Quantifying the Safety Benefits of Traffic Control Devices – Benefit-Cost Analysis of Traffic Sign Upgrades

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ABSTRACT

"Brighter signs are better signs." "Older drivers require better guidance". "New headlights affect visibility of signs". "Crash reductions desired". "New guidelines on minimum retro-reflectivity".

These are all common themes in the traffic engineering and traffic safety community. Every traffic professional has a goal of making the system safer for all drivers. The key problem faced by most practitioners is the budget limitation that is ever-present. Finding new money is difficult at best and existing funding sources are stretched to the limits. Combine that with most public agencies' other priorities and the safety upgrades, while valued, do not measure up to the economic development project or other high profile expenditure. To justify an upgrade in our safety system, we must first prove that the upgrade is cost effective and will make an improvement on safety on the roadways.

Traffic professionals must get the absolute most of the investments they make. This includes staff, equipment and materials. Traffic control devices have long been understood to be some of the most cost-effective methods to addressing safety problems and hazard locations. Typically, this is framed in new installations where the signs are providing new or additional information. What is the impact of upgrading signs to a higher retro-reflectivity? In other words, is brighter better, and if so, by how much?

In 2004, a study was completed by the author that identified four separate locations that had completed sign upgrades. Each location changed signs from ASTM Type 1 to ASTM Type 3 or 9. The reasoning and circumstances were different in each case but all showed positive results in their crash experience when compared to a period before the changes. Since the differences between the applications varied greatly, as did the readily available before and after information it was difficult to identify, with any certainty, what a crash-benefit analysis may be for a practitioner trying to sell a similar project to its financial decision makers.

This research goes further in-depth into the upgrade programs implemented by Sioux City, IA, Mendocino, CA, Putnam County, NY and the Insurance Institute of British Columbia, CA and identifies other projects were sign materials have been upgrades. The process evaluates each specific implementation practice and takes a closer look at the crash results including the types of crashes, locations of signs in relation to the crashes, time of day, light vs. dark, weather and other factors that may have influenced their effectiveness. In addition, state and/or national baseline crash information will be obtained for the same time periods to assist in the establishment of trends

The purpose of the research is to establish and document a Benefit to Cost ratio that can be used by practitioners to anticipate the safety benefits compared to the costs incurred by a signing system upgrade. This information is intended to be most useful when comparing various safety programs while evaluating the numerous demands on the financial resources of a public agency.

Key words: Signs—Benefit to Cost ratio—Safety

INTRODUCTION

With the challenge to traffic professionals to make roadways safer without increasing budgets and subject to strong oversight and demand for instant results, there are few safety improvements that can have such a resounding and widespread impact as the upgrade of traffic signing.

According to the Manual on Uniform Traffic Control Devices (MUTCD), "The purpose of traffic control devices, as well as the principles for their use, is to promote highway safety and efficiency…"[i] The MUTCD continues to state "Traffic control devices notify road users of regulations and provide warning and guidance needed for the reasonably safe, and efficient operation of all elements of the traffic stream".

It has long been accepted that making signs more visible increases their effectiveness and therefore safety. In a 2003 research report completed for the Minnesota Department of Transportation[ii] to address safety at rural intersections some key observations were made regarding signs:

- "At intersections with crashes, the use of more and larger STOP signs appears to reduce the number of Ran the STOP crashes"
- "The use of brighter retro-reflective sheeting material appears to reduce the frequency of both total crashes and right angle crashes. The highest usage of diamond grade sheeting was at intersections with no crashes and the lowest usage was at intersections with multiple Ran the STOP crashes." and
- "STOP AHEAD signs were in place at all but one intersection. At intersections with crashes, it appears that the use of larger, bright advance warning signs reduce the frequency of Ran Thru the STOP crashes."

The MNDOT study concludes that "Increasing the conspicuity of traffic control devises by using bigger, brighter or additional signs and markings appears to lower the Ran the STOP crashes".

The MNDOT study was focused on rural intersections and a specific type of crash but the conclusions have broader application in that the use of brighter signs improves the conspicuity of signs and therefore the compliance of signs resulting in improved safety of roadways.

Many cities, counties and DOT's have been following this principle for years and have felt that the practice has improved the safety of their respective roadways. This study looks at four very different communities who implemented sign upgrade programs in very different ways and reviews the results of the improvements for comparison purposes.

The methods for implementation by each organization are as diverse as the populations they represent. However, in cooperation with the organizations, this review highlights the process and results of four programs intended to improve the safety of their roadways through sign system upgrades by improving the reflectivity and visibility of material used for sign sheeting.

The agencies that were reviewed are spread across North America as shown in **Figure 1** and have implemented sign program upgrades in different ways. Despite the differences, each program had similar results. The sign upgrade programs studied includes:

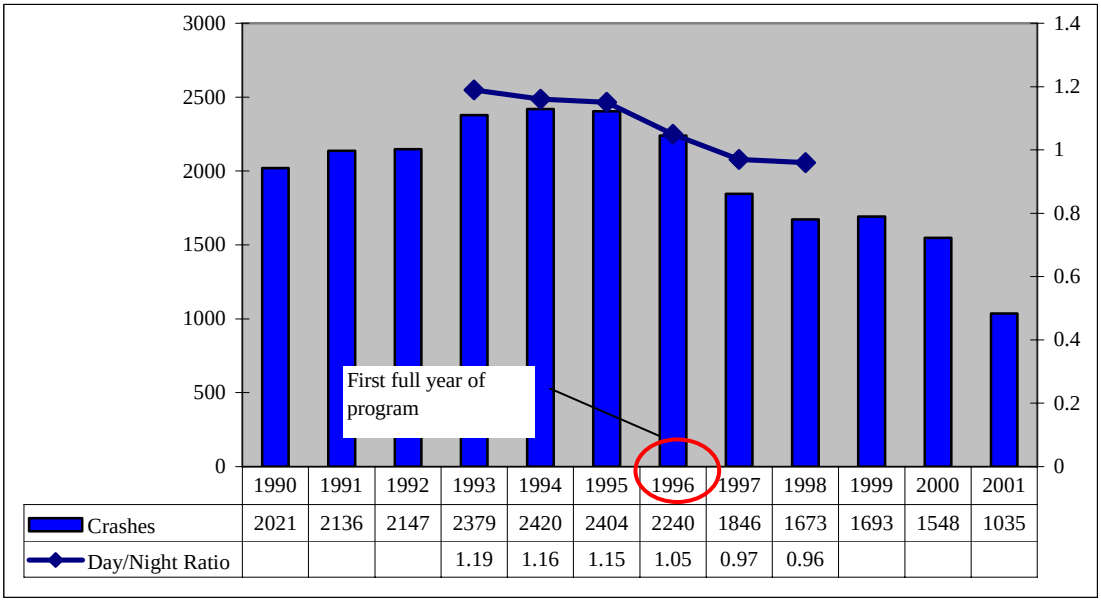
- City of Sioux City, IA
- Insurance Corporation of British Columbia
- Mendocino County Department of Transportation, California
- Putnam County Highway Commission, New York

Figure 1. North America study locations

In each case, the sign programs consisted of upgrading existing Engineer Grade signs to High Intensity (ATSM Type III) and/or Diamond Grade™ (ASTM Type IX) reflective sheeting. The methods and rational where different in each case and provide a good illustration that there are many ways to implement a sign safety program. In each case, the results have been extremely positive in such a way that the programs have been continued and in most instances expanded. A summary of each case study follows.

SIOUX CITY, IOWA

The City of Sioux City, Iowa began a broad based upgrade of its traffic signs throughout the community of 85,000 people in late 1995 and 1996[iii]. Prior to the project, the City used exclusively engineer grade (ASTM Type I) reflective sign sheeting on city routes. The program consists of a complete inventory change-out from engineer grade sheeting to Diamond Grade™ (ASTM Type IX) reflective sheeting for all sign series except parking. The aggressive upgrade process began as a high intensity upgrade program in late 1995 but Diamond Grade™ (ASTM Type IX) material replaced the high intensity material in 1996. The City began replacing approximately 10% of the total sign inventory per year with 3M's VIP™ (ASTM Type IX) material in 1996.



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Crashes	2021	2136	2147	2379	2420	2404	2240	1846	1673	1693	1548	1035
Day/Night Ratio				1.19	1.16	1.15	1.05	0.97	0.96			

Figure 2. Sioux City crash experience[iv]

Figure 2 illustrates the before and after crash numbers and shows an actual reduction of more than 700 crashes from 1993 to 1998. The actual crashes were reduced by approximately 30% and continue through 2001. Figure 2 also shows the reduction of actual crashes as well as the night/day ratio reduction for the years where data is available.

The program has been successful according to R. Scott Carlson, City Traffic Supervisor:

> *"Not only have total accidents gone down but the night/day ratio is a real testament to higher visibility signs and durable/better retro-reflective pavement markings"*

A summary of the program in the Iowa Traffic Control and Safety Association newsletter compared the total number of crashes to the amount of traffic on the roadways. The newsletter states "The crash rate on Sioux City Streets has fallen from 6.53 accidents per million miles in 1995 to 4.03 in 1998 using traffic volumes from the Iowa Department of Transportation and crash records from Access-ALAS". The article continues to state "Based on these observations, it could be concluded that the enhanced visibility of upgraded signs and markings has been effective in contribution to reduced crashes in Sioux City, especially at night."[v]

The city estimated the cost of the program to be $ 144,925 from 1997-1999 and the city estimates a cost savings to the public of $ 4,920,900 from the reduction of crashes over the same time period using the average crash cost of $2,350. Using the city's calculations, the benefit to cost ratio for their program was $ 33.95 to $ 1 over the three year period.

In addition to the sign system improvements, the city also began an upgrade to durable, more reflective pavement markings at approximately the same time. The pavement marking program began on a few corridors and each year additional roadways have been added. While it is difficult to attribute all the safety benefits to the sign upgrades alone, there is clearly a connection between the improvements made by the city and the improved safety results.

INSURANCE CORPORATION OF BRITISH COLUMBIA

In 1996 the Insurance Corporation of British Columbia (ICBC) in Vancouver, British Columbia, Canada began a program to help pay for the costs associated with upgrading traffic control signs from Engineer Grade sign sheeting to Diamond Grade™ (ASTM Type IX) sheeting. The program only included safety related signs such as regulatory and warning signs. Information and guidance signs are not included in the program. The sign program was applied throughout various locations in British Columbia. [vi]

In addition to the signing upgrades, highly retro-reflective pavement markings were also installed. The combination of the improvements makes a direct comparison difficult based on crash data alone. However, in 1998 ICBC commissioned a study on the success of the safety program. Since the applications were widespread and the improvement types were not consistent throughout the program there has not been a detailed study of the before and after crash statistics of the various locations directly related to the sign upgrades.

The study completed by G.D. Hamilton Associates Consulting Ltd.[vii] did estimate the safety benefits of the improvements and found that the program was cost effective assuming a single collision was prevented due to the sign upgrades. **Table 1** was recreated from the 1998 Study.

Table 1. Safety benefit-cost ratio (Highly Reflective Traffic Signs)[6]

Type of Collision	Collision Claim Cost1	Incremental Cost of Sign Improvement2		Benefit-Cost Ratio3	
		1 Sign	4 Signs	1 Sign	4 Signs
PDO	$3,400	$31.25	$125.00	>10:1	>10:1
INJURY	$35,000			>10:1	>10:1
FATALITY	$226,000			>10:1	>10:1

Notes:
1. Average collision claim cost from ICBC
2. Based on incremental cost of replacing existing 75-cn Engineering Grade STOP signs with 75 cm Diamond Grade STOP signs
3. Based on prevention of one collision due to installation of highly reflective signs

In addition, the Hamilton Study found:

> *"Implementation of highly reflective signs and pavement markings has the potential to reduce night-time collisions by increasing sign conspicuity, sign legibility, and consequently driver perception time. 'Before and after' studies performed in the UK of sites at which highly reflective signs were installed showed statistically significant reductions in injury collisions following installation of highly reflective signs, though these studies could not provide a reliable estimate of the percentage reduction in collisions that could be expected."* [6]

In 1996 when the program began, the ICBC spent approximately $12,000 on the program. Based on the Hamilton Associates research and positive program results, the ICBC spent $750,000 on the safety program in 2003. The overall safety program also includes intersection and roadway improvements of all types. While specific crash data is not available on the sign only improvements, the ICBC considers the program a resounding success.

In reviewing the entire road improvement program, a study completed by Sayed, et al.[viii] concluded through using claim prediction models that the overall ICBC road improvement investments, including sign upgrades along with various other safety remedies are cost effective.

MENDOCINO COUNTY, CALIFORNIA

In the 1990's the Mendocino County Department of Transportation began a program to improve roadway signing and markings on arterial and collector roadways.[ix] The program consisted of completing a review of selected roadways, identifying deficiencies such as obsolete or inconsistent signs, poor sign locations or unmarked hazards, recommending corrective actions and reviewing the results.

The program included upgrading the signing on County maintained roads. 2,400 signs of the 11,000 signs in the county were modified through removal, new installations and/or modifications to the signs. When new signs where installed, high intensity reflective sheeting was used whereas before 1993 all signs were installed using engineering grade reflective material. Crashes were reviewed over three year cycles before and after the improvements. In addition, two control groups were evaluated to better measure the actual improvements compared to the control group roadways.

Table 2 illustrates the crash reductions seen on the roadways improved as part of the safety program as compared to two control groups, roadways that were not improved as part of the safety program. Improvements to the program roadways included removing unnecessary signs, replacing outdated signs, modifying existing or installing new signs where needed based on the results of the initial safety review.

Table 2. Mendocino County sign upgrade crash experience[8]

Study Group	Change in Crashes over 6 year study period
Roadways with improved signing	-42%
Control Group1-No Improvements	26%
Control Group 2-No Improvements	-3%

The cost to complete the work was approximately $79,300. Based on average crash costs from the State of California of $34,100 and the actual reduction in crashes, it is estimated that the program saved between $12.5 Million and $23.7 Million with a benefit to cost ratio between 1:159 and 1:299.

Since the original results were so positive, the program was expanded in 1996 to include local streets with some crash history and continues today. Since 2000 some of the signs are being converted to more reflective Diamond Grade™ (ASTM Type IX).

PUTNAM COUNTY, NEW YORK

The Highway Commission of Putnam County, New York, located just north of the New York City metro area, began a traffic sign replacement program in 1993 that replaced more than 2000 signs from engineer grade sheeting to a combination of high intensity sheeting (ASTM Type III) and diamond grade sheeting. The high intensity (ASTM Type III) upgrades were used for regulatory and warning signs for roads with recommended speeds of 30 MPH and above. Diamond Grade™ (ASTM Type IX) sheeting was installed on arrows and chevrons and warning signs with recommended speeds of 25 MPH or less.

This action was done based on the premise of driving being a visual action and typical county roads do not have overhead illumination. A before-and-after study was completed from 1992-1995[x]. Signing improvements were the only significant improvements completed during the study period according to county representatives. The county saw a reduction of crashes of 26%, a reduction of injuries of 23% and a reduction in nighttime crashes of 50%. **Table 3** illustrates the crash experience.

Table 3. Putnam County crash reductions[9]

Year	1992	1995	% Change
Fair Street	42	21	-50%
Croton Falls	39	39	0%
Stoneleigh Ave	31	23	-35%
Total	**112 Crashes**	**83 Crashes**	**-25%**

The Croton Falls location did not see a real number decrease in crashes. However, nighttime crashes were reduced by 53% and wet pavement was a contributing factor in 21 of the crashes.

Of greater significance is the type of crashes that were improved. The improvements were completed on warning and chevron type signs. The crashes that may be related to these types of conditions showed even more dramatic reductions as shown in **Table 4**.

Table 4. Contributing factors for crashes 1992 vs. 1995[9]

Contributing Factors	1992	1995	Reduction
Failure to Yield ROW	16	2	88%
Unsafe Speed	23	2	91%
Slippery Pavement	22	4	82%
Following Too Close	8	1	88%
Improper Lane Usage	4	2	50%
Driver Inattention	1	2	-100%
Other	24	2	92%

The improvements took place on locations with crash history. The county invested approximately $160,000 (1999 dollars) which included the cost of all equipment, sheeting, aluminum blanks and installation. Based on an average cost per crash of $6,400 the county saved $185,000 in its first year of the program.

> *"In 1995, there were 29 fewer crashes on these roads compared to 1992. The cost savings of these crashes can be estimated at $185,600 ($6,400 x 29.) Monetary savings*

in the full first year of the improved signage have already surpassed the initial safety investment."[9]

In addition, the results of the program are summarized by the county as:

"The benefits to the county appear to be phenomenal. By taking an active role in roadway safety, the Putnam County Highway Department offers its customer – the vehicular and pedestrian traffic on county roads – a much safer environment. This improvement will continue to yield positive results as the county population grows and ADT's continue to rise."[9]

Putnam County has continued the program and is currently replacing the signs originally installed wit High Intensity (ASTM Type III) sheeting with Diamond Grade™ (ASTM Type IX) signs.

PROGRAM COMPARISON

Since each program was initiated, implemented and evaluated differently, it is difficult to draw absolute similarities between the different approaches. The fact that the programs were not controlled laboratory studies makes it additionally difficult to eliminate all of the variables that could have impacted the success of each program. However, enough is know to draw comparisons and to look at the different methods used to calculate the benefit to costs ratios to provide a good idea of a range of results that could be anticipated if similar programs are undertaken by other agencies.

The City of Sioux City estimates it spent $144,925 over three years and had a total savings to the public of $4.92M. Mendocino County estimated a total cost of $79,300 over 6 years with a savings to the public of 12.5M -$23.7M. Putnam County completed their program in I year with an expense of $160,000 and a savings of $185,000. The ICBC did not track specific costs and benefits as discussed previously. **Table 5** shows the four programs and how they varied in their approach.

Table 5. Program comparison based on local data

Location	Years	Savings*	Costs	B/C Ratio
Sioux City	3	$4.92M	$144,925	33.95:1
Putnam County	1	$185,600	$160,000	1.16:1
Mendocino County	6	$12.5M -$23.7M	$79,000	159:1 299:1
ICBC	3	NA	$1.5 M	> 10:1

* Savings based on local data provided by each agency

To compensate for the variations in years and cost savings, each program was adjusted to spread the costs and savings over a ten year period (the approximate life of the signs). The crash savings which were calculated by each community based on their local data were also adjusted to a similar cost per crash basis of $6,400 per crash. **Table 6** shows the adjusted costs, savings, and benefit to cost ratios that result.

Table 6. Program comparison using similar cost basis

Location	Years	Savings*	Savings Adjusted**	Costs	B/C Ratio	B/C Ratio Adjusted for 10 Years**
Sioux City	3	$4.92M	$11.6M	$144,925	33.95:1	**267:1**
Putnam County	1	$185,600	$185,600	$160,000	1.16:1	**11.6:1**
Mendocino County	6	$12.5M - $23.7M	$2.4M – $4.5M	$79,000	159:1 299:1	**50.6:1 to 94.9:1**
ICBC	3	NA	NA	$1.5 M	> 10:1	**NA**

* Savings based on local data provided by each agency
** Crashes adjusted to a 1997 NSC Estimate of $ 6,400 -Signs adjusted for 10 Year Life

When comparing the various programs, it is difficult to eliminate all of the variables. However, each program, when adjusted to constant costs and time periods shows a benefit to cost ratio of between 11.6 to 1 and 267 to one. The Mendocino County study, which had the only control data to compare to, when adjusted showed a benefit to cost ration of about 50 to 1. Regardless of the application differences between programs, all of the results where positive.

SUMMARY AND CONCLUSIONS

As mentioned in the introduction, each community is very different and the programs that were undertaken were also very different. Such things as location, roadway types, sign series' implemented, and available data can vary widely.

However, each of the programs has similarities that establish trends and results. Each program was completed at approximately the same time period (1990's), and probably most importantly, each of the programs was deemed successful enough to continue or expand in all cases. Representatives from each area were contacted and all felt the program had achieved positive results that were measurable in the various ways.

The programs in Sioux City, IA, Mendocino County, CA, and Putnam County, NY all showed crash reductions that can be attributed to the sign upgrade program. The ICBC research showed that if a single crash was prevented by upgrading a sign, the program would have a benefit to cost ratio of greater than 10 to 1. Therefore, evidence is clear that completing a sign upgrade from Engineering Grade to High Intensity (ASTM Type III) and/or Diamond Grade™ (ASTM Type IX) reflective sheeting will improve safety and have a positive cost to benefit ratio.

As this review shows, there are various ways to implement a sign upgrade program and each method will have safety benefits to the roadway users. Sign series' can be selected, target roadways can be implemented first, spot locations can be identified or a system wide upgrade completed. In each method,

the results from upgrading the signing system using high- performance reflective sheeting are a reduction in crashes. As shown in the Hamilton Associates study, given the relative expense of a sign upgrade, even a single crash prevented can have a positive benefit-to-cost ratio of more than 10 to 1.

Identifying what an expected benefit might be is more difficult due to the amount of variables in each circumstance, limited available data and the dynamics surrounding each program. However, when comparing the different programs over a similar time frame and using similar crash costs/savings, an expected range can be identified between 11.6 to 1 and 267 to one. The Mendocino County study was the most controlled application and resulted in an adjusted benefit to cost ratio of 50-95 to 1.

The original goal of identifying one expected benefit to cost ratio was not achieved since there were too many variables to provide a true comparison. Despite the differences, in each case, regardless of the implementation process, the results of improving signs from ASTM Type I to Type III and/or Type IX was positive in the actual reduction in crashes and the dollar benefits to the driving public when compared to the costs.

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