Comparison of Safety Performance of Urban Streets Before and After Landscape Improvements

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ABSTRACT

Environmental psychologists suggest that appropriately landscaped roadside scenes may have influence on travel-related stress recovery. In addition, it was revealed that landscaped center strips or median planting appears to reduce perceived land width and therefore, to discourage speeding. Generally, the discouraged speed is one of the contributing factors of decreases in crash rates or pedestrian accidents on streets. Based on the assumed safety properties of modern freeways, parkways, and landscape enhancement features, researchers hypothesized that parkway or landscape-improved sections appear to be safer compared to parallel freeway sections or street sections before landscape improvements. In addition, researchers compared the safety performance of parallel sections of freeways and parkways in terms of fatal accident rates, and the safety performance of urban arterial road sections before and after landscape improvements in terms of crash rates.

The findings of this study show parkway or landscape improved sections are significantly safer than the compared parallel freeways sections in pairs or street sections before the landscape improvement. Particularly, urban parkway corridors show a significant decrease in fatal accident rate and accident cost compared to urban freeway sections. Crash rates at urban arterial road sections also show a significant decrease after the landscape improvement. In addition, median landscape treatments appear to be a meaningful safety measure. However, this study suggests further research is required to verify a relationship between driver or pedestrian visual perception according to travelway corridor landscape treatments and traffic safety effects.

INTRODUCTION

The Intermodal Surface Transportation Efficiency Act of 1991(ISTEA), mandated a more balanced approach to transportation system development by including considerations of environmental, cultural, economic, and social conditions. The act also included funding set asides for transportation enhancements, and scenic byways. Landscape and aesthetic improvements to rights-of-way are a significant part of the enhancements program. ISTEA emphasized that, in addition to being safe and cost effective, projects must fit their surrounding environments, especially in scenic, historic or culturally sensitive areas. Federal planning and design guidelines published in 1995, stated that designs may take into account: the constructed and natural environment of the area; impacts of the project upon environmental, scenic, aesthetic, historic, community and preservation interests; and access for other modes of transportation. Then in 1997, FHWA published “Flexibility in Highway Design” which has evolved into what has become known as Context Sensitive Design/Context Sensitive Solutions (CSD/CSS). This approach to the project delivery process applies the principles of flexibility in delivering new transportation projects or reconstructing current transportation projects.

The American Association of State Highway and Transportation Officials (AASHTO), has long recognized that the proper landscape and aesthetic development of urban streets provides a desirable touch of natural beauty in a built environment. These improvements are often the means of improving the economic values of the areas adjacent to the streets and creating a sense of community identity (AASHTO, 1970).

On the other hand, some AASHTO safety interests have expressed concern about the potential hazards of vehicle tree collisions. Concerns about collisions with fixed roadside objects must be balanced against the positive factors of visual preference, noise abatement, and erosion control achieved by roadside landscape development (AASHTO, 1984).

Given these seemingly antithetical views of the roadside landscape, an additional study was undertaken to see if urban freeways with significant landscape improvements would show similar increases in safety performance. This effort attempted to compare the safety performance of urban arterial road sections before and after landscape improvements.

BACKGROUND AND BROAD CONCEPTS OF STUDY

Research background of study

Several field studies of the impact of landscape enhancements have demonstrated a variety of positive impacts on communities and traffic safety. Topp's study of German streetscape enhancements which were characterized by a landscaped center strip was found to be effective in calming traffic and increased traffic safety. Over the period of Topp's study, overall accidents were reduced by 30 percent, the number of accidents with injuries was cut by about 60 percent, and accidents involving street crossing pedestrians were reduced by about 80 percent. In Toronto, Bahar and Naderi (1997) found that the frequency and severity of mid-block accidents decreased after landscape improvements were installed. Mid-block accidents decreased significantly at all the sites studied while city-wide, there was an increase in the number and severity of mid-block accidents.

At a larger scale Mok and Landphair (2003) compared the safety performance of parallel sections of freeway and parkway in seven regional locations. The parkway-freeway pairs were selected on the basis of having similar numbers of lanes, similar traffic counts and similar destinations, so that either route could be selected to move between the same destinations. The results of this study showed that the parkways safety performance was significantly better than that of the freeways. But of even greater interest, the urban sections of the parkways showed the best safety performance of all sections included in the study.

Environmental psychologists have suggested that appropriately landscaped roadside scenes may have influence on travel-related stress recovery. Others have developed theories that attempt to explain the relationship between people's interest and attention to their environment. One of the better known theories was advanced by Berlyne who related interest to the visual complexity of what was seen. Berlyne suggested that attention was aroused as visual stimulus increases, and that if visual stimulus continues to become more complex, subjects will become confused and lose interest. This is known as Berlyne's "Arousal Theory."

In a 1976 study, Wohlwill applied Burlyne's theory to landscape aesthetics. Wohlwill hypothesized that there was an optimal level of stimulus information from the landscape, that is too much information is stressful, and too little information is boring. Taylor et al (1987) demonstrated that driving information is mostly obtained from the outside environment. Generally, parkways and carefully landscaped roadside edges have enough features to be interesting, but not so many that it is confusing or oppressive.

Nature scenes may have comparatively restorative influences on stress, since natural settings may tend to have an optimal level of complexity to be interesting (Wohlwill, 1976). It was revealed that roadside vegetation and aesthetics may affect driver's visual preference, and visual exposure to vegetation-dominated scenes can be stress-reducing, as well as roadside environments dominated by natural elements can mitigate travel-related stress (Kaplan, 1977; Parsons et al., 1998; Ulrich, 1974; 1979). Topp (1990) also indicated that appropriate tree planting and landscaping has a psychological effect of reducing driving speed. In other words, rebuilt street characterized by a landscaped center strip or median planting may reduce perceived lane width of drivers and therefore, discourage driving speed. The discouraged speeding allows drivers to experience wider fields of vision (Swirsky, 2002).

Trees on the Roadside

Trees are often cited as the most hazardous roadside objects. Trees account for more single-vehicle, fixed-object fatalities than any other object along the roadway (Anderson, 1987). Turner and Mansfield (1990) studied urban tree collisions in Michigan and Huntsville, Alabama. According to the Michigan tree study review, the major reason for fatal tree collisions was drinking and reckless driving. More than 60 percent of the drivers in fatal crashes with trees had been drinking, and over 60 percent of the fatalities were under the age of 35. Male drivers outnumbered female drivers by more than two to one. In addition, greater than two-thirds of these collisions occurred on weekends, with the prime time being the extremely late hours of Friday and Saturday nights (Zeigler, 1986).

Therefore, the most frequently encountered problem related to tree collisions is the treatment of existing trees that may present an obstruction to errant motorists (AASHTO, 1996). The issue of trees on the roadside is often a political and social issue among community residents, environmentalists, historical preservationists, and traffic safety engineers when substantial mature trees are involved. What is not clear in these studies is the location of the trees in relation to the driving lanes and other roadside conditions. This issue was explored further in this project.

Roadside Landscape and Aesthetics Design Guidelines

It is generally assumed that modern freeway characteristics of paved shoulders, concrete median barriers and extended vegetation clear zones represent safety related design elements. On the other hand, parkways are characterized by landscaped edges, grassed shoulders, vegetated medians, other landscape elements within 30 feet of the edge of the driving lanes, and in harmony with existing nature and surrounding development.

Texas Department of Transportation's Landscape and Aesthetics Design Manual (2001) incorporates many safety criteria in the guidelines for roadside landscape and aesthetic treatments. Planting guidelines used by TxDOT are as follows:

1) Roadside vegetation should be designed or maintained to accomplish specific goals of sight-distance, clear view of obstructions, erosion control, and aesthetics.
2) Plants must not be planted where they may obstruct any signs, sightlines, or driver visibility.

3) On frontage roads, allow a minimum of 3 feet clear space between the back of curb and any area to be maintained for maintenance personnel.
4) Plant use in intersection areas must be limited to low-growing varieties.
5) Plants must not be placed near merging lanes.
6) Landscape improvements must avoid the creation of unsafe conditions for motorists or maintenance personnel.

Many of these guidelines avoid specific dimensions because of liability issues associated with discrete dimensions. Research is ongoing to develop more definitive standards for visibility and clearance.

METHODS OF STUDY

This research was based on comparisons of the safety performance of selected sites before and after landscape improvements on major urban arterial streets and freeways. Sites with landscape development were selected from across Texas and all types of crash data were collected for the comparisons of sections before and after landscape improvements.

Case selections

Before and after landscape improvement sites were selected from over 27 candidate projects in Texas. Researchers interviewed several officials in the Landscape Design Section of TXDOT, landscape architects with the Texas Transportation Institute (TTI), and carefully reviewed the TxDOT landscape project list. From 27 candidate locations in Texas, 10 landscape construction sites were selected (Table 1). These 10 sites represent 8 different cities, 8 of the 10 sites selected reflect Interstate or major arterial highways, and 2 were city streets.

Data collection

Data collection involved state accident data and TxDOT roadway inventory data. The accident data for study sections were extracted from the Texas accident dataset, for 3 to 5-year periods before and after landscape improvements in each study section. The Texas accident data contains all types of crashes that occur on state system roads and streets. These data are maintained and reported by the Texas Department of Public Safety. Each site included a runoff zone of approximately 1,000 feet on either end of the project site and the section of improved landscape development. Sites were selected to avoid major intersections which could confound the data.

Experimental design

A quasi-experimental design is applied to this study because it is practically impossible to assign an experimental treatment randomly (Cook and Campbell, 1979; Council et al., 1980). The before-and-after comparison design was applied to urban highway sites. The concerns for dealing with threats to reliability and internal validity were main issues when the quasi-experimental method was adopted. To minimize the threats to reliability, multiple cases were selected and applied to this research. By imposing the treatment at multiple locations and at different times, treatment effect would be separated from the “uniqueness” of a particular treatment location, and the likelihood of falling to "an unknown history threat" would be reduced. In addition, increased numbers of accident data obtained from multiple locations and times may increase statistical power (Griffin, 1982). Also, control variables help the internal validity of the research constituted by careful case selection, data filtering, and data analysis.

The traffic volume before and after landscape improvements at the study sections was controlled through the calculation of crash rates. Crashes within construction/maintenance zones were ruled out to control construction zone bias. In addition, data recording change in the Texas accident dataset was controlled. That is, property damage only (PDO) crashes were ruled out from the dataset to control data recording bias, because the PDO recording threshold was changed in Texas on July 1, 1995.

Research hypotheses

Based on the review of related theories and research, and considering the research problems, the research hypotheses of this study are:

1) crash rates are significantly decreased after the landscape improvement at Texas study sites,
2) there is a difference in the safety performance according to the landscape treatments, and
3) a decrease is observed in the number of tree collisions and pedestrian accidents before and after landscape improvements.

DATA ANALYSIS

Crash rate before and after landscape improvements

Researchers collected crash data for the ten study locations selected to test for any change of crash rate in sections with landscape improvements. Crash data were collected for 3 to 5-year periods before and after the landscape improvements, omitting any crashes that may have occurred during the construction period. Conceptual explanation of crash data collection and unknown research threats for the comparison period at each study location is delineated in Figure 1.

According to TxDOT Standard Specifications Item 192, roadside planting or landscape establishment period in Texas is 90 to 365 days. Therefore, crashes in the year of landscape construction are ruled out to control landscape construction bias. Also, to minimize the likelihood of falling into unknown threats to statistical validity and separate the treatment effect from the 'uniqueness' of a particular treatment location, multiple cases at different times and different locations are studied. According to Griffin (1997), by imposing the treatment at multiple locations and aggregating the multiple cases at different times, the effects of unknown threats would be reduced. In addition, to control crashes related to construction zones, crashes that occurred during construction were ruled out. To control for changes in the Texas accident data recording protocol, PDO crashes were filtered from the dataset. Traffic volume was controlled using the crash rate per one million VMT. The calculation formula of the crash rate is as follows:

$$\textit{Crash Rate}(CR) = \frac{\text{Number of Crashes} \cdot 1{,}000{,}000}{\text{Traffic Volume} \cdot \text{Section Length} \cdot \text{Years} \cdot 365}$$

Where:

- Crash Rate = Number of crashes per one million VMT at a study road section in a period of time
- Number of Crashes = Number of crashes at a study road section in a period of time before and after the landscape improvement
- VOL = Average of Average Annual Daily Traffic (AADT) volume at a study road section in a period of time
- Section Length = The length of a study road section
- Time Period (yrs) = At least 3 to 5 year periods before and after landscape improvements at the 10 study sections between the years 1984 and 1999

The calculated crash rates showed decreases in traffic accidents at eight of the ten study sections after the landscape improvements (Table 2). The accident rates for two sites increased (locations 1 and 6) and decreased at the other eight sites. Both of the sites that showed increases in accidents were complex grade separated interchanges.

There were also two outstanding positive sites, locations 3 and 9. Because both of the sites had significant improvement they were tested against the other sites and each of them showed to be within three standard deviations (3D) of the mean for the 10 sites. Within the 3D limit does not suggest an extreme or anomalous value. Change in crash rate at all study sites was tested by one-sided paired t-test. The results show that there was a significant crash decrease after landscape improvements at the 95 percent confidence level (p-value: 0.0437, N=10).

Interestingly, two negative sites reflect landscape improvements in interchanges. According to the TxDOT Landscape and Aesthetic Design Manual (2001), the primary feature of an interchange is vertical grade separation of the intersecting routes. The grade separation is achieved using a series of ramps and bridges to accommodate the various directional movements. The series of ramps and bridges in interchange areas need a number of bridge columns or roadside vertical objects (Figure 2). On these sites detailed data analysis revealed that about 50 percent of vehicle crashes at this location were related to roadside fixed objects such as median barriers, concrete traffic barriers, guardrails, and sides of bridges.

Crash rate by the landscape treatments

The landscape improvements to the urban highways can be divided into four types:

- roadside landscaping,
- median landscaping,
- interchange landscaping, and
- sidewalk widening and tree planting.

The analysis of differences in the average crash rates seems to suggest that the 'roadside landscaping' (one-sided paired t-test p-value: 0.0727, N=5), 'median landscaping' (N=2), and 'sidewalk widening and tree planting' (N=1) treatments positively affect safety performance. Median landscape treatments showed a higher decrease in average of crash rates (from 1.1786 to 0.4974) after landscape improvements (Figure 3). However, it is not suggested that this is particularly significant since there were only two instances of median treatments in the sites studied. On the other hand, the 'interchange landscaping' did not appear to impact the crash rate. Trees or other landscaped objects at interchanges are relatively small in scale compared to the bridge columns and other fixed objects. Likewise, the variations in road elevation and curvature of the ascending and descending ramps in these complex interchanges probably require more driver attention and skill, and it may be that the landscape has little impact in these situations. Therefore, impacts of landscape treatments at complex interchanges may not significantly impact overall safety performance.

Analysis for tree collisions and pedestrian accidents

The number of tree collisions in the research was compared by a reduction factor. The reduction factor method is commonly used in simple before-and-after study design to compare treatment effects before and after the treatment intervention (Al-Masaeid, 1997). The tree collision reduction factor formula is given by:

$$\text{Reduction Factor} = \frac{(X_b - X_a)}{X_b} \cdot 100$$

Where:

- X_b = Number of tree collisions before the landscape improvements at the study sections.
- X_a = Number of tree collisions after the landscape improvements at the study sections.

The calculated reduction factor shows a decrease of about 70.83 percent of tree collisions after the landscape improvements at ten study locations (Table 3). As shown in Table 3, there were no extreme changes in tree collisions before and after landscape improvements except for site 3. This site is on a four lane divided section of US 75 North in Dallas (Figure 4). This section has grade separated interchanges and is bounded by frontage roads. After the installation of roadside landscape improvement the site showed a significant decrease in tree collisions. The change appears to be associated with the landscape treatment in 1992 (Figure 5). The change may also be explained by TxDOT landscape design changes which brought the site into compliance with clear zone rules and planting setback rules.

While not a primary objective of this study, a marked decrease in the number of pedestrian fatalities was noted in the analysis phase of the work. Using the same reduction factor procedure noted earlier there was a 46.91 percent decrease in pedestrian accidents after the landscape improvements at the locations studied (Table 4). According to the information received from TxDOT none of the 10 locations had additional improvements such as installation of walls or barriers for pedestrian safety during the study period. There were some additions of retaining walls with planting. But, these were outside the 30 foot clear zone. Most of the pedestrian accidents happened in the main lanes when pedestrians were crossing roads. After the landscape improvement, accidents related to pedestrian crossing, walking, or standing in roadways showed a decrease. Fatal pedestrian accidents were significantly decreased from 18 to 2 after the landscape improvements at all 10 study locations (Table 5). It is interesting to note that the median planting showed a slight increase in pedestrian accidents after the landscape improvements were added when analyzed by landscape treatment. This is in contrast to the apparent performance related to vehicle accident reduction noted earlier.

The apparent reduction in pedestrian accidents is very interesting but it is impossible at this point to attribute the observed findings in pedestrian accidents to the landscape improvements without a more detailed study focused on pedestrian safety and landscape treatments.

CONCLUSIONS AND IMPLICATIONS FOR URBAN STREETS

Conclusions

The findings in this work seem to support earlier work by Topp, Naderi, Taylor, Kaplan, and others who have looked at the impact of environmental variables such as landscape on human performance and safety. At the same time, the authors are very cautious about suggesting that any precise conclusions can be drawn about the degree to which landscape development could be used as a tool to improve the safety of transportation corridors in our urban centers.

On the other hand, the fact that this and several other studies have demonstrated a connection between landscape development on the roadside and improved safety if measured by accident reduction warrants further study and consideration. In this regard several findings seem to have implications when considering the design and development of urban streets and highways:

- The finding from earlier work that urban parkways seem to have fewer accidents than parallel sections of limited access freeway suggest that the setting of the street or highway does have impact on overall performance as suggested by environmental psychologists such as Topp and Berlyne.

- When developing urban corridors, consideration should be given to the development of the landscape as an integral part of the corridor. The landscape not only contributes to greater aesthetic compatibility between the urban environment and the highway but may potentially contribute to a safer street.

One very important observation made from this particular study was that all of the landscape improvements made on the sites studied adhered strictly to rules governing setback of non-yielding obstructions and visibility considerations. These are often criticized by well meaning community leaders and other members of the design professions whose primary area of practice is not transportation. It is the considered opinion of the authors that good roadside design can be accomplished within the established criteria for geometry and safety while meeting the desires of the community for streets with more aesthetic appeal.

The apparent reduction in pedestrian injuries and incidents was an unexpected sideline to this study. Since it was not an objective of the research no data was collected about specific improvements to accommodate pedestrians. In most cases it does appear that sidewalks were added along the frontage roads. This single improvement may account for much of the improvement in accident rates.

Need for further study

The before and after studies provided a simple means to test the hypothesis that urban landscape improvements had a positive impact on accident rates and therefore may contribute to better safety performance of our streets. However, the measures and the data are very coarse. That is, it is very difficult due to the way the data is recorded to get an accurate fix on the exact location of an accident if it did not occur in an intersection. Likewise, the lack of information on property damage only accidents prevents developing a better understanding of accident types in relation to landscape improvements. Numbers of sites is also a concern because sites with just roadside improvements were relatively easy to find on state rights of way. However, municipalities do not always keep records of their streetscape development making it difficult to compare data between sites and landscape types. Obtaining a more complete understanding of whether, and to what degree, the roadside landscape contributes to overall safety performance will require developing more complete data for study sites.

Of particular interest and of the most immediate concern is the issue of the impact on pedestrian safety. The reduction in pedestrian accidents at the Dallas, US 75 project suggests that this needs to be looked at carefully to see what specific improvements were made that might have contributed to the dramatic reduction in pedestrian incidents. Furthermore, the apparent increase in pedestrian incidents related to median plantings should be explored further. These kinds of questions are closely tied to greater demand for traffic calming measures in urban neighborhoods such as bulb-outs and pedestrian refuge islands that may need further consideration with respect to pedestrian safety.

The initial findings are most encouraging and do seem to suggest that the roadside landscape may be a tool that, when better understood, can be used to improve the safety and performance of urban streets. Clearly, more work will be required to develop specific tools or recommendations that have direct design application. However, given the strong correlations between this study and the work in other disciplines the potential benefits would appear to be worth continued pursuit.

REFERENCES

1. Federal Highway Administration (FHWA), *Flexibility in Highway Design*. U.S. Department of Transportation, Washington, DC., 1997.
2. American Association of State Highway and Transportation Officials (AASHTO), *A Guide for Highway Landscape and Environmental Design*. Washington, DC., 1970.
3. American Association of State Highway and Transportation Officials (AASHTO), *A Policy on Geometric Design of Highways and Streets*. Washington, DC., 1984.
4. Topp, H.H. Traffic Safety, Usability and Streetscape Effects of New Design Principles for Major Urban Roads, *Transportation.* Vol. 16, 1990, pp. 297-310.
5. Bahar, G.B. and J.R. Naderi. An Integrated Approach to Environmental Impact Mitigation and Safety Management Case Studies in the Municipality of Metropolitan Toronto. In session, roads/transportation and the environment, *XIIIth World Meeting of the International Road Federation.* Toronto, Ontario, Canada. 1997.
6. Mok J. and H.C. Landphair. Parkways or Freeways: Safety Performance Linked to Corridor Landscape Type , *Proceeding of Transportation Research Board 82nd Annual Meeting*. Washington DC., January 12-16, 2003.
7. Berlyne, D.E. *Aesthetics and Psychobiology*. Appleton Century Crofts, New York. 1971, pp. 1-48.
8. Wohlwill, J. F. *Environmental Aesthetics: the Environment as a Source of Affect*. In: Altman, I., Wohlwill, J. F. (Eds.), Human Behavior and Environment. Plenum, New York. 1976, pp. 37-86.
9. Taylor, J.G., Zube, E.H., Sell, J.L. *Landscape Assessment and Perception Research Methods*. In: Bechtel, R.B., Marans, R.W., Michelson, W., (Eds.), Methods in Environmental and Behavioral Research. Van Nostrand Reinhold Company, New York, 1987, pp. 361-393.
10. Kaplan, R. *Preference and Everyday Nature: Method and Application*. In: Stokols, D. (Ed.), Perspectives on Environment and Behavior: Theories, Research, and Application. Plenum, New York. 1977, pp. 54-72.
11. Parsons R., Tassinary, L.G., Ulrich, R.S., Hebl, M.R., Alexander, M.G., The View from the Road: Implication for Stress Recovery and Immunization. *Journal of Environmental Psychology*, Vol. 18, 1998, pp. 113-140.
12. Ulrich, R.S. *Scenery and the Shopping Trip: The Roadside Environment as a Factor in Route Choice*. Michigan Geographical Publication No. 12. Dept. of Geography, University of Michigan, Ann Arbor. 1974.
13. Ulrich, R.S. Visual Landscapes and Psychological Well-being. *Landscape Research*. Vol. 4, 1979. 17-23.
14. Swirsky, K. Main Street: From Footpath to Highway, Proceedings of Safety, Aesthetics and Community Partnerships: Context-Sensitive Solutions. *A Regional Workshop on Context Sensitive Design*. Seattle, WA, April 30-May 1, 2002.
15. Anderson, R.W. Roadside Trees-reducing the Risk through Management. *Transafety Reporter*, Vol. 5(6), No. 3. 1987.
16. Turner, D.S. and E.R. Mansfield. Urban Trees and Roadside Safety. *Journal of Transportation Engineering*. Vol. 116, No.1, 1990, pp. 90-104.
17. Zeigler, A. J. *Guide to Management of Roadside Trees*. Report No. FHWA-IP-86-17, Michigan Department of Transportation. Lansing, MI. 1986.

18. American Association of State Highway and Transportation Officials (AASHTO), *Roadside Design Guide*. Washington, DC., 1996.
19. Texas Department of Transportation (TxDOT). *Landscape and Aesthetic Design Manual*. 2001.
20. Cook, T.D. and D.T. Campbell. *Quasi-Experimentation-Design and Analysis Issues for Field Settings*. Rand McNally College Publishing, Chicago. IL. 1979, pp. 95-102.
21. Council, F.M., Reinfurt, D.W., Campbell, B.J., Roediger, F.L., Carroll, C.L., Dutt, A.K., Dunham, J.R., *Accident Research Manual*. Highway Safety Research Center, University of North Carolina, Chapel Hill, NC. 1980, pp. 42-60.
22. Griffin, L.I. *Three Procedures for Evaluating Highway Safety Improvement Programs*. TARE Technical Report No. 51. Texas Transportation Institute, Texas A&M University, College Station, TX. 1982.
23. Griffin, L.I. *A Preface to a Discussion of Six Procedures for Evaluating Highway Safety Projects*. Research Report No. FHWA-RD-08-033. Texas Transportation Institute, Texas A&M University, College Station, TX. 1997.
24. Al-Masaeid, H.R. Performance of Safety Evaluation Methods. *Journal of Transportation Engineering*. Vol. 123, No.5, 1997, pp. 364-369.

Table 1. Urban Arterial Roads or Streets Before and After Landscape Improvements in Texas.

Location Number	Section Locations	Landscape Treatments	Treatment Year
1. Austin	Interchange (Loop 1 & US 183)	Interchange landscaping	1993
2. Dallas	SPUR 303 (from Co. line to Mountain Creek Lake)	Roadside landscaping	1992
3. Dallas	US 75 North (from Loop 635 to Co. line)	Roadside landscaping	1992
4. McKinney	US 380 (from US 75 to SH 5)	Median landscaping	1995
5. Plano	US 75 (from Plano Pkwy to Spring Creek Dr.)	Roadside landscaping	1995
6. Houston	Interchange (IH 10 & IH 45)	Interchange landscaping	1996
7. Lubbock	IH 27 (from 58th St. to 82nd St.)	Roadside landscaping	1995
8. Odessa	BI 20 (from Loop 338 to SH 349)	Roadside landscaping	1988
9. Austin	Airport Blvd. (from IH 35 to Manor Rd.)	Median landscaping	1988
10. Amarillo	Amarillo Route 6th Street (SL 279)	Sidewalk improvement and roadside planting	1996

Table 2. Number of Crashes and Crash Rates Before and After Landscape Improvements.

Locations	Number of Crashes[1,2,3]			Crash Rates		
	Before	After	Difference[4]	Before	After	Difference[4]
1. Interchange landscaping	1	2	+1	0.0157	0.0564	+0.0407
2. Roadside landscaping	313	315	-2	2.9545	2.7285	-0.2260
3. Roadside landscaping	2694	1202	-1492	1.3682	0.5939	-0.7743
4. Median landscaping	15	11	-4	0.6340	0.3264	-0.3076
5. Roadside landscaping	139	89	-50	0.4822	0.2447	-0.2375
6. Interchange landscaping	32	81	+49	0.2749	0.5970	+0.3221
7. Roadside landscaping	2	2	0	0.0876	0.0778	-0.0098
8. Roadside landscaping	227	173	-54	0.4296	0.4171	-0.0125
9. Median landscaping	320	128	-192	1.7231	0.6684	-1.0547
10. Sidewalk improvement and roadside planting	64	64	0	2.2802	2.1005	-0.1797
Total	3807	2067	-1744			
Average				1.0250	0.7811	-0.2439

1. The number of crashes was counted from the crash dataset selected from 10 study sections for 3 to 5-year periods before and after landscape intervention from the year 1984 to the year 1999.
2. The number of PDO crashes was ruled out to control PDO crash recording bias in Texas.
3. Crashes within construction/maintenance zone were ruled out to control construction zone bias.
4. The values are obtained by deducting crashes or crash rate (before) from crashes or crash rate (after).

Table 3. Number of Tree Collisions Before and After Landscape Improvements.

Location Number (treatment types)	Number of Tree Collisions[1,2,3]		
	Before	After	Difference[4]
1. Interchange landscaping	0	0	0
2. Roadside landscaping	2	1	-1
3. Roadside landscaping	**18**	**3**	**-15**
4. Median landscaping	0	1	+1
5. Roadside landscaping	1	1	0
6. Interchange landscaping	0	0	0
7. Roadside landscaping	0	0	0
8. Roadside landscaping	1	0	-1
9. Median landscaping	0	0	0
10. Sidewalk improvement and roadside planting	2	1	-1
Total	24	7	-17
Tree Collision Reduction Factor	$\frac{24 - 7}{24} \times 100 = 70.83\ \%$		

1. The number of tree collisions was counted for 3 to 5 year periods before and after the landscape improvements at 10 study sections between 1984 and 1999.
2. The number of PDO crashes was ruled out to control PDO crash recording bias in Texas.
3. Tree collisions within construction/maintenance zone were ruled out.
4. The value was obtained by deducting the crash rate (before) from the crash rate (after).

Table 4. Number of Pedestrian Accidents Before and After Landscape Improvements.

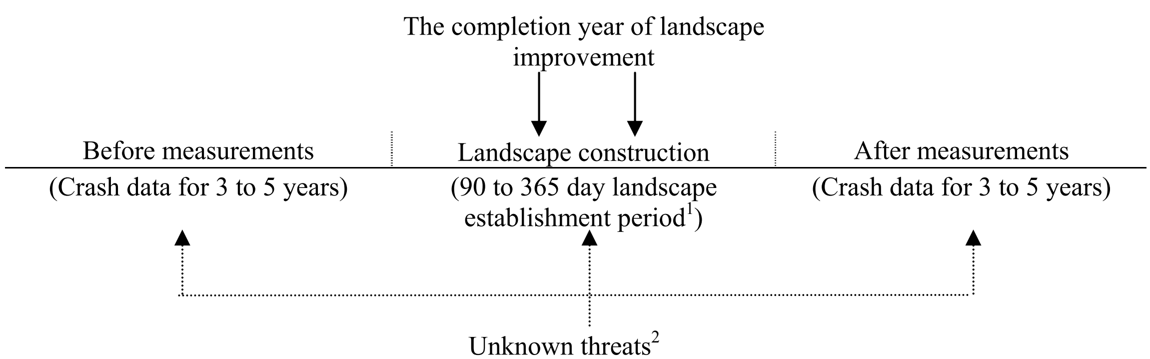
Locations	Number of Pedestrian Accidents[1]		
	Before	After	Difference[2]
1. Interchange landscaping	0	0	0
2. Roadside landscaping	7	3	-4
3. Roadside landscaping	**62**	**34**	**-28**
4. Median landscaping	0	0	0
5. Roadside landscaping	1	0	-1
6. Interchange landscaping	0	0	0
7. Roadside landscaping	0	0	0
8. Roadside landscaping	7	3	-4
9. Median landscaping	1	2	+1
10. Sidewalk improvement and roadside planting	3	1	-2
Total	81	43	-38
Pedestrian Accident Reduction Factor	$\frac{81 - 43}{81} \times 100 = 46.91\ \%$		

1. The number of pedestrian accidents was counted for 3 to 5 year periods before and after the landscape improvement at the 10 study sections from the year 1984 to 1999.
2. The value was obtained by deducting the crash rate (before) from the crash rate (after).

Table 5. Pedestrian Accidents Related to Treatments, Severities, Parts of Roadway, and Pedestrian Actions.

		Before[1]	**After[1]**
Pedestrian accidents by landscape treatments	Roadside landscaping	**73**	**38**
	Median planting	1	2
	Interchange landscaping	0	0
	Sidewalk improvement and roadside planting	3	1
Pedestrian injury severity	K (fatal)	**18**	**2**
	A (incapacitating injury)	20	21
	B (nonincapacitating injury)	23	13
	C (possible injury)	20	7
Part of roadway related to pedestrian accidents	Main lane	55	39
	Frontage road	24	3
	Connection	2	1
Pedestrian actions related to pedestrian accidents	Crossing road at intersection	17	6
	Crossing road not at intersection	24	13
	Getting on or off vehicles	2	2
	Walking in roadway	5	2
	Standing in roadway	10	4
	Pushing or working in road	15	13
	Other working in roadway	7	3
	Playing in roadway	1	0

1. Number of pedestrian accidents at 10 study sections



1. TxDOT standard specification Item 192 (Landscape Planting and Establishment).
2. Other events happened between the pretest and posttest or before pretest that also affect posttest observation.

Figure 1. Concept Diagram of Data Collection and Unknown Threats to Statistical Validity.

a) Study location No. #1 in Austin

b) Study location No. #6 in Houston

Figure 2. Photos of Interchange Landscape Treatments.

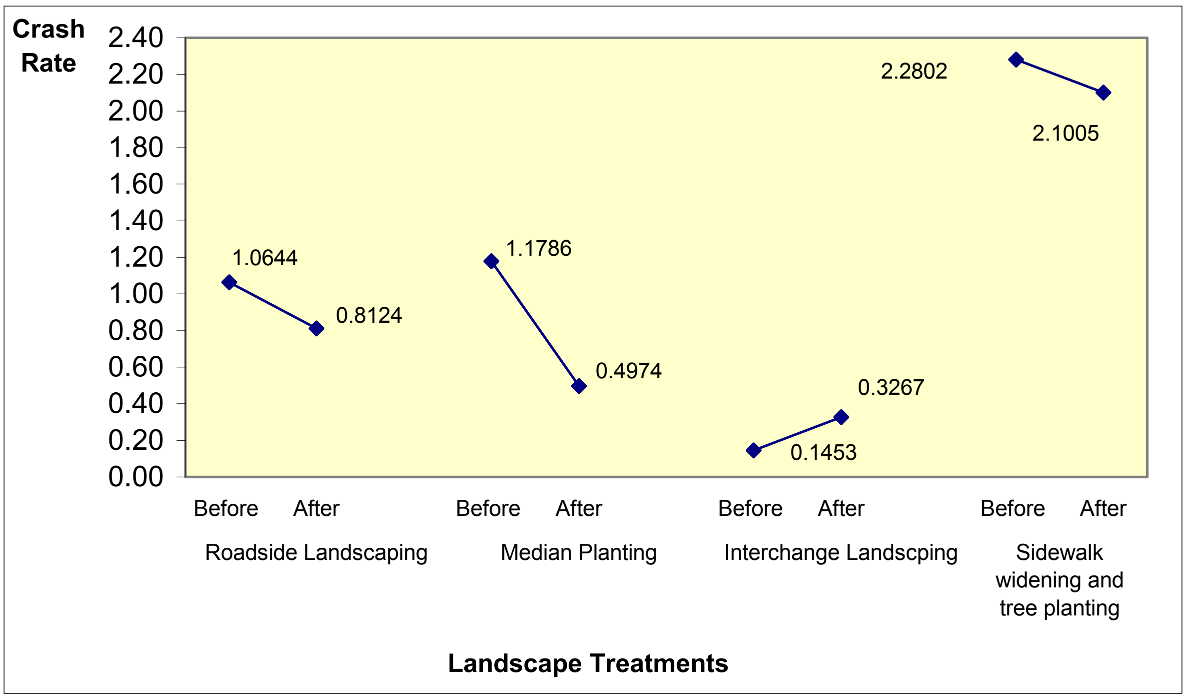


Figure 3. Average of Crash Rate (Before and After) by Landscape Treatments.

a) Landscape improved frontage road
b) Landscape improved section along US 75 North (Note: CTB existed prior to landscape development)

Figure 4. Photos of Us 75 North in Dallas (Study Location No. #3).

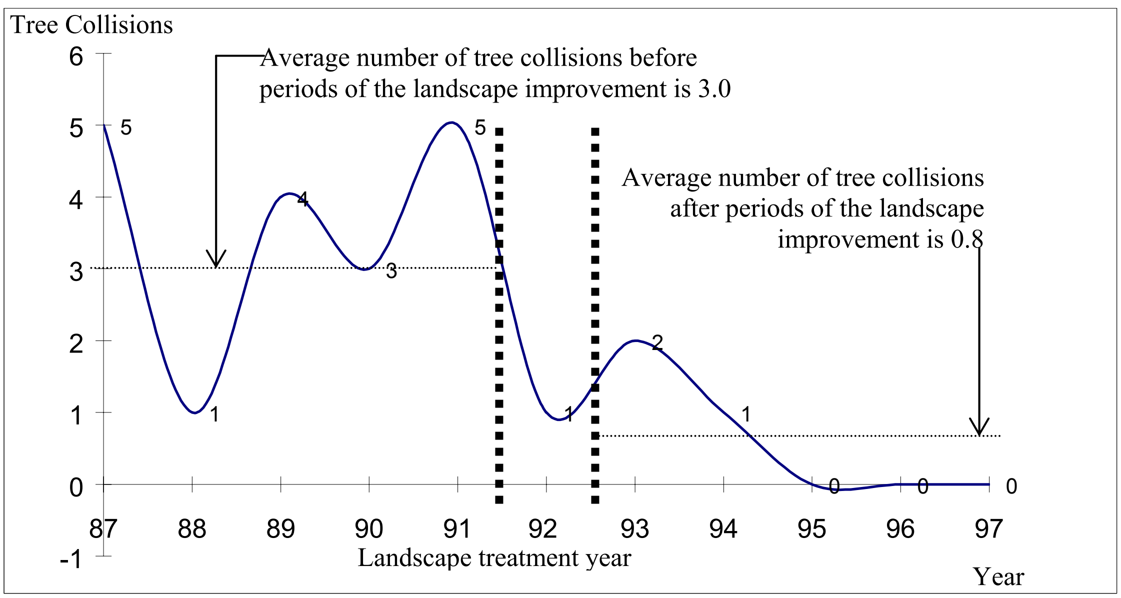


Figure 5. Number of Tree Collisions at Study Location No. #3 (Us 75 North In Dallas).