility benefits was found. It is believed that good signing for both day and night conditions has positive effects on traffic flow. These include:

- More compliance to regulations when they are conspicuous and legible.
- Less disruption of traffic as driver attempt to navigate in unfamiliar areas and either slow down or make abrupt lane changes.

- Increased mobility for older drivers
- "Thinning" the sign system by removing all but the necessary signs to reduce driver information overload.
- Upgrade street name signs to promote traffic flow by allow motorist to more easily find their destinations.
- Upgrade size of signs to address the needs of an aging driving population.

In addition, agencies can use the proposed minimum levels to undertake sign-improvement related efforts that may be beneficial to their community. These might include:

- Use the guidelines to bring traffic control devices into their asset management system
- Regular inspections assure quality & effectiveness
- Provides the information needed for full realization of useful life of assets
- Assures improved compliance with the MUTCD
- Link sign inventory system with work order and materials inventory control to better manage sign shop and sign crews.

Linking the sign inventory with GIS is not necessary to improve night sign visibility, but it would provide the option to more readily correlate sign location with crashes, land use features, underground utilities and other information. These efforts can help to offset the costs associated with sign upgrades and the long-term maintenance of night sign visibility.

5.0. Summary and Conclusions

A summary of the findings from the review of various reports on the subject is provided in Appendix B. The study name or agency that conducted it is given in the first column. A summary of the reported impacts is provided in column two. Column three reflects the comments made in the critiques of the effort and the last column presents the implications of the study on the current effort to assess the impacts of the new provisions on state and local agencies. The following statements summarize the findings and conclusions of this report:

- There are many elements of sign cost, but not all can be attributed as impacts to state and local agencies resulting from the implementation of proposed minimum maintained levels for traffic sign retroreflectivity.
- The most direct impact of the minimum maintained levels of retroreflectivity will be the increased costs to agencies necessary to use sign face materials with higher retroreflective properties. The increases would most likely range from 95 to 250% for the sign face materials themselves, but these only translate to increases of 9-12% per sign installation. There is only limited information available on the nature of materials currently in use by state and local agencies, so it is not possible tom determine actual cost impacts.
- The labor, equipment, and logistics costs for replacement of non-compliant signs (i.e., those with retroreflectivity values below the proposed minimum levels) should be attributed to planned maintenance cycles, not the proposed minimum maintained levels for traffic sign retroreflectivity.
- Considering life cycle costs may allow agencies to upgrade their signs with higher performance and longer life materials at a lower total cost.
- There are many costs associated with sign management processes, but these are not considered part of the impact of the proposed minimum maintained levels for traffic sign retroreflectivity.
- Sign assessment costs should not be considered in the impacts because the MUTCD already suggests that agencies to conduct periodic day and night inspections.
- The costs associated with the development and implementation of sign inventories and management systems should not be attributed to the proposed minimum levels because they are not necessary to improve the night visibility of traffic signs. They are recommended as a means to provide a greater attention on the condition of sign systems and agency efficiency in maintaining retroreflectivity.
- Previous studies by the NCHRP and FHWA found minimal impacts from proposed minimum levels where a long-term implementation period was planned. This allowed signs to be upgraded as part of planned maintenance cycles over a 7-10 year period.
- Three states have reported their findings relative to the impact of the proposed minimum maintained levels of traffic sign retroreflectivity. The Texas study found that sign crews were more likely to recommend sign replacements for reasons other than the non-compliance to the minimum levels. Indiana found that more than 95% of their signs were already in compliance. North Carolina reported that about 10% of their signs did not meet the proposed minimum levels, but they proposed major efforts to improve sign management to better maintain sign visibility in the future.
- The updated national impacts estimate generated using the previously developed models, indicated that the states could expect to annually spend an additional $44.4 to $49.7 million and local agencies would spend $209.9 to $234.0 million more. These estimates

are believed to over-estimate the impact to state and local agencies as they are based on full sign replacement outside of planned sign replacement schedules.

- An expanded national impacts analysis based upon the differential costs for sign face improvement assuming sign replacement as part of normal replacement cycles was undertaken. It included regulatory, warning, and guide signs, street name signs, and overhead guide signs. The expanded national impacts analysis considered a 7-year implementation period for regulatory, warning, and guide signs and a 10-year implementation period for overhead guide and street name signs. Based upon this analysis, it was determined that state and local agencies might expect additional costs ranging from $50.6 to $72.3 million per year.
- Table 12 provides a summary of the various estimates of cost impact for State and local agencies and the reasons for the differences.
- Research has not yet been able to provide a sound, direct quantitative estimate of the safety benefits that might be attributed to improving the night visibility of traffic signs.
- The USDOT's annual Highway Safety Evaluation reports, which were published between 1983 and 1996, indicated that sign improvements had B/C ratios above 20:1. While some have questioned the procedures used to generate these measures, they indicate that sign improvements lead to safety benefits.
- Measures of the operational benefits associated with traffic signs have not been determined, but good signage for both day and night conditions are believed to promote improved traffic flow.
- Indirect benefits to the driver, safety, mobility, and the community can result from efforts to improve traffic signs and sign systems.
- Tort liability for issues related to sign visibility at night has not been a problem, but it is a concern to agencies.

It is hoped that new minimum maintained levels for traffic sign retroreflectivity will lead to better maintenance of traffic signs and the associated improvements in visibility, particularly for night conditions. Better maintenance will enhance safety and mobility for highway users. Traffic operations (and hence mobility) will be enhanced when regulatory, warning, and guidance information is effectively communicated to the road user. This can be expected to keep traffic moving at the proper speeds and smoothly positioning themselves for turns and merges.

Table 12 – Summary of Various Cost Impact Estimates and Reasons for the Differences

Report	State	Local	Total	Reasons
1998 FHWA Impacts Report	$32.0	$144.0	$176.0	- Based on total sign replacement costs. - Does not include overhead or street name signs.
2001 estimate (see Table 6 in Section 3.4)	Low $44.4	$209.0	$253.4	- Based on total sign replacement costs. - Does not include overhead or street name signs. - Assumes 25% inflation rate over 1993 unit costs.
	High $49.7	$234.0	$283.7	- Based on total sign replacement costs. - Does not include overhead or street name signs. - Assumes 40% inflation rate over 1993 unit costs.
2004 estimate (see expanded analysis in Section 3.5)	Low $17.3	$33.8	$51.1	- All signs - 7 & 10 year implementation periods - One-step sign face material upgrade costs
	High $23.2	$50.1	$73.3	- All signs - 7 & 10 year implementation periods - Two-step sign face material upgrade costs

Note: The "total" represents the sum of the state and local costs.

References:

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4. Hawkins, H.G., Carlson, P.J., Schertz, G.F., Opiela, K.S.; "Workshops on Nighttime Visibility of Traffic Sign: Summary of Workshop Findings," prepared for the FHWA, Washington, DC, March 2003.
5. McGee, H.W. and S. Taori; "Impacts on State and Local Agencies for Maintaining Traffic Signs within Minimum Retroreflectivity Guidelines," FHWA-RD-97-053, Federal Highway Administration, Washington, D.C., 1998.
6. Carlson, P.J., H.G. Hawkins, G. Schertz, K.S. Opiela, and D.J. Mace. Developing Updated Minimum In-Service Retroreflectivity Values for Traffic Signs. Accepted for presentation at the 2003 TRB Annual Meeting, Preprint Number 03-2377, Transportation Research Board, Washington, D.C., 2003.
7. McGee, H.W.; et al, Implementation Strategies for Sign Retroreflectivity Standards," NCHRP Report 346, Washington, DC, 1992.
8. Hawkins, H.G. and Carlson, P.J. "Sign Retroreflectivity- Comparing Results of Nighttime Visual Inspections with Application of Minimum Retroreflectivity Values," from TRR 1754, Transportation Research Board, Washington, DC, 2002.
9. Bischoff, A.; Bullock, D.; "Field Evaluation of Sign Retroreflectivity," paper submitted for publication by TRB, Washington, DC, 2001.
10. McGee, H. W. and J.F. Paniati. An Implementation Guide for Minimum Retroreflectivity Requirements for Traffic Signs. FHWA-RD-97-052, Federal Highway Administration, Washington, D.C., 1998.
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12. USDOT, "Highway Statistics 2001," USGPO, Washington, DC, 2002.
13. ATSSA, Sign Replacement & Refurbishing Programs: Inventory and Process Survey, Fredericksburg, VA, May 1992.
14. FHWA, "1996 Annual Report on Highway Safety Improvement Programs," prepared by the Office of Highway Safety, Washington, DC, 1996.
15. Ford, S.H., Calvert, E.C.; "Evaluation of Low Cost Program of Road System Traffic Safety Reviews for County Highways," submitted for presentation at TRB Conference on Low Volume Highways, June 2003, Reno, NV.

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 and practical minimum requirements, as well as means to facilitate their implementation. The information provided here represents one of the latest products of FHWA efforts.

Recent Research:

The FHWA has been involved in research investigating driver night visibility needs since the early 1980's. 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 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 this report were modified somewhat after workshops with practitioners in 1995. These requirements were published in a report entitled "An Implementation Guide for Minimum Retroreflectivity Requirements for Traffic Signs" (FHWA-RD-97-052) in 1998. 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" (pub. 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. It can be noted that this single table combines the requirements for all color and sign applications.

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 1. Minimum Maintained Retroreflectivity Levels

Sign Color	Criteria	Sheeting Type (ASTM D4956-01a)					
		I	II	III	VII	VIII	IX
White on Red	See Note ①	35//7					
Black on Orange or Yellow	See Note ②	*	50				
	See Note ③	*	75				
Black on White	—	50					
White on Green	Overhead	*//7	*//15	*//25	250//25		
	Shoulder	*//7	120//15				

NOTES:
Levels in cells represent legend retroreflectivity // background retroreflectivity (for positive contrast signs).
Units are cd/lx/m^2 measured at an observation angle of 0.2° and an entrance angle of -4.0°.
① Minimum Contrast Ratio ≥ 3:1 (white retroreflectivity ÷ red retroreflectivity).
② For text signs measuring 48 inches or more and all bold symbol signs.
③ For text signs measuring less than 48 inches and all fine symbol signs.
* Sheeting type should not be used.

Bold Symbol Signs	• W1-1 – Turn • W1-2 – Curve • W1-3 – Reverse Turn • W1-4 – Reverse Curve • W1-5 – Winding Road • W1-6 – Large Single Arrow • W1-7 – Large Double Arrow • W1-8 – Chevron • W1-9 – Turn & Advisory Speed • W1-10 – Horizontal Alignment & Intersection • W2-1 – Cross Road • W2-2, W2-3 – Side Road • W2-4 – T Intersection • W2-5 – Y Intersection • W2-6 – Circular Intersection • W3-1a – Stop Ahead • W3-2a – Yield Ahead • W3-3 – Signal Ahead • W4-3 – Added Lane • W6-1 – Divided Highway Begins • W6-2 – Divided Highway Ends • W6-3 – Two-Way Traffic • W10-1, -2, -3, -4 – Highway-Railroad Intersection Advance Warning • W11-2 – Pedestrian Crossing • W11-3 – Deer Crossing • W11-4 – Cattle Crossing • W11-5 – Farm Equipment • W11-5p, -6p, -7p – Pointing Arrow Plaques • W11-8 – Fire Station • W11-10 – Truck Crossing • W12-1 – Double Arrow
Fine Symbol Signs	All symbol signs not listed in the bold category are considered fine symbol signs
Special Case Signs	• W3-1a – Stop Ahead o Red retroreflectivity ≥ 7 • W3-2a – Yield Ahead o Red retroreflectivity ≥ 7, White retroreflectivity ≥ 35 • W3-3 – Signal Ahead o Red retroreflectivity ≥ 7, Green retroreflectivity ≥ 7 • W14-3 – No Passing Zone , W4-4p – Cross Traffic Does Not Stop, or W13-2, -3, -1, -5 – Ramp & Curve Speed Advisory Plaques o Use largest dimension

Appendix B – Summary of Reported Impacts of Proposed Minimum Maintained Levels for Traffic Sign Retroreflectivity

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 &n highway 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.

Fleury, Nicolle

From: Fleury, Nicolle
Sent: Tuesday, April 06, 2004 12:48 PM
To: Krammes, Ray; Opiela, Kenneth; Hatzi, Peter; Schertz, Greg
Cc: Downey, Julie
Subject: RE: Retroreflectivity Draft Impacts Analysis

Maintaining Traffic Sign Impac...

I have made the necessary changes based on Ken/Ray's input. Attached is the version that incorporates that changes that have been discussed and agreed to over the last week. Please let me know by cob today if this version is OK to send to OST.

Thank you.

-----Original Message-----
From: Krammes, Ray
Sent: Tuesday, April 06, 2004 10:10 AM
To: Fleury, Nicolle; Opiela, Kenneth; Hatzi, Peter; Schertz, Greg
Cc: Downey, Julie
Subject: RE: Retroreflectivity Draft Impacts Analysis

Ok, I probably made things worse. The estimate for street name signs was based on an estimate of intersections to start with (3,000,000 nationally) and estimated the state and loacl shares by multiplying by .196 and .774 respectively. That left about 3% that would be associated with Federal. It has caused problems with numbers not totally corrctly and so on. I think that it is probably safe to assume the intersection were all state and local. That would allow a consistency with numbers and no need to explain a new set of totals. My computer died this morning so I can't make the changes, but here is what I propose:

o Change Table 10 as follows - third row values $3.22,$12.90, and $16.12 (note that this 16.12 value is the same as in Table 8); fourth row values to $6.68, $26.71, and $33.39; last in the totals columns the last two rows should be $51.06 (rounds to 51.1) and $73.29 (rounds to 73.3); last remove the note below the table.

o In table, you can change the estimate to 2004 to reflect when it was made, but the point I was trying to make was that the data reflects 2001 road mileage, price indices, and other costs. That was the most current data when this analysis was undertaken. I believe that 2002 data is now available, but it would take a couple of days to go back and recompute everything with the 2002 values.

o I don't understand your comment about including both figures in Section 3.5.

I am leaving today to travel to New Jersey this afternoon and will not be back until next week. Hopefully, this can be resolved before then.

-----Original Message-----
From: Fleury, Nicolle
Sent: Monday, April 05, 2004 6:31 PM
To: Opiela, Kenneth; Hatzi, Peter; Schertz, Greg
Cc: Downey, Julie; Krammes, Ray
Subject: RE: Retroreflectivity Draft Impacts Analysis

Ken, does the "estimating error" account for the difference in the total cost of this rulemaking? Two weeks ago and in version 9, the cost range for this rulemaking was $51.1 to $73.3 million per year. In version 10, the cost range is $50.6 to $72.3 million. Is the difference that the $51.1 to $73.3 million estimates include the cost to Federal roads? I will need to provide a clear and detailed explanation to OST why the figures changed. If it is just a matter of including or not including Federal roads, I think both figures should be listed in section 3.5.

I also note that in table 12 you are labeling the final row as the "2001 Estimate (see expanded analysis in section 3.5)". I have concerns with this label. OST will ask why we didn't do a 2004 estimate, since we are publishing the proposed rulemaking in 2004. For this reason, I strongly suggest that the last row be called the "2004 Estimate."

Ken, thanks again for all your hard work.

-----Original Message-----
From: Opiela, Kenneth
Sent: Monday, April 05, 2004 5:45 PM
To: Fleury, Nicolle; Hatzi, Peter; Schertz, Greg
Cc: Downey, Julie; Krammes, Ray
Subject: RE: Retroreflectivity Draft Impacts Analysis

I made changes to all the tables in Section 3.5 to hopefully make it clearer where the numbers came from in later tables and to remove that estimating error associated with Federal roads (3%). The state and local portions are provided along the way. I hope this is acceptable. I will be in the office for a short while tommorrow early, but on travel the rest of the week. Thanks

-----Original Message-----
From: Fleury, Nicolle
Sent: Monday, April 05, 2004 3:30 PM
To: Opiela, Kenneth; Hatzi, Peter; Schertz, Greg
Cc: Downey, Julie; Krammes, Ray
Subject: RE: Retroreflectivity Draft Impacts Analysis

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Cc: Downey, Julie; Krammes, Ray
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ext. 61352

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Cc: Downey, Julie
Subject: Retroreflectivity Draft Impacts Analysis

All:

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Nicolle
ext. 61352

P.S. Ken - Please give me a call to discuss.

Fleury, Nicolle

From: Krammes, Ray
Sent: Tuesday, April 06, 2004 10:10 AM
To: Fleury, Nicolle; Opiela, Kenneth; Hatzi, Peter; Schertz, Greg
Cc: Downey, Julie
Subject: RE: Retroreflectivity Draft Impacts Analysis

Ok, I probably made things worse. The estimate for street name signs was based on an estimate of intersections to start with (3,000,000 nationally) and estimated the state and loacl shares by multiplying by .196 and .774 respectively. That left about 3% that would be associated with Federal. It has caused problems with numbers not totally corrctly and so on. I think that it is probably safe to assume the intersection were all state and local. That would allow a consistency with numbers and no need to explain a new set of totals. My computer died this morning so I can't make the changes, but here is what I propose:

o Change Table 10 as follows - third row values $3.22,$12.90, and $16.12 (note that this 16.12 value is the same as in Table 8); fourth row values to $6.68, $26.71, and $33.39; last in the totals columns the last two rows should be $51.06 (rounds to 51.1) and $73.29 (rounds to 73.3); last remove the note below the table.

o In table, you can change the estimate to 2004 to reflect when it was made, but the point I was trying to make was that the data reflects 2001 road mileage, price indices, and other costs. That was the most current data when this analysis was undertaken. I believe that 2002 data is now available, but it would take a couple of days to go back and recompute everything with the 2002 values.

o I don't understand your comment about including both figures in Section 3.5.

I am leaving today to travel to New Jersey this afternoon and will not be back until next week. Hopefully, this can be resolved before then.

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From: Fleury, Nicolle
Sent: Monday, April 05, 2004 6:31 PM
To: Opiela, Kenneth; Hatzi, Peter; Schertz, Greg
Cc: Downey, Julie; Krammes, Ray
Subject: RE: Retroreflectivity Draft Impacts Analysis

Ken, does the "estimating error" account for the difference in the total cost of this rulemaking? Two weeks ago and in version 9, the cost range for this rulemaking was $51.1 to $73.3 million per year. In version 10, the cost range is $50.6 to $72.3 million. Is the difference that the $51.1 to $73.3 million estimates include the cost to Federal roads? I will need to provide a clear and detailed explanation to OST why the figures changed. If it is just a matter of including or not including Federal roads, I think both figures should be listed in section 3.5.

I also note that in table 12 you are labeling the final row as the "2001 Estimate (see expanded analysis in section 3.5)". I have concerns with this label. OST will ask why we didn't do a 2004 estimate, since we are publishing the proposed rulemaking in 2004. For this reason, I strongly suggest that the last row be called the "2004 Estimate."

Ken, thanks again for all your hard work.

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Sent: Monday, April 05, 2004 5:45 PM
To: Fleury, Nicolle; Hatzi, Peter; Schertz, Greg

Cc: Downey, Julie; Krammes, Ray
Subject: RE: Retroreflectivity Draft Impacts Analysis

I made changes to all the tables in Section 3.5 to hopefully make it clearer where the numbers came from in later tables and to remove that estimating error associated with Federal roads (3%). The state and local portions are provided along the way. I hope this is acceptable. I will be in the office for a short while tommorrow early, but on travel the rest of the week. Thanks

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Sent: Monday, April 05, 2004 3:30 PM
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