Analyzing the Retroreflectivity Mandate

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Executive Summary

The purpose of this analysis is to examine the costs and benefits of the federal mandate that requires local agencies to assess, replace and maintain the retroreflectivity of all traffic signs that are on a public road as outlined in 23 Code of Federal Regulations (CFR), Part 655, Subpart F (FHWA, 2011). It is also a requirement that all signs be inventoried along with their GPS locations for easier maintenance in the future.

Sign retroreflectivity maintenance is important because crash rates at night are much higher than they are during the day despite there being fewer cars on the road. Additionally, the elderly population is growing and with age, eye sight decreases. Having signs that reflect the appropriate amount of light can help deter some crashes by grabbing the attention of drivers at night.

My analysis focused on two alternatives: an alternative that considers the costs to self-administer the initial assessment and one that considers the costs to contract the assessment out to the Bluegrass Area Development District. The Self-administered alternative allowed counties and public agencies to carry out their own assessment. The Contracted Alternative placed assessment responsibility with the Bluegrass Area Development District. My findings showed higher net benefits when counties chose to pay an administrative fee to the Bluegrass Area Development District to the initial assessment regardless of using a Blanket Replacement Method or 50% replacement method.

These findings are important because in the current economic climate, many local governments are struggling to fund other higher priority projects let alone projects that they have

little choice but to carry them out or risk losing Federal-aid funds (FHWA, 2012). This mandate is *not funded* by the Federal Government and so these local governments must finance the assessment and management program themselves or by paying an administrative fee.

Literature Review

A recent study released by the National Safety Council (NSC) shows that nighttime crash rates are 3 times higher than daytime rates (NSC, 2009). The NSC estimates that approximately 42,000 fatalities have occurred on American roads during each of the past 8 years. Even though only one fourth of vehicular road travel occurs at night, about half of all fatalities occur during nighttime hours (NSC, 2009). It was unclear what the ultimate reason for these fatalities were strictly due to poor sign visibility, but brighter signs may help inebriated drivers as well. Additionally, nighttime visibility is growing increasingly more important as the elderly population rises. The NSC estimates that by the year 2020, about one fifth of the U. S. population will be age 65 years or older (NSC, 2009). This population has declining vision and slower reaction times. By having road signs that are easier to see and read at night, older drivers can remain independent and continue to be mobile.

One of the Federal Highway Administration's (FHWA) primary missions is to "improve the safety of the nation's roadways (FHWA, 2012)." One way they do this is by releasing the Manual on Uniform Traffic Control Devices (MUTCD) as published by the U. S. Department of Transportation. This publication contains basic standards and principles for traffic signs which emphasize safety and efficiency. All agencies that maintain public roadways must comply with these standards. Recently, the MUTCD implemented new language that requires all agencies that maintain public roads to adopt sign maintenance programs that maintain traffic sign retroreflectivity at a specified minimum level.

Retroreflectivity is a type of reflectivity. It is the ability of a device or material to reflect light back to its original light source. In other words, when a light source (such as car headlights) hits a retroreflective surface (like a traffic sign) it will return back to the car and the driver. This differs from other forms of reflectivity like specular reflection where light is reflected off of the surface at the angle it came in on or matte (or diffuse) reflection that scatters like a projection screen (University of Kentucky Technology Transfer, 2012).

The new language for maintaining minimum retroreflectivity levels occurs in 23 Code of Federal Regulations (CFR), Part 655, Subpart F (FHWA, 2011). It covers the purpose of the new language, definitions, standards, and ways of achieving basic uniformity, project procedures, materials and funding sources. As cited in the 2009 MUTCD Section Number 2A.08:

> Implementation and continued use of an assessment or management method that is designed to maintain regulatory and warning sign retroreflectivity at or above the established minimum levels**.**

These new levels are outlined in the chart below. Explanations of different levels of sheeting are discussed in the Explanatory Information section. The chart below outlines the minimum retroreflective level that each color must meet in order to be compliant. For example, for Type I sheeting, a sign that is green (i.e. highway signs with white writing and denoted in the chart by a capital ‘G’), must be at least a minimum level of seven. For a black on yellow or black on orange sign using Type II or Type III sheeting, yellow (‘Y’) and orange (‘O’) must meet a minimum level equal to or greater than fifty.

Table 1 – Minimum Reflectivity Levels

www.fhwa.dot.gov/retro Maintaining Traffic Sign Retroreflectivity (2007) Page 3

New MUTCD Table 2A-3. Minimum Maintained Retroreflectivity Levels ①

SIGN COLOR	SHEETING TYPE (ASTM D4956-04)				ADDITIONAL CRITERIA
	Beaded Sheeting			Prismatic Sheeting	
	I	II	III	III, IV, VI, VII, VIII, IX, X	
White on Green	W*; G ≥ 7	W*; G ≥ 15	W*; G ≥ 25	W ≥ 250; G ≥ 25	Overhead
White on Green	W*; G ≥ 7	W ≥ 120; G ≥ 15			Ground-mounted
Black on Yellow or Black on Orange	Y*; O*	Y ≥ 50; O ≥ 50			②
Black on Yellow or Black on Orange	Y*; O*	Y ≥ 75; O ≥ 75			③
White on Red	W ≥ 35; R ≥ 7				④
Black on White	W ≥ 50				—

① The minimum maintained retroreflectivity levels shown in this table are in units of cd/lx/m² measured at an observation angle of 0.2° and an entrance angle of -4.0°.
② For text and fine symbol signs measuring at least 1200 mm (48 in) and for all sizes of bold symbol signs
③ For text and fine symbol signs measuring less than 1200 mm (48 in)
④ Minimum Sign Contrast Ratio ≥ 3:1 (white retroreflectivity ÷ red retroreflectivity)
* This sheeting type should not be used for this color for this application.

(FHWA, 2007)

Detailed information on the cost of materials and labor are readily available from companies and organizations like 3M and the Kentucky League of Cities. However, data on the costs and benefits of sign retroreflectivity are scarce. This is primarily because not much research has been done to measure the effects of improved sign maintenance and retroreflectivity. Douglas A.

Ripley of the Traffic Control Corporation performed a study on four different locations that had recently completed sign upgrades. Differences between the methods of application between the four locations varied greatly. Despite the differences between all the programs in this study, all experienced positive results in decreased crash rates and positive net benefits. This study established a basic benefit-cost ratio to apply to the benefits and costs of applying a similar program to other communities (Ripley, 2005).

Explanatory Information

Retroreflective Sheeting

Retroreflective sheeting comes in two different formats, beaded sheeting and prismatic sheeting. The difference between beaded and prismatic sheeting is that beaded sheeting uses "microscopic glass spheres to bend and reflect light back to its source (UK Transportation Center, 2012)." Beaded sheeting is about 30% efficient in returning light back to its source. A major advantage to this type of sheeting is that it is more affordable than prismatic sheeting. Prismatic sheeting reflects light via prisms. It is about 80% efficient at returning light back to its source and is therefore, brighter. This type of sheeting reflects light at a much narrower angle and acts more like a spot light. Because of that property it is more useful at longer distances but is also more expensive.

Beaded and prismatic sheeting are broken down further into ten different levels of retroreflectivity with Type I being the lowest level and Type X being the highest level. Type I is commonly called "Engineering Grade" sheeting. This type of sheeting maintains the minimum level of retroreflectivity as required by the Federal Highway Administration and carries the shortest expected sign life. As such, it is also the cheapest material. Type II is called “Super Engineering Grade” sheeting and Type III is called “High Intensity Beaded” sheeting. Type II is slightly more retroreflective than Type I and carries a longer expected sign life than Type I. Type III is more retroreflective than Type II and carries an even longer expected sign life that types I or II. Their costs increase accordingly.

Prismatic sheeting is broken down to Type IV through Type X. This type of sheeting is the most expensive but has a longer warranty and expected sign life than beaded sheeting. Although, it was unclear as to whether or not the various types of Prismatic Sheeting carried different expected sign lives. Up close it is difficult to tell the difference between the different types of sheeting after Type III but as distance increases the differences become clearer.

Table 2 – Cost of Sheeting per Street Sign

Cost of Sheeting	Price (per SQ FT)	4.828*
3M Type I Sheeting (Engineer Grade)	$0.99	$4.78
3M Type 3,4,10 (High Intensity Sheeting)	$2.00	$9.66
3M Type 8,9,11 (Diamond Grade^3)	$5.64	$27.23

*4.828ft³ is average size of stop sign
(FHWA, 2012)

Assessment Methods

The FHWA outlines two different methods for the evaluation of individual signs within an agency’s jurisdiction. These two methods are the *Visual Assessment Method* (VAM) and the *Measured Sign RetroreflectivityMethod* (MSRM). It is recommended that both methods be used to ascertain the status of signs out in the field, however it is not mandatory, so counties and agencies may choose a single method.

Visual Assessment Method

The Visual Assessment Method entails a Nighttime Inspection where 'on-the-fly-assessments of retroreflectivity are made by an inspector during nighttime condition. Multiple procedures are suggested to support the visual inspection and though not all of them are mandatory in order to complete a visual assessment, it is a good idea to perform all three. In the first supporting procedure, the inspector views a 'calibration sign' prior to conducting the nighttime inspection. The signs are at or above the minimum levels and set up in a manner similar to the nighttime inspections. After viewing the calibrations signs the inspector establishes a threshold for that night's inspection. The second procedure uses comparison panels to assess signs out in the field. When the inspector determines that a sign is questionable, small panels that meet or exceed the minimum requirements are attached to the sign being tested and the two are compared. The last procedure is conducted under similar factors that were used in the research to develop the minimum retroreflectivity levels such as using a sport utility vehicle and an inspector who is at least 60 years old to make the assessment.

Measured Sign Retroreflectivity Method

The Measured Sign Retroreflectivity Method available for sign evaluation is to measure the sign's exact retroreflectivity level using a special gun called a retroreflectometer. In this method, the inspector holds the retroreflectometer flush with the sign and takes a scientific measurement which is then compared to the minimum level appropriate of that sign.

Management Methods

After the initial assessment of a community's signs, it is necessary to have a management method in place to ensure that signs are replaced as their life-cycle ends and retroreflectivity levels fall below the minimum requirements. There are three acceptable methods for maintaining sign retroreflectivity levels.

Expected Sign Life

In this approach, signs are replaced before they reach the end of their expected life-cycle. The end of a sign's life-cycle occurs when retroreflectivity levels degrade to the point where they no longer meet the minimum requirements. Since there is not much data on the expected life-cycle of road signs, many transportation districts base the life-cycle of roads signs on their warranties.

Signs with higher life expectancies take longer to fall below the minimum required retroreflectivity levels. If a sign takes a longer period of time to degrade, then it will need to be replaced less often. As a result, turn-over costs are less for signs with higher grades of retroreflective sheeting despite it being a more expensive material.

Table 3 - Typical Warranty Life

ASTM D4956 Type	Years of Warranty*
I and II	7
III and IV	10
VII, VIII, IX, X	12
* May be different for fluorescent sheeting materials	

(FHWA, 2007)

Blanket Replacement

This method replaces all signs in a given area or of a certain type at specified intervals based on their expected sign life. This method may require the replacement of signs that have recently been replaced and have not yet fallen below the minimum levels. It is often the most expensive method for sign replacement.

Control Signs

The method uses a sample of signs as a control to represent all of an agency's or district's signs. As the control signs begin to fall below the minimum requirements, signs out in the field are replaced accordingly. This method can be tricky because a plan must be developed beforehand to determine the appropriate number and type of control signs. Additionally, an appropriate assessment method must be used in order to determine when a control sign has fallen below the minimum required levels. It can also be difficult because unless the blanket replacement method has recently been carried out, it will be difficult to keep track of which signs need immediate replacement and which signs will continue to meet the minimum requirements.

Research Design

Public agencies, such as state, county, local/townships, Federal Land Management agencies and Tribal governments, which maintain roads open for public travel, are responsible for carrying out the requirements of the Retroreflectivity Mandate. Furthermore, these agencies are mandated to devote resources to retain the visibility and legibility of traffic signs. They are to ensure that signs remain properly mounted and in good working (visible) condition. Given the current economic climate for many county and local governments, funding is a major concern.

The Federal Government has made funding available to assist in carrying out the requirements laid out in the mandate; however that does not guarantee that a city or county will succeed in receiving said funding. One of the frequently asked questions on the FHWA website asks what the consequences are if agencies do not comply with mandates. In the case of this mandate, counties may lose Federal-aid money. Non-compliance may also result in a tort liability lawsuit should an accident result because of poor sign visibility.

The costs of carrying out this mandate can quickly add up when the cost of labor and materials is taken into account. For that reason, the Bluegrass Area Development District (BGADD) has offered to perform the initial GPS inventory and retroreflective testing for an administrative fee.

One of the important costs to consider in thinking about the assessment and management of traffic signs is the cost of materials. The University of Kentucky Transportation Center has contacts at both Avery Dennison and 3M. Both of these companies manufacture the retroreflective materials and the kits containing comparison panels and the calibration signs, however pricing for the 3M compliance kit was not available. Professional Pavement Products Inc. (PPP) manufactures a retroreflectometer kit that comes with the necessary software to interpret and transfer the readings from the gun to the computer. Since the gun is a possible alternative the cost of it must also be taken into account.

The assessment costs in Table 4 allow counties to assess all signs within their boundaries. The components that make up the PPP Retroreflectometer Kit and the Avery Deinnison Minimum Compliance Kit are not 'one-and-done' components. They can be used repeatedly which will allow them to be used on every sign in a county.

Table 4 – Assessment Cost of Compliance Materials

Assessment Materials Costs	Price (USD)
Avery Dennison Min. RR Compliance Kit	$2,725.00
Professional Pavement Products Retroreflectometer (Kit*)	$9,750.00

*Kit comes with gun plus software
(Avery Dennison, Professional Pavement Products)

The second half of the mandate requires that all agencies and counties have a management method in place. After the initial assessment of all signs in the field, there must be some kind of plan in place to replace signs that failed the assessment and to keep an eye on those that passed. Passing signs will eventually fall below the minimum levels. When that time comes, a plan must be in place to ensure that they are replaced effectively and efficiently. This requires taking into account the cost of replacing signs either by control signs, blanket replacement or through existing sign life. For my analysis I have taken into account a blanket replacement method and a 50% replacement per year method assuming a singular choice of material. In other words, I am considering one management method in which counties will choose a singular type of sheeting to replace either all of their signs in a given year or they will choose a singular type of sheeting and only replace 50% of total signs in a given year. After all signs have been replaced then control signs or sign warranty could be used as time passes to ensure that retroreflectivity levels do no fall below the minimum standard. However, for this analysis, costs after the initial replacement have not been considered. Both Avery Dennison and 3M produce the retroreflective sheeting which bills by the square foot but only sheeting produced by 3M was taken into consideration since it was specifically cited in the reference materials given out by FHWA.

Table 5 – Management Costs for Sign Replacement

Sign Management Costs	Blanket Replacement	50% Replacement
3M Type I Sheeting (Engineer Grade)	$191,200.00	$95,594.40
3M Type 3,4,10 (High Intensity Sheeting)	$384,400.00	$193,120.00
3M Type 8,9,11 (Diamond Grade^3)	$1,089,200.00	$544,598.40

(Total number of signs being considered per county = 40,000, LFUCG Traffic Engineering, 2012)

Another cost I have taken into account is the cost of labor. The labor costs I have taken into consideration cover one worker to perform the assessment of all signs within a county for one year. It does not take into account the costs of vehicle operation. In order to carry out the sign assessment, two people must be present. One person will have to drive and hold up the comparison panels and the second person will make the actual assessment of each sign. If a county chooses to carry out the mandate itself, they will have to pay two salaries or hourly wages.

On the other hand, counties can choose to pay an administrative fee to the Bluegrass Area Development District's Geographic Information Systems Department (BGADD GIS) to perform the assessment and make a GPS inventory of each sign. The BGADD GIS owns all of the necessary equipment to perform the assessment and the GPS technology to inventory all the traffic signs on the county's behalf.

Table 6 – Labor Costs for Assessment Performance

Wages/Salaries	
Maintenance Worker (Maximum per year)	$40,289.00
Admin Fee to Bluegrass Area Development District (Maximum)	$10,000.00

(Kentucky League of Cities, 2010; Bluegrass Area Development District, 2012)

A few studies have been done to figure out the implications of sign management programs. The benefits would come in the form of decreased crash rates (i.e. decreased number of crashes that result in injury and fatalities and a decrease in property damage). The valuation of injuries and fatalities is quite accurate as shadow prices or, in other words, plug-in "best estimate" values. Boardman, Greenberg, Aidan and Weimer (2011) provide these values in the textbook "Cost Benefit Analysis, Concepts and Pracitce."

Douglas Ripley's 2005 study, "Quantifying the Safety Benefits of Traffic Control Devices: Benefit-Cost Analysis of Traffic Sign Upgrades," followed crash rates in four separate locations across the United States and Canada before and after traffic sign upgrades. Only three of those locations resulted in three different crash reduction rates. For my analysis I averaged those three crash reduction rates from the Ripley study and transferred those benefits (in the form of reduced number of crashes) to the 2011 crash rates for each county as well as the composite number of crash reductions within the BGADD. When I calculate the number and percentage of crashes reduced I can use the shadow prices and calculate the total value of the benefits to the BGADD (Ripley, 2005). It should be noted that these were the only estimates available and therefore the effects seen in counties within the BGADD may be different because of differences in population density and terrain.

Table 7 details the values attributed to vehicular crashes beginning with crashes that result in property damage only. This table covers varying degrees of car accidents that end in injuries and concludes with crashes that result in fatalities. Table 8 depicts the number of crashes per county inside the BGADD region. Only crashes that ended in property damage only, the number crashes that end in injury per county, the number of crashes that end in fatalities per county were counted. The columns that depict crash reductions are calculated using the 32% reduction rate averaged from the Ripley study (Ripley, 2005).

Table 7 – Shadow Prices of Vehicle Crashes

Injury	Monetary Value (In 2008 dollars)	
Motor Vehicle Accident Costs - Property Damage Only	$3,150.00	per vehicle
Abbreviated Injury Scale 1	$18,670.00	per injured person
Abbreviated Injury Scale 2	$196,350.00	per injured person
Abbreviated Injury Scale 3	$390,576.00	per injured person
Abbreviated Injury Scale 4	$909,404.00	per injured person
Abbreviated Injury Scale 5	$2,987,090.00	per injured person
Abbreviated Injury Scale 6 - Fatality	$4,184,651.00	per fatality

(Boardman et al., 2011, Table 16-1)

Table 8 – Number of crashes and number of crashes avoided for Bluegrass Area Development District**

County	Collision with PDO	32 % PDO Reduction	Collision with Injury	32% Injury Reduction	Collision with Fatality	32% Fatality Reduction	Total Collisions	Total 32% Collision Reduction
Anderson Co	125	40	17	5.44	1	0.32	188.44	60.3008
Bourbon Co	176	56.32	34	10.88	2	0.64	279.2	89.344
Boyle Co	213	68.16	34	10.88	1	0.32	327.04	104.6528
Clark Co	229	73.28	57	18.24	3	0.96	380.52	121.7664
Estill Co	58	18.56	13	4.16	2	0.64	95.72	30.6304
Fayette Co	13872	4439.04	2468	789.76	42	13.44	21610.8	6915.456
Franklin Co	482	154.24	66	21.12	2	0.64	725.36	232.1152
Garrard Co	100	32	21	6.72	1	0.32	160.72	51.4304
Harrison Co	172	55.04	33	10.56	1	0.32	271.6	86.912
Jessamine Co	350	112	67	21.44	1	0.32	551.44	176.4608
Lincoln Co	114	36.48	39	12.48	3	0.96	204.96	65.5872
Madison Co	775	248	96	30.72	9	2.88	1158.72	370.7904
Mercer Co	146	46.72	40	12.8	0	0	245.52	78.5664
Nicholas Co	32	10.24	14	4.48	0	0	60.72	19.4304
Powell Co	83	26.56	17	5.44	2	0.64	134	42.88
Scott Co	392	125.44	83	26.56	5	1.6	632	202.24
Woodford Co	231	73.92	58	18.56	1	0.32	382.48	122.3936
Gross Totals	**17550**	5616	**3157**	1010.24	**76**	24.32	**27409.24**	**8770.9568**

*Property Damange Only
**Using a 32% crash reduction rate
(CrashInformationKY.org, 2011)

There are multiple alternatives to consider, but for my analysis I have chosen to look at four. One alternative will consider the cost of counties performing a self-assessment and paying for all of the compliance materials (the gun, the compliance kit, and labor). The second alternative will look at the cost to counties should they choose to contract with the Bluegrass Area Development District and pay the administrative fee to comply with the required assessment. Both alternatives are further categorized by sheeting type and management method. Regardless of the assessment method each county chooses to go with, all counties will be responsible for the cost of management and either blanket or 50% sign replacement methods. Whether they choose to go with a blanket replacement or 50% replacement at the beginning and then replace signs as they reach their warranty is up to the county but they will still be responsible for the costs of the sheeting materials.

Results and Recommendations

Overall, I discovered that the net benefits (NB) were greater when a 50% Replacement Method was chosen as opposed to the Blanket Replacement Method (BRM). This is because, in the 50% Replacement Method, only one half (50%) of the signs out in the field are replaced at one time. Choosing to replace half of the signs at a time makes more financial sense than choosing to replace all of the signs all at once. The first alternative has been broken down by sheeting type.

Table 9 – Net Benefits of Self-Administered Sign Assessment

Alternative 1 – Self Assessment	Net Benefits - Blanket Replacement	Net Benefits - 50% Replacement
3M Type I Sheeting (Engineer Grade)	$8,463,704.00	$8,559,309.60
3M Type 3,4,10 (High Intensity Sheeting)	$8,270,504.00	$8,461,784.00
3M Type 8,9,11 (Diamond Grade^3)	$7,565,704.00	$8,110,305.60

*Net Benefits = (Number of Crashes Reduced * Total Monetary Gross Benefits) – (Assessment Costs + Labor + Cost of Replacement Method)*

The second alternative, also broken down by sheeting type, shows even greater net benefits because the assessment costs are only $10,000.00. The BGADD already owns a retroreflectometer and a compliance kit. The $10,000.00 Administrative fee covers the cost of the labor for our GIS team to perform the assessment. It should also be noted that $10,000.00 is a maximum fee. There is a chance that our labor costs may not even come to that amount in which case the net benefits would be even greater.

Table 10 – Net Benefits of Bluegrass Area Development District Administered Sign Assessment

Alternative 2 – BGADD Assessment*	Net Benefits - Blanket Replacement	Net Benefits - 50% Replacement
3M Type I Sheeting (Engineer Grade)	$8,506,468.00	$8,602,073.60
3M Type 3,4,10 (High Intensity Sheeting)	$8,313,268.00	$8,504,548.00
3M Type 8,9,11 (Diamond Grade^3)	$7,608,468.00	$8,153,069.60

*Bluegrass Area Development District Administrative Fee

Based on my analysis, it is clear that opting to pay the Bluegrass Area Development District administrative fee and opt for the 50% Replacement Method results in the highest net benefits overall. This method results in higher net benefits because only half of the signs are being replaced at a time. Only paying for 20,000 signs to be replaced is half as expensive than paying for 40,000 signs.

Net benefits were calculated by multiplying the number of overall crashes reduced by total of the value of injuries minus the aggregate costs of labor plus the compliance materials.

Figure 1 – Equation for Calculating Net Benefits
*Net Benefits = (Number of Crashes Reduced * Total Monetary Gross Benefits) – (Assessment Costs + Labor + Cost of Replacement Method)*

All calculations were made under the assumption of a one year assessment and replacement period. The BGADD option even results in higher net benefits than a Self-Assessment method for a Blanket Replacement if the county chooses to use the Type I retroreflective material.

The only time utilizing the BGADD did not result in higher net benefits was when the county chose to follow the 50% Replacement Method and opted to use Type I grade of retroreflective material. In the long run this may end up a more expensive option because the lower grade sheeting has a shorter warranty and sign life and would require a higher turn-over. Decreasing the amount of turn-over is one way to cut back on costs. Whether or not crash rates are affected more or less depending on the sheeting type was not considered because that data is unknown.

It is my recommendation that counties choose the BGADD to perform the initial assessment. In terms of performing the maintenance method, I believe it is a wise decision to start with the 50% Replacement Method using a higher grade retroreflective material (either the High Intensity or Diamond Grade Prismatic). The warranty is longer and so the cost of replacing the signs after their initial assessment will be cheaper because it will have to happen less often than if counties choose to pay for the lower grade sheeting and have to replace the signs more frequently.

Limitations

No continuous inventory or GPS inventory has ever been taken, so the total number of signs within a given county is an estimate at best. In fact, a GPS inventory of sign locations and the exact number of signs present in the field has always been on the Federal Highway Administration "wish list" but because of other higher priorities and budget constraints nothing has been done until now. This mandate has provided the perfect opportunity for states and local governments to do just that. Once all the counties have their assessment and management practices in place, crash information can be cross referenced with the GPS locations of signs and data can start being taken to get a more accurate account of crash reductions.

Again, since there is little data on how sign management programs affect crash rates, it was difficult to find a reduction rate that would be representative of the counties within the Bluegrass Area Development District. The reduction rates found in Ripley's study were averaged because detailed descriptions of traffic patterns and location demographics were not available so there was no way of knowing if one location was more representative of counties within BGADD than the others. In looking towards future analyses, a more exhaustive study may take into account rural roads versus urban and municipal roads where traffic and population densities may be heavier. It would also take into account the wide variety of sizes among traffic signs. I chose to be conservative in my estimate by sticking to the square footage of a stop sign but the true range of sign sizes is vast as speed limit signs are much smaller than stop signs and the big green highway and interstate signs are much larger.

Furthermore, a more exhaustive study would take into account other manufacturers that sell similar kits and retroreflectometers. I chose to only consider 3M retroreflective sheeting because it was specifically cited in the literature released by the Federal Highway Administration. Additionally, I only considered one producer of the retroreflectometer because that kit was comparable in price to others but included not just the gun but the software needed to transfer and interpret the measurements taken. This analysis was also meant to be a quick, at-a-glance report so in the interest of simplicity I only considered the bare minimum of alternatives.

The crash data specific to each county, while close to the actual numbers, may not be 100% complete. I collected data on crashes that occurred between January 1, 2011 and December 31, 2011. Given that some crashes ultimately end with fatalities, those deaths may not have occurred yet as persons injured could still be in the hospital. However the percentage of those not yet dead as part of the final counts should be miniscule in comparison to what I collected previously.

Other concerns that should be taken into account are the difficulty in knowing the life cycle of signs. It has been well documented that Type I retroreflective material does not last as long as Type II or Type III materials. Different brands result in different warranties and sign lives. Additionally, there are many other factors that can affect the life of a traffic sign such as graffiti, theft and just being dirty. While the primary purpose of a sign management program may be to replace and maintain signs that meet minimum retroreflectivity requirements, it may also end up being used as a way to replace signs that have been damaged and not because they no longer meet the minimum requirements.

Overall, there is an indication that maintaining a minimum level of sign retroreflectivity produces net benefits. These net benefits come in the form of reduced nighttime crash rates. Additionally, the assessment and inventory of all signs out in the field will be helpful for all angencies that maintain public roads because it will enable them to track when signs fall below these minimum retroreflective levels. It will also help agencies keep track of how many and which signs are located on any road within an agency's jurisdiction. This will allow for effective and efficient replacement of road signs in the future.

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