*Abridgment*

# Evaluation of Freeway Crash Cushion Delineation Treatments

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ABSTRACT

Presented in this paper are the results of a study conducted to evaluate the effectiveness of improved delineation techniques in reducing accident frequency at freeway gore areas with crash cushions. Four delineation treatments were developed. Three treatments included only reflective static elements whereas the fourth consisted of both static elements and flashing lights. Each treatment was installed at two sites and two additional sites where no changes were made were used as controls. The repair history of each site was used as an indicator of the accident frequency. Treatment effectiveness was assessed by comparing the repair rate before treatment installation to the repair rate after treatment installation. The analysis revealed that the treatment that combined static elements with flashing lights did reduce the frequency of repairs at sites with high initial repair rates (9 to 12 per year). In general, treatments with only static elements had little effect on the repair rate at sites with moderate initial repair rates (3 to 6 repairs per year). However, one static treatment was more effective than the group when the group was considered as a whole.

The severity of accidents at highway gore areas has been greatly reduced by the use of crash cushions although their use does not reduce accident frequency (1). Even though the potential for serious injury has been lessened by their use, collisions with crash cushions can still result in personal injury and property damage. Another consequence of these accidents is the cost of the repair work required to restore a damaged cushion's effectiveness. Attempts to recover the repair costs are made by billing the person who damaged the cushion; however, in many cases, the costs cannot be recovered and are consequently absorbed by the highway department that is responsible for crash cushion maintenance.

Another important aspect of the repair work is the hazard presented to the motoring public and work crews while the damaged crash cushion is being repaired. Gore areas are often located at the interchange of two high-speed, high-volume roadways and, during a crash cushion repair job, special traffic control procedures are required, such as closing off the traffic lanes adjacent to the gore and using flashing arrowboards and flagmen to aid in traffic handling. Because of the complex nature of the situation, both the crew and the motoring public are exposed to greater hazard than if the repair was not necessary. For these reasons, District 12 of the Texas State Department of Highways and Public Transportation (SDHPT) enlisted the aid of the Texas Transportation Institute to develop and test accident countermeasures for freeway gore areas with crash cushions.

## STUDY PURPOSE

The accident countermeasure approach that was chosen for investigation was improved delineation. The delineation treatments tested were intended to increase the conspicuity, or visibility, of the gore area and crash cushion. It was thought that improved delineation would tend to counteract the influence of other factors, such as roadway geometrics and driver inattentiveness, which contribute to crash cushion accidents.

The primary purpose of this study was to develop and implement treatments that would reduce accidents at sites with recurring accidents. The evaluation was performed to see if any of the delineation treatments could decrease accidents and, if so, what level of delineation was required to effect such a reduction.

## STUDY APPROACH

Several delineation treatments were developed, implemented, and evaluated in this study. Treatment descriptions, study site locations, and the before-after evaluation method are included in the following sections.

### Delineation Treatments

Four delineation treatment levels were developed. Figures 1 through 4 illustrate the four treatment levels and demonstrate how delineation elements were added to form each successive level. The elements of each treatment are listed in Table 1.

The base treatment, Level 1 (Figure 1), was made up of three elements that were common to all the treatment levels: (a) yellow and black reflectorized nose panel, (b) yellow painted barrels with reflectorized stripe, and (c) raised reflective pavement markers. The other three levels were formed by adding delineation elements to the basic configuration. As can be seen from Table 1 and Figures 1-4, Treatment Level 2 was formed by adding a yellow and black reflectorized back panel to Level 1. Level 3 consisted of the four elements of Level 2 and reflectorized chevron alignment signs. Level 4 included

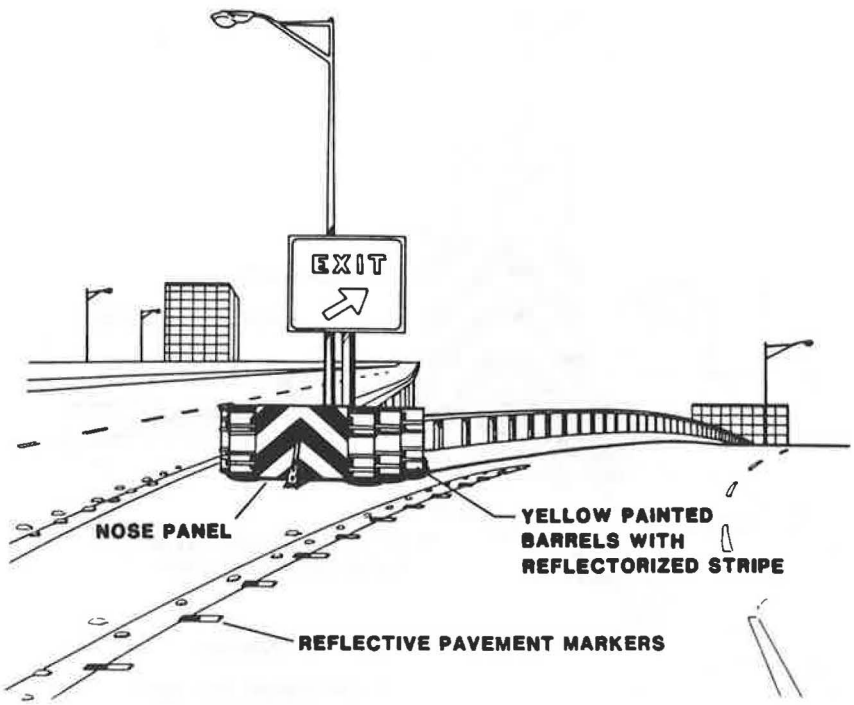


FIGURE 1 Treatment Level 1.

all the elements of Level 3 plus amber flashing lights. It is important to note the distinction between treatment Level 4 and all the other levels. Level 4 is the only level that included a dynamic delineation element, the flashing lights. All the other treatments included only static reflective elements.

Study Sites and Treatment Implementation

Ten of the most frequently repaired freeway crash cushion sites in Houston, Texas, were selected for study. Table 2 lists the average repairs per year for the 3-yr period before treatment implementation for each site. Each of the four treatments was in-

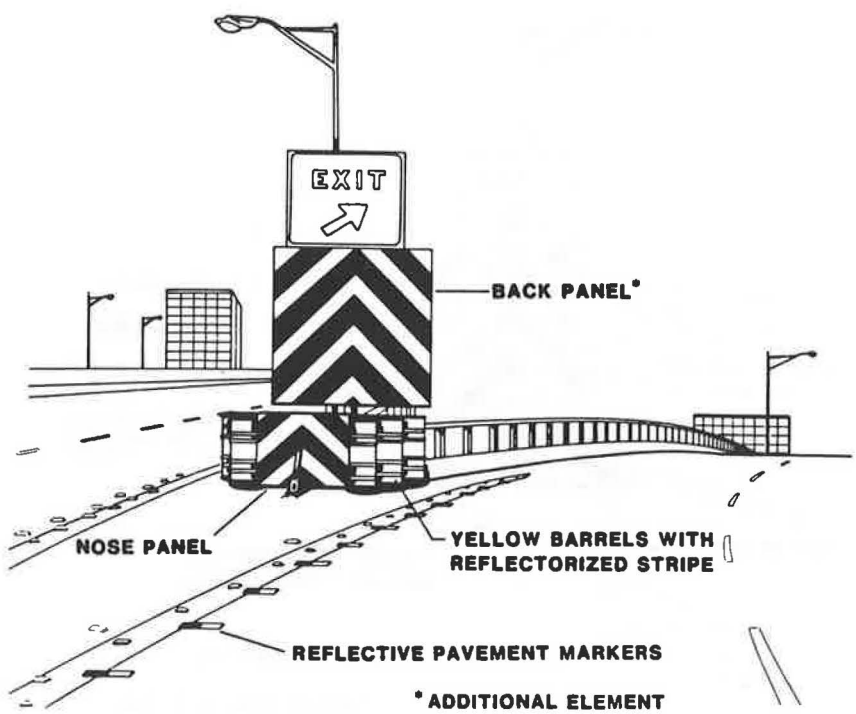


FIGURE 2 Treatment Level 2.

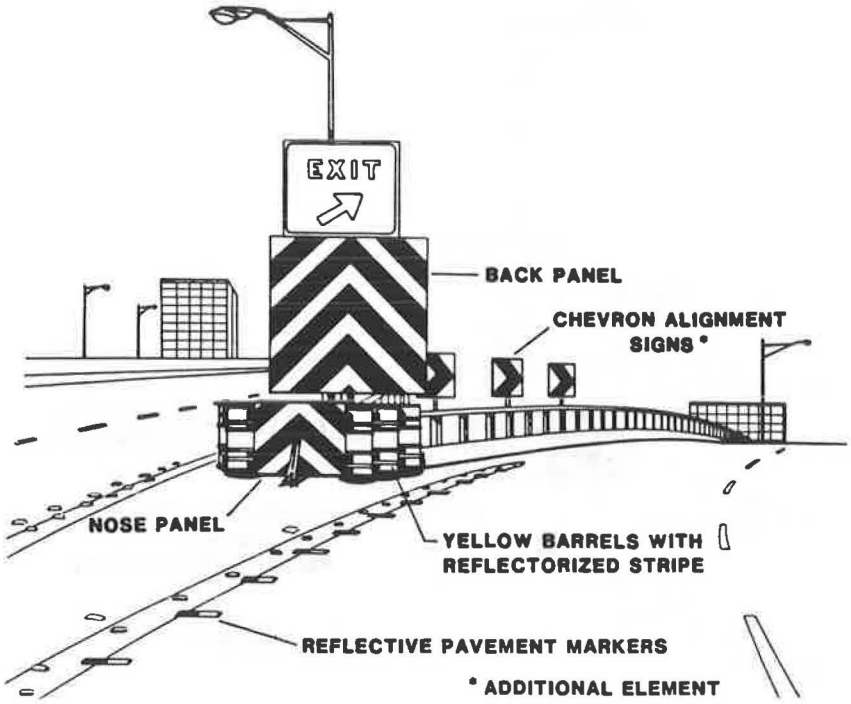


FIGURE 3 Treatment Level 3.

stalled at two sites. No changes were made at Sites 1 and 35 and these sites were designated as controls. The assignment of treatments to sites was based on 3-yr repair histories. The rationale for treatment assignment was based on matching the degree of treatment of the frequency of repairs; therefore, treatment Level 4, which included flashing lights, was installed at the two sites with high average repair rates (9 to 12 repairs per year). The remaining sites all had moderate repair rates (3 to 6 repairs per year). The lowest treatment level, 1, was installed at two sites that had rates at the low end of the moderate repair rate range. The two remaining treatments, Levels 3 and 4, were assigned to four sites with moderate rates. The two sites where treatments were not installed also had moderate rates. Thus, two distinct groups of sites (those with moderate repair rates and those with high re-

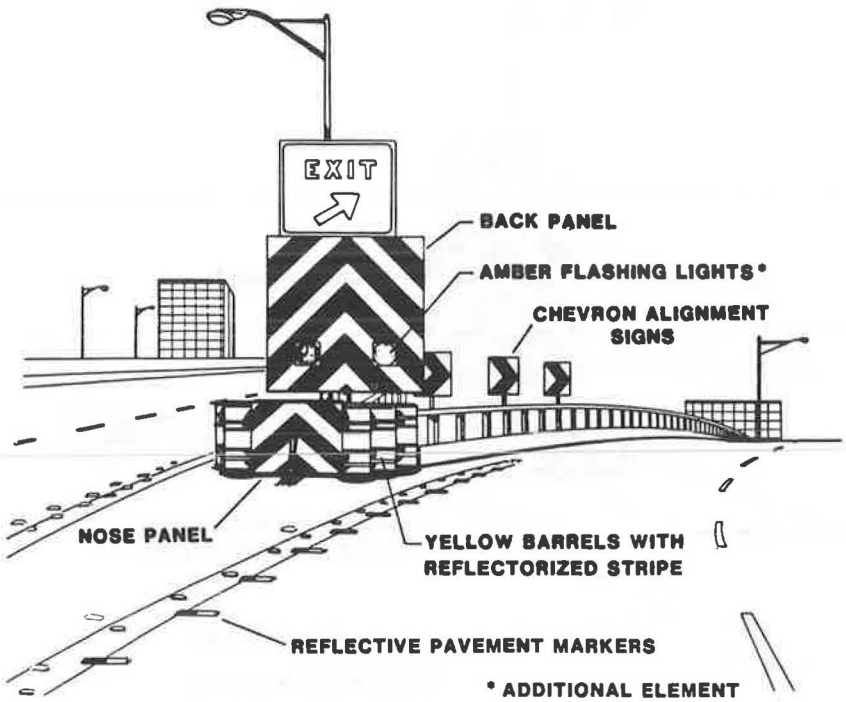


FIGURE 4 Treatment Level 4.

**TABLE 1 Delineation Elements Included in Each Treatment Level**

| | Basic Delineation Elements | | | Supplemental Delineation Elements | | |
|---|---|---|---|---|---|---|
| Treatment Level | Nose Panel[a] | Painted Barrels with Reflectorized Stripe[b] | Raised Reflective Pavement Markers | Back Panel[a] | Chevron Alignment Signs[c] | Flashing Lights[d] |
| 1 | X | X | X | | | |
| 2 | X | X | X | X | | |
| 3 | X | X | X | X | X | |
| 4 | X | X | X | X | X | X |

[a]Yellow and black alternating stripes (reflectorized).
[b]Yellow barrels and reflectorized stripe.
[c]MUTCD Sign No. W1-8 (reflectorized).
[d]Amber lenses.

**TABLE 2 Study Site Summary**

| Site | Avg Repairs/ Year Before Treatment Installation[a] | Treatment | Site | Avg Repairs/ Year Before Treatment Installation[a] | Treatment |
|---|---|---|---|---|---|
| 1 | 3.7 | None | 6 | 4.7 | Level 2 |
| 2 | 3.7 | None | 7 | 4.7 | Level 3 |
| 3 | 3.0 | Level 1 | 8 | 6.0 | Level 3 |
| 4 | 3.7 | Level 1 | 9 | 12.0 | Level 4 |
| 5 | 5.7 | Level 2 | 10 | 9.0 | Level 4 |

[a]Based on 3 yr of repair data.

pair rates) could be identified, and distinctly different delineation approaches--static reflective treatments versus static reflective with flashing light treatments--were assigned to the two groups.

## Treatment Evaluation

The delineation treatments developed in this study were intended to reduce accidents. It was therefore desirable to evaluate them on the basis of their accident-reduction capability. Because most crash cushion collisions are not reflected in police accident reports and are generally not compiled specifically for gore areas, another measure of treatment effectiveness was needed. Repairs to damaged crash cushions were chosen.

In Houston, repairs to gore area crash cushions are made whenever damage is reported or discovered. Repair records will reflect hits except when another collision occurs before the original damage can be repaired. The best information available suggests that most repairs are made before another collision occurs and that damage is no more likely to go unrepaired at one site than another. Accurate crash cushion repair records are maintained by Texas SDHPT District 12 maintenance personnel. Because of the need for historical data and limitations of the existing accident data base, the consistency of repair procedures during the course of the study meant that repair rates represented the best readily available evaluation measure. The repair frequency serves as an indicator of the accident history of the sites during the same period. It was therefore assumed that changes in repair rates reflected changes in accident rates, and that treatment effectiveness could be judged on the basis of the changes in repair rates before and after treatment installation. Repair data were obtained for 3 years prior to treatment installation and for a period of 12 to 22 months after treatment implementation (depending on the initial installation date). The main limitation of a before and after study, however, is the possibility that changes in the repair rate are a result of factors other than the treatment.

Because it is not practical to control these other factors, there is a chance that changes between the periods of before and after treatment installation are not a result of the treatment. Study designs do exist that randomize the influence of factors other than the treatment. However, these designs generally call for several treatments to be installed at each site and were not practical due to time and cost considerations. In this study, each treatment was assigned to two sites to help balance any possible outside effects. Additionally, the two control sites provide an indication of what the accident experience might have been if no changes in delineation had been made.

# RESULTS

The crash cushion repair data were analyzed two different ways. First, the repair rates for the group of six sites where treatments with static delineation only were installed were compared to the repair rates of the group of two sites where flashing lights were installed in addition to static elements. Second, the results for each treatment level were compared.

## Comparison of Treatment Groups

The comparison of repair rates between the group of sites where only static treatments were installed and the group where flashing lights were also installed revealed two major findings:

1. Delineation treatments with static reflective signing and flashing lights appeared to reduce the number of repairs at sites with high initial repair rates (9 to 12 repairs per year).
2. Considered as a group, delineation treatments with static reflective signing only did not appear to reduce the number of repairs at sites with moderate initial repair rates (3 to 6 repairs per year).

The basis for these findings is clear after inspection of Figure 5. The "before" and "after" repair histories are shown for the two groups of sites: (a) those with moderate repair rates and static delineation treatments, and (b) those with high repair rates with flashing lights.

As can be seen in Figure 5, the average repair rate for the six sites with static delineation treatments changed only slightly over the study period. A slight decrease of about one repair per year per site occurred in the year after treatment installation, but the repair rate returned to previous levels in the second year after treatment installation.

A different pattern was evident, however, for the two sites where flashing lights were installed in conjunction with static elements. The average number of repairs per year increased during all three years before treatment installation, culminating with an average of 15 repairs per year in the year prior to implementation. The annual repairs per site decreased to about 5 in the year following installation. Importantly, repair rates continued to decline during the second year after treatment installation. The second year repair rates are based on 10 months of data for the group with high rates and an average of almost eight months for the group with moderate rates.

A decline following a sudden increase might be expected as a result of a regression to the mean ef-

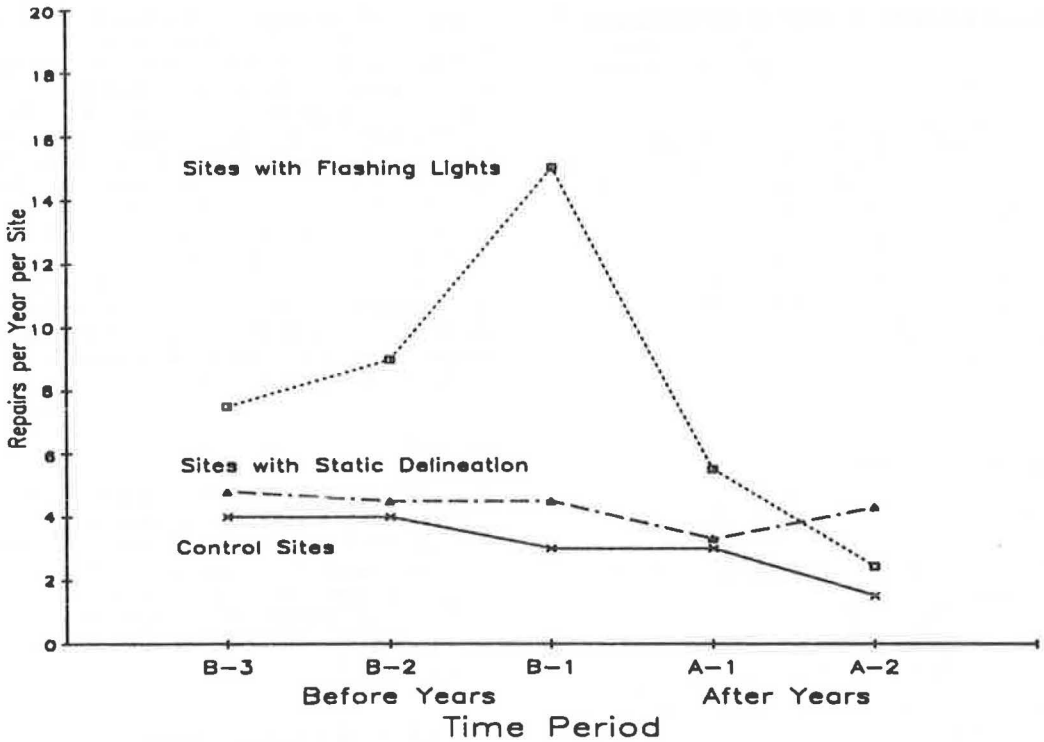


FIGURE 5 Repair rate trends.

fect. On the other hand, the increasing repair rate trend before installation was followed by a consistent reduction to a level below the original average and this occurred at both sites where Level 4 was installed. Other explanations for the changes in repair rates are possible; however, there is evidence that the treatment was responsible for at least some of the reduction, especially if the trends in repairs are examined.

The control group history could normally be used to determine what the accident experience would have been in the absence of a treatment. It is unfortunate, however, that the variation in the repair histories before treatment installation at the high repair rate sites does not match the control group. The control group experience is therefore not appropriate for comparison with the high repair rate group. In addition, the results neither indicate whether treatments involving only static treatment delineation elements would have caused a reduction in repairs at the high repair rate locations, nor do they provide information on the possible effects of flashing lights at sites with moderate repair rates.

## Comparison of Individual Treatments

An inspection of the results on a treatment-by-treatment basis reveals that one of the static delineation treatments, Level 2 (base plus back panel), had a greater effect on the repair rate than other static delineation treatments. This finding is demonstrated in Table 3. A reduction in repairs of 58 percent, or 3.0 repairs per year per site, was noted for the sites with Level 2. In contrast, the Level 1 sites experienced an increase in repairs of 12 percent while a reduction of 2 percent was observed for the sites with Level 3.

It should be noted that the Level 2 and Level 3 treatments are very similar, and the Level 3 treatment had a minimal effect on the repair rate at two sites where it was implemented. Thus, it is important to consider the results from both Level 2 and Level 3 sites to assess the effectiveness of this type of treatment. The indication is that the Level 2 or Level 3 type treatment might be effective at some locations, but there is evidence that at other sites, the impact is slight. Site characteristics are likely to have a significant effect on treatment effectiveness. For example, both sites where the Level 3 treatment was installed were located on narrow gores. The sites where the Level 2 treatment was installed were at the gore of two roadways with a greater angle between the two diverging roadways.

TABLE 3 Comparison of Repair Rates Between Treatment Levels

| | Repairs per Year per Site | | | |
|---|---|---|---|---|
| Treatment | Before[a] | After[b] | Change | Change (%) |
| None | 3.7 | 2.4 (20) | -1.3 | -35 |
| 1 | 3.3 | 3.7 (17) | +0.4 | +12 |
| 2 | 5.2 | 2.2 (21) | -3.0 | -58 |
| 3 | 5.3 | 5.2 (18) | -0.1 | -2 |
| 4 | 10.5 | 4.2 (22) | -6.3 | -60 |

[a]Based on data for 3 yr.
[b]Based on data for the number of months listed in parentheses.

## SUMMARY

This study had provided evidence that supports the following three statements:

1. Treatments that combine flashing lights and static elements reduced repairs at sites with high initial repair rates.
2. Considered as a whole, treatments with the static delineation elements studied did not reduce repairs at sites with moderate initial repair rates.

3. At two sites where the Level 2 treatment (base plus back panel) was installed, reductions in repairs were experienced that were greater than the average found at sites where static treatments were considered as a whole.

It should be kept in mind, however, that this study did not control for changes in other factors, such as traffic volumes and advance signing, which could have influenced the frequency of accidents and, consequently, repairs. In particular, changes in traffic volumes can account for variations in accident frequency. Specific information on year-to-year traffic fluctuations at each site was not available. The best information available, however, suggests that variation in traffic volume was not the cause of the increases in repair rates at the high repair rate sites. Most freeways in Houston have experienced steady growth in traffic during the study period.

It cannot be said with absolute certainty that the changes in repair rates were solely a result of the changes in delineation. However, the results were consistent within groups of sites with similar treatments and repair histories. This investigation of delineation effectiveness at gore areas has provided insight to the problem and has indicated that accidents may be reduced through improved delineation. However, since the treatment with flashing lights was only installed at sites with high initial repair rates and static treatments were installed only at sites with moderate repair rates, the following additional questions are raised by this study:

1. Can treatments that involve only static delineation elements cause a reduction in repairs at sites with high initial repair rates?
2. Can treatments that include flashing lights and static delineation elements cause a reduction in repairs at sites with moderate repair rates?
3. Was the reduction observed at sites with high initial repair rates truly a result of treatment effectiveness?

The use of increased delineation to reduce accidents shows promise and the questions raised in this study warrant further investigation. It is suggested that additional research, using a rigorous study design that accounts for other possible influential factors (especially traffic volumes) be conducted to further explore delineation of crash cushions in gore areas.

## ACKNOWLEDGMENTS

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## REFERENCE

1. L.I. Griffin. How Effective Are Crash Cushions in Reducing Deaths and Injuries? Public Roads, March 1984.

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