Delineation of Urban Freeway Gore Area Crash Cushions in Texas

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The objectives of this study were to identify and document current delineation practices for urban freeway gore area crash cushions in Texas and to evaluate the long-term effectiveness of experimental crash cushion delineation treatments. The treatments examined were implemented as part of a previous research study in 1982. A survey of the Texas State Department of Highways and Public Transportation (SDHPT) found that most districts used some type of delineation on steel drum crash cushions but varied considerably as to the type and amount used—from small object markers to nose and/or back panels and flashing lights. A problem cited by the districts was that there are currently no standards or guidelines in Texas for delineating crash cushions in freeway gore areas. Experimental treatments investigated in a previous study in Houston were reevaluated to determine their long-term effectiveness. The results indicated that treatments installed several years ago had retained their effectiveness in reducing crash cushion repairs over time. Delineation of steel drum crash cushions at eight study sites was considered to be cost effective. Using a cost estimate from a previous study, it was estimated that average annual savings in labor and replacement material costs for the treatments ranged from $990 to $4,400 per site. Total savings at the eight sites, accumulated over the 4-year period, were estimated to be approximately $88,000.

Crash cushions are commonly used at freeway gore areas to reduce vehicle impact severity and occupant injuries resulting from fixed object collisions (*1*,*2*). However, replacement costs of the attenuators (either in part or whole) and the exposure of maintenance personnel to potentially hazardous situations during repair activities offsets, to a degree, the safety benefits derived from crash cushion use.

Recent studies have addressed the idea of increasing crash cushion conspicuity in an attempt to reduce accidents with urban freeway gore area crash cushions. When sight distance to the gore area on an urban freeway is limited, added delineation has been shown to reduce the frequency of crash cushion repairs and vehicle encroachment rates through the gore (*3*,*4*). The short-term reductions in repairs were so impressive in Houston that the Texas State Department of Highways and Public Transportation (SDHPT) installed nose and back panels at most freeway gore area crash cushions in that city.

Recent research on crash cushion delineation (*5*) has suggested that delineation requirements are not the same for all urban gore areas. A classification scheme was developed as part of that study, based on the effective sight distance and geometric alignment in advance of the gore area. With this scheme, it became apparent that sites with limited sight distance to the crash cushions might benefit from increased delineation (such as a back panel) to increase the effective sight distance.

Little guidance is available regarding the delineation of freeway gore area crash cushions. Previous studies of crash cushion delineation treatments have been limited to short-term evaluations of their effectiveness. Since crash cushion accidents are relatively rare, additional research on the performance of delineation over time would be useful in determining whether delineation eventually loses its effectiveness (due to weathering or to drivers becoming accustomed to the crash cushion's presence). In addition, a longer evaluation period would provide a larger database upon which to evaluate the effectiveness of the delineation treatments.

The specific objectives of this study were

- To determine similarities, differences, and problem areas of gore area crash cushion delineation in Texas; and
- To perform a long-term evaluation of crash cushion delineation treatments installed in a previous study to determine the effectiveness of the treatments over time in reducing crash cushion impacts.

This paper presents a summary of the results of the research. More specific details concerning the study can be found elsewhere (*6*,*7*).

CURRENT GORE AREA CRASH CUSHION DELINEATION PRACTICES IN TEXAS

As an initial step, a telephone survey of 23 of the 24 SDHPT districts was conducted to determine current practices regarding the delineation of urban freeway gore area crash cushions. (One district was not contacted because it had no urban freeways.) The survey provided information on the different types of delineation being used across the state as well as the similarities, differences, and problem areas with current delineation procedures. Site visits were made to five of the districts to examine and further document the different types of delineation currently in use in Texas.

Extent and Types of Delineation Use

Fourteen of the districts were found to use crash cushions at one or more urban freeway gore areas. Three of these reportedly do not use delineation to improve conspicuity. Of the other 11 districts using delineation, the amount and type of

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delineation varied considerably. Some districts used different types of delineation, depending on site-specific characteristics.

Table 1 presents a summary of the different types of delineation used for gore area crash cushions on urban freeways and the number of districts using each type. The most common delineation treatments include object markers—type 1 and type 2, as described in the *Texas Manual on Uniform Traffic Control Devices* (*8*)—and chevron-patterned reflective nose panels mounted on the front of the cushions. Examples of these treatments are shown in Figures 1 and 2. Colors used for the nose panels vary by district, with black/yellow, black/white, and orange/white panels currently in place.

In some cases, the nose panel is supplemented with a back panel to add conspicuity and increase the effective sight distance to the gore area. Flashing lights have also been installed at some gore areas in the Houston, Dallas, and Ft. Worth districts. At some relatively high accident locations, several types of delineation have been combined to further increase the conspicuity of the crash cushions. Examples of these supplemental delineation treatments are shown in Figures 3 and 4.

TABLE 1 COMMON DELINEATION PRACTICES FOR URBAN FREEWAY GORE AREA CRASH CUSHIONS

Type of Crash Cushion Delineation		Number of Districts Using*
Nose Panels		5
black/yellow stripes	(3)	
black/white stripes	(2)	
Object Markers on or at Nose		6
Reflective Paint on Crash Cushions		1
Guardrail Delineators		1
Supplemental Delineation:		
flashing lights		3
full gore area lighting		1
back panels		3

*Some Districts use multiple types of delineation treatments

FIGURE 1 Type 2 object marker at front of crash cushion.

Delineation Problems Encountered

The most common problem reported by the districts was loss of reflectivity due to road film covering the delineation treatment. The districts do not have an efficient method of cleaning delineation treatments, nor do they have the manpower to clean them often enough. Also, cleaning exposes the worker to traffic, increasing the possibility of an injury.

Another problem identified was that no specific guidelines exist as to when, how much, or what type of delineation should be used. The wide variety of treatments and combination of treatments shown in Figures 1 through 4 are evidence of this. Finally, there has been little communication among districts regarding the results of delineation techniques and devices

FIGURE 2 Chevron nose panel and type 1 object marker.

FIGURE 3 Type 2 object marker with supplemental flashing lights.

that have been tried. Although some districts were aware of the delineation efforts of others, a widespread knowledge of general activities throughout the state was absent.

Survey Summary

Based on the survey results, there appears to be considerable variety in crash cushion delineation procedures statewide. However, there were some similarities for delineating freeway gore crash cushions. Nose panels and object markers were the most common types of delineation, with supplemental back panels and flashing lights used at some locations with relatively high accident occurrences.

Although similarities do exist, there were far more differences among delineation practices across the state. Color combinations for nose or nose/back panel configurations varied among black/yellow, black/white, and orange/white. There is a lack of guidelines in Texas regarding the number and types of delineation that should be used, as well as guidelines concerning the feasibility or appropriateness of delineating freeway gore area crash cushions. However, a recent step toward uniformity was taken by the SDHPT in designating the black/yellow combination as proper colors for crash cushion delineation treatments. The installations currently not in compliance will be changed as it becomes necessary to replace them.

FIGURE 4 Nose panel supplemented with back panel, flashing lights, and chevron alignment signs.

LONG-TERM EFFECTIVENESS OF CRASH CUSHION DELINEATION

This portion of the study addressed the long-term evaluation of experimental crash cushion delineation treatments at freeway gore area locations in Houston. These sites were previously investigated in a 1982 study by Wunderlich (*3*), which compared the short-term effectiveness of delineation treatments having varying levels of delineation.

The Wunderlich study used crash cushion repairs to investigate the effects of the experimental delineation treatments. These treatments, which are summarized in Table 2, consisted of varying levels of static delineation (pavement markers, chevrons, and nose and back panels) and one dynamic treatment (flashing lights). Treatments 1 through 4 are shown in Figures 5 through 8, respectively. Each treatment was installed at two sites. Generally, those sites having initially high average repair frequencies received more conspicuous treatments. Two additional sites did not receive any delineation and were used as control sites. Crash cushion repair records from each site were obtained for 3 years prior to treatment installation. The repair records were then collected for a period of time after treatment installation (17 to 22 months) and compared to the records from before installation.

The Wunderlich study indicated that static delineation in combination with flashing lights significantly reduced crash cushion repairs at sites with initially high repair rates (six or more repairs per year). However, it appeared that the static delineation treatments alone did not, as a group, reduce

TABLE 2 DELINEATION ELEMENTS INCLUDED IN EACH TREATMENT LEVEL (*3*)

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

[a] Yellow barrels and reflectorized stripe

[b] Yellow and black alternating stripes (reflectorized)

[c] MUTCD Sign No. W1-8 (reflectorized)

[d] Amber Lenses

Source: Reference (3)

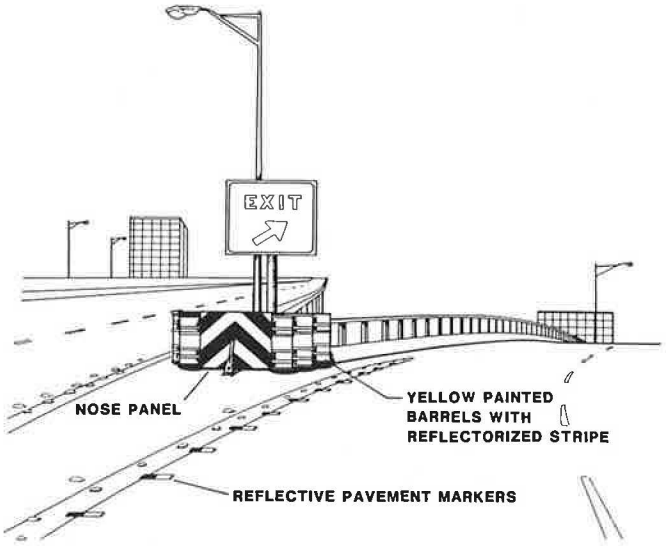

FIGURE 5 Treatment 1.

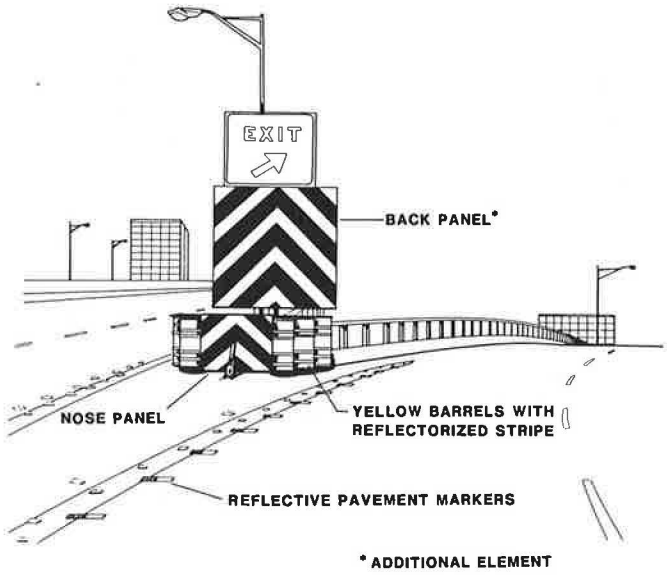

FIGURE 6 Treatment 2 (with supplemental back panel).

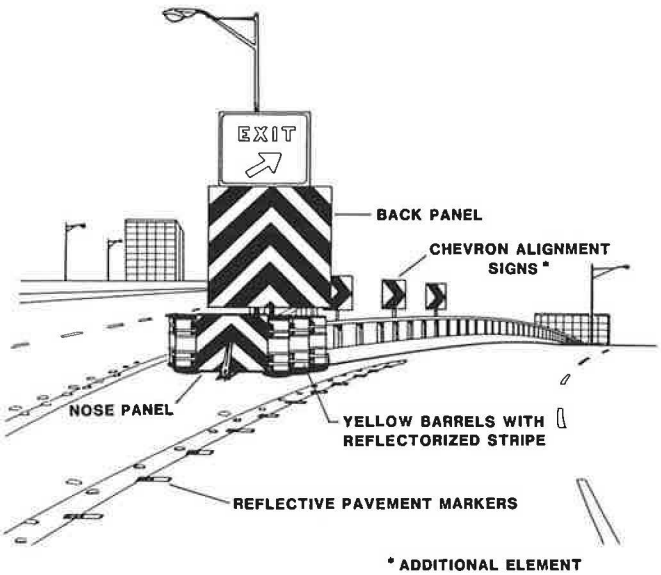

FIGURE 7 Treatment 3 (with supplemental back panel and chevrons).

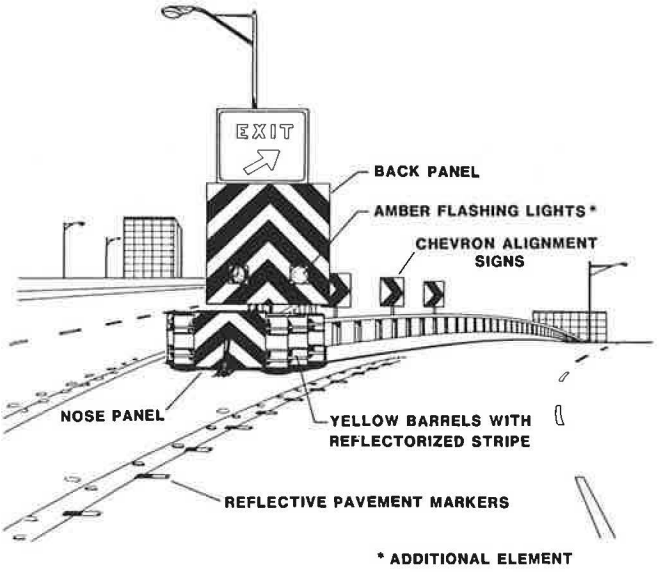

FIGURE 8 Treatment 4 (with supplemental back panel, chevrons, and flashing lights).

repair rates at sites with moderate repair rates (four to six per year). When evaluated on a site-by-site basis, though, some reductions in crash cushion repairs were evident (*3*).

Methodology

Although accidents would be considered the most suitable measure of effectiveness for this type of study, collisions with crash cushions are not always reported. As in the Wunderlich study, crash cushion repairs were used as the measure of effectiveness in this research. Not all accidents with crash cushions require repairs; however, repair records are considered to be a better measure of accident frequency than are accident reports. For this evaluation, crash cushion repair records for the eight Houston sites were obtained for 4 years before and 4 years after the initial treatment installation. The timeframe of the analysis was from January 1, 1979, to December 31, 1986. Crash cushion repair frequencies were examined to determine how the delineation treatments performed over time (in particular, whether crash cushion repairs remained lower or increased).

Results

Table 3 is a summary of crash cushion repairs over an 8-year period at the eight gore area sites examined in the earlier study. Also shown in the table is the treatment level installed

TABLE 3 SUMMARY OF CRASH CUSHION REPAIRS (STEEL DRUMS)

Location	Treatment Level	Year: Before Delineation 79	80	81	82	After Delineation 83	84	85	86
IH-10 EB @ US 59 NB	1	4	4	2	6	3	2	1	2
IH-610 (E.L.) NB @ SH 225 EB	1	0	4	3	3	2	3	3	1
IH-610 (W.L.) SB @ US 59	2	6	6	4	6	3	3	3	2
IH-610 (W.L.) SB @ IH-10	2	5	8	4	4	0	3	4	1
US 59 SB @ IH-45	3	10	6	3	6	4	2	2	3
IH-45 NB @ US 59 SB	3	10	5	6	5	6	2	3	1
IH-610 (W.L.) NB @ US 59	4	12	10	13	12	5	7	7	5
US 59 NB @ RICHMOND AVE.	4	3	7	14	5	4	2	2	4

W.L. = West Loop

E.L. = East Loop

NB = Northbound, SB = Southbound, etc.

TABLE 4 REDUCTION IN CRASH CUSHION REPAIRS BY DELINEATION TREATMENT

Treatment Level	Total Accidents Before Delineation	Total Accidents After Delineation	Percent Change	Statistically Significant*
1	26	17	-35	No
2	43	19	-56	Yes
3	51	23	-55	Yes
4	76	36	-53	Yes

*Statistically significant based on Chi-Square Test with 0.05 Level of Significance

at each site. The number of repairs shown in the table suggests that the delineation treatments did, in fact, remain effective over time.

Table 4 summarizes the reduction in repair frequencies by treatment level for the 8-year period. Due to the similarity between sites, repair frequencies for individual sites were combined for each treatment level. The results indicate that the treatments were effective in reducing the frequency of crash cushion repairs over time. Treatments 2, 3, and 4 showed reductions of more than 50 percent (statistically significant using a chi-square test with 0.05 level of significance). The 35-percent reduction associated with treatment 1 was not found to be statistically significant; however, this is most likely due to the smaller number of repairs, not the treatment effectiveness.

The study by Wunderlich suggested that repairs were not affected by treatments 1, 2, and 3 at the sites with moderate repair frequencies; however, these data were gathered less than 2 years after the treatments were installed. Examining the repairs over a 4-year period indicates that these treatments were somewhat effective in reducing crash cushion repairs.

A comparison of the total repair costs before and after delineation treatments at each of the study locations would have been helpful. However, since these data were not available, an estimated average repair cost was used for comparative purposes. An earlier study (*9*) estimated an annual cost of $1,760 per repair for steel drum crash cushions; however, this figure was for a very limited number of repairs. Recent repair cost data for a sample of 56 repairs were obtained from the SDHPT District Maintenance Office in Houston. The average cost per repair was approximately $880. This compares favorably with the $763 per repair for steel drum installations estimated by McFarland et al. in 1975 (*10*).

Using an average repair cost of $880, the average annual savings in repairs for the various treatments were estimated to range from $990 to $4,400 per year (see Figure 9). This estimate includes only the labor and material costs for the actual repair of the crash cushion; it does not include the average cost to motorists who collide with steel drum crash cushions. The values in Figure 9 show that all treatments did result in some yearly cost savings. These values should not be used to compare the relative effectiveness among treatments, as predelineation repair frequencies varied dramatically from site to site.

Overall, the delineation of the crash cushions at the eight study sites appears to have been cost effective. Total savings at the original sites, accumulated from the installation of the delineation treatments through 1986, are estimated to be approximately $88,000, based on the previous cost estimates. The installation and maintenance costs for the delineation treatments themselves are, for the most part, minimal. Treatment 4, which uses flashing lights, is the most expensive of the treatments examined since it requires a source of power to operate the lights. The costs of items such as pavement markers, chevrons, and nose and back panels are relatively minor by comparison.

CONCLUSION

The primary objectives of this study were (a) to identify and document current delineation practices for crash cushions in urban freeway gore areas and (b) to evaluate the long-term effectiveness of experimental treatments having varying levels of delineation. The treatments examined were implemented as part of a previous research study.

A survey of SDHPT districts in Texas revealed that most districts use delineation on freeway gore area crash cushions. However, there a variety of types are used (such as object markers, nose panels, and back panels). A problem cited by districts was that there are currently no guidelines in Texas for delineating crash cushions.

Long-term evaluations of crash cushion delineation treatments installed and evaluated in a previous study were conducted for sites in Houston. Based on these studies, it appears

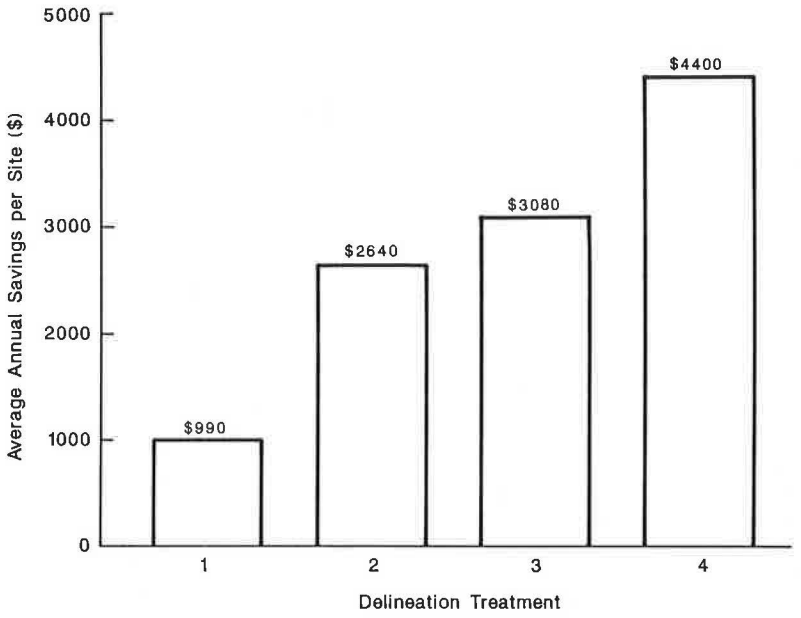

FIGURE 9 Estimated average annual savings in crash cushion repair costs.

that delineation treatments using a combination of nose and back panels (treatments 2, 3, and 4) continued to be effective over time. The nose panel alone (treatment 1) also showed a reduction in repairs; however, the results were not conclusive enough to indicate whether the reduction was related to the treatment itself or occurred by chance. Traffic volumes in the vicinity of the study sites increased slightly over the 8-year study period; therefore, the reduction in repairs was more likely attributable to the delineation treatments and not to reduced exposure to traffic.

Using a cost estimate of $880 per repair (labor and materials) for steel drum crash cushions, the estimated average annual savings for the delineation treatments ranged from $990 to $4,400. Delineation of the crash cushions at the eight study sites is considered to have been cost effective. Total savings at the eight sites, accumulated from the installation of the delineation treatments through 1986, are estimated to be approximately $88,000, based on previous cost estimates. When compared with the savings, installation and maintenance costs of the treatments were considered to be negligible.

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