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Landscape improvement impacts on roadside safety in Texas

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Abstract

Environmental psychologists suggest that appropriately landscaped roadside scenes may have a reducing influence on travel-related stress or may improve attention, yet there is very little data available that establishes the nature of the relationship between roadside landscaping and driver safety. Traditional transportation researchers suggest that aesthetic enhancements are a problematic component of the roadside landscape because of the severity of vehicle/tree collisions and a perception that roadside aesthetics can distract the driver causing safety risk. Costly planning processes arise as members of the local communities debate with public utility and transportation management staff on the subject of appropriate roadside landscaping.

To test the effect of landscape improvements on driver performance, this study used a comparison of before-and-after crashes as a quantitative measure of roadside greening. Researchers examined 61 road sections in Texas that were landscape designed as either urban arterials or state highways. The hypothesis tested was to determine whether landscape-improved sections of the roadway were safer compared to the same road section before landscape improvements at 10 sites were very well controlled as study sites. The findings of this study show a significant decrease in crash rate after landscape improvements were implemented at the 95% confidence level on 10 urban arterial or highway sites in Texas. The contribution of this study is to further investigate the effect that landscape features are having on driver behavior which appear to be associated with positive changes in safety result from design. However, these findings need further research to verify a relationship between driver's visual perception according to travelway corridor landscape treatments.

Keywords: Roadside landscape; Streetscape enhancements; Visual perception; Crash rate; Safety

1. Introduction

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

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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).

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), mandated a more balanced approach to transportation system development in the United States by including considerations of environmental, cultural, economic, and social conditions in vehicular transportation projects. The Act also included funding set asides for transportation enhancements, and scenic byways both within and outside transportation rights-of-way. 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. In 2001, Texas State Department of Transportation (TxDOT) published its "Landscape and Aesthetic Design Manual" which provided engineering and transportation staff with guidance on the planning design and implementation of roadside landscapes.

This study attempts to compare the safety performance of urban arterial road sections before and after landscape improvements. This before-and-after comparison study allows researchers to examine the difference of safety performance by landscape treatments. This study contributes to further investigate the effect that landscape features are having on driver behavior which appear to be associated with positive changes in safety result from within and outside transportation rights-of-way design.

2. Background and broad concepts of study

Several field studies on the impact of landscape enhancements have demonstrated a variety of positive impacts on communities and traffic safety. Topp's study (1990) of German streetscape enhancements characterized by a landscaped center strip, found these to be effective in calming traffic and increased traffic safety. Over the period of Topp's study (1990), overall accidents were reduced by 30%, the number of accidents with injuries was cut by about 60%, and accidents involving street crossing pedestrians were reduced by about 80%. 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 there was an increase in the number and severity of mid-block accidents city-wide.

2.1. Research background of study

Environmental psychologists 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 attention to the visual complexity of what was seen. Berlyne (1971) suggested that attention was aroused as visual stimulus increases up to a level of complexity, at which point 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 Berlyne's theory to landscape aesthetics. Wohlwill hypothesized that there was an optimal level of stimulus or information from the landscape; too much information is stressful, and too little information is boring. With this in mind, we look at the work of Taylor et al. (1987) who demonstrated that driving information is mostly obtained from the outside environment. The landscape along the roadside will contribute to the decisions made by drivers with either positive or negative results. Mok and Landphair's research (2003) on parkways suggest that carefully landscaped roadside edges which have enough features to be interesting may be the feature which makes the drive a more pleasant experience than the interstate highway option and may also contribute to higher degrees of attentiveness. The landscape levels of the parkway are not so complex that they were confusing or oppressive. The speculation is that both increased quality of visual aesthetic and increased attention may indicate a positive influence on improvement in driver safety.

Nature scenes may have comparatively positive influence on driver behavior, since natural settings may tend to have an optimal level of complexity to be interesting (Wohlwill, 1976). Topp (1990) also indicated that appropriate tree planting and landscaping has a psychological effect of reducing driving speed. In other words, streets characterized by a landscaped center strip or median planting may alter drivers' perception of lane width and therefore reduce driving speeds associated with increases in severity of accidents.

Our interest here is to measure the impact of roadside landscape on the functionality of the driver using primarily crash results as an indicator of impact. Generally, road capacity is identified by how many vehicles a specific roadway design can carry in a day over a specific period of time based on the speed and geometry of the road. Within this context, many aspects of the road have an impact on safety and a series of design standards used in roadway construction today have been developed from research on road configuration, sight triangles, construction materials, pavement markings, etc. (AASHTO, 1996). The contribution this study is to further investigate the effect that landscape features are having on driver behavior which appear to be associated with positive changes in safety results from design.

2.2. Trees on the roadside

Trees are often cited as the most hazardous roadside objects by researchers in the field of transportation safety. Trees account for more single-vehicle, fixed-object fatalities than any other object along the roadway (Turner and Mansfield, 1990). This study focused on 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% of the drivers in fatal crashes with trees had been drinking, and over 60% 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). The most frequently encountered problem related to tree collisions results from errant motorists (AASHTO, 1996). However, the issue of trees on the roadside is often a political and social issue among community residents, environmentalists, historical preservationists, and traffic safety engineers who view roadside trees as integral to local community identity, contributing to economic revival, public health, and pedestrian safety.

2.3. Roadside landscape 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 ft. of the edge of the driving lanes, and in harmony with existing nature and surrounding development.

In case of Texas, Texas Department of Transportation (TxDOT) has a Landscape and Aesthetics Design Manual (TxDOT, 2001) for Texas system roads and streets to incorporate many safety criteria in the guidelines for roadside landscape and aesthetic treatments. Planting guidelines used by TxDOT are as follows:

- Roadside vegetation should be designed or maintained to accomplish specific goals of sight-distance, clear view of obstructions, erosion control, and aesthetics.
- Plants must not be planted where they may obstruct any signs, sightlines, or driver visibility.
- On frontage roads, allow a minimum of 3 ft. clear space between the back of curb and any area to be maintained for maintenance personnel.
- Plant use in intersection areas must be limited to low-growing varieties.
- Plants must not be placed near merging lanes.
- Landscape improvements must avoid the creation of unsafe conditions for motorists or maintenance personnel (see Fig. 1).

Interchange of IH 10 and IH 45 in the City of Houston — An exit to frontage road from IH 10 in Houston

Fig. 1. Photos of landscape edges for motorists or maintenance personnel safety.

There are planting guidelines which states have developed that support safer driver performance. What is of question here is whether proper application of planting standards is resulting in overall safety improvements that are being unrecognized. Standards or guidelines which assist in improving safety need to be identified in roadside landscaping, 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.

3. Methods of study

This research was based on comparisons of the safety performance of selected sites before and after landscape improvements on major urban freeways and arterial streets. 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.

3.1. Case selections

Before and after landscape improvement sites were obtained from various data source. Firstly obtained landscape improvement projects were 61 in Texas, USA. They consist of 39 landscaping/streetscape enhancement projects along urban roads and city streets and 22 landscape development projects along urban arterial roads in Texas.

Thirty nine landscaping/streetscape enhancement projects of the total 61 projects were as follows: 30 TxDOT 'Enhancement Projects (Landscaping/Streetscapes)' between the year 1995 and 2000, five landscaping projects in City of Austin, three projects extracted from 'Austin Metropolitan Area Transportation Plan–2050 Roadway Plan' and one streetscape enhancement project in City of Lubbock extracted from 'Visual Database of Transportation Enhancement'. Only two projects (Amarillo Route 6th street and Austin Airport Blvd.) from the 39 enhancement projects were remained. Thirty-seven were removed as following reasons:

- Absence of completion year or Control Section Job (CSJ) number of projects: several projects have no information to verify 'landscape construction year' or 'exact landscape construction location'.
- Bias in sample of sites: study sites should be treated by only landscaping treatment but many projects were treated by other treatments, such as pedestrian sidewalk widening, expansion of existing shoulders, or installation of bicycling path.
- Unsuitable projects in terms of accident data: landscape construction should be finished between the year 1987 and 1996 for comparing 3–5 year periods before and after landscape intervention because the Texas accident data is available from the year 1984 to 1999.

Twenty-two landscape development projects of the total 61 projects were as follows: 12 TxDOT landscape development projects (only landscaping) along

Table 1
Urban arterial highways and streets before and after landscape improvements in Texas

Location		Section locations (average of average annual daily traffic for 3–5 years before and after landscape intervention)	Landscape treatments (section length)	Treatment year (year period)
Urban arterial road/highway	1. Austin	Interchange (Loop 1 & US 183) (before: 35,000/after 19,440)	Interchange landscaping (1 mile)	1993 (1988–1998)
	2. Dallas	SPUR 303 (from Co. line to Mountain Creek Lake) (before: 10,895/after 11,873)	Roadside landscaping (5.328 mile)	1992 (1987–1997)
	3. Dallas	US 75 North (from Loop 635 to Co. line) (before: 138,237/after 142,096)	Roadside landscaping (7.805 mile)	1992 (1987–1997)
	4. McKinney	US 380 (from US 75 to SH 5) (before: 7893/after 11,244)	Median landscaping (2.053 mile)	1995 (1991–1999)
	5. Plano	US 75 (from Plano Pkwy to Spring Creek Dr.) (before: 49,348/after 62,265)	Roadside landscaping (4.001 mile)	1995 (1991–1999)
	6. Houston	Interchange (IH 10 & IH 45) (before: 106,307/after 123,901)	Interchange landscaping (1 mile)	1996 (1993–1999)
	7. Lubbock	IH 27 (from 58th St. to 82nd St.) (before: 5150/after 5800)	Roadside landscaping (3.036 mile)	1995 (1991–1999)
	8. Odessa	BI 20 (from Loop 338 to SH 349) (before: 17,681/after 13,880)	Roadside landscaping (20.47 mile)	1988 (1984–1992)
City street	9. Austin	Airport Blvd. (from IH 35 to Manor Rd.) (before: 64,080/after 66,081)	Median landscaping (1.985 mile)	1988 (1984–1992)
	10. Amarillo	Amarillo Route 6th Street (SL 279) (before: 9550/after 10,367)	Sidewalk improvement and roadside planting (4.026 mile)	1996 (1993–1999)

urban arterial roads in Texas between the year 1984 and 1999 and 10 TxDOT landscape development projects (only landscaping) between the year 1993 and 1999. Only eight projects from the 22 landscape development projects were remained. Fourteen projects were removed as following reasons:

- Thirteen projects were taken out because there was no the CSJ number or landscape construction year. Projects along minor arterial roads in Texas cannot be verified by the CSJ number because the CSJ number was assigned for only major arterial roads in Texas.
- One project in Houston was also taken out because it was not coincidence with the location of major landscape construction indicated by the CSJ number in the project file.

Ten sites for the study were selected from 61 projects through the verifying of landscape construction year/location and crash date/location for controlling variables (Table 1). These 10 sites represent 8 different cities, 8 of the 10 sites selected reflect interstate or major arterial roads and 2 were city streets. Overall 5874 crashes at 10 sites for 3–5 year periods before and after landscape intervention were used for analyzing crash rate in this research. It is an important contribution to control sample bias and to get a number of crashes from study sites to increase the reliability of research findings.

3.2. 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 3–5 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 1000 ft. 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.

3.3. Research hypotheses

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

- Crash rates significantly decreased after the landscape improvement at study sites.
- A decrease in the number of tree collisions occurred after landscape improvements.

The two hypotheses that were tested are based on the work of the environmental psychologists who indicated that there may be a positive benefit from roadside greening that current standards may not be sensitive to.

3.4. Research methodology

To assess the crash rate reduction effectiveness of landscape improvement projects, many different evaluation methodologies and statistical techniques can be employed. However, it should be emphasized that the methodology can be used in this research might be referred to as a quasi-experimental design because researchers cannot assign treatment to locations randomly and cannot control conditions prior to the imposition of treatment. Before-and-after design is commonly found in the highway research literature, referenced sites will not be given (Council et al., 1980). In the simple before and after design, measurements are taken in time: one before the imposition of the treatment and one after the treatment has been put in place. The most basic assumption underlying the before-and-after design is that if the treatment in question had not been imposed, the after measurement would equal the before measurement. Therefore, any difference in the before and after measurement is attributable to the treatment (Griffin, 1982).

The before-and-after design is however relatively weak in terms of internal validity (Cook and Campbell, 1979; Council et al., 1980; Griffin, 1997). To overcome this weakness in internal validity, 'the concept of multiple cases' was applied to this research design. According to Griffin (1997), by imposing the treatment at multiple locations and aggregating the multiple cases at different times, treatment effect would be separated from the 'uniqueness' of a particular treatment location, and the likelihood of falling to 'an unknown threat' (other events happened between the pretest and posttest or before pretest that also affect posttest observation) would be reduced. In addition, increased number of accident data by combining data from several locations may increase sample size and statistical power (Griffin, 1997).

Researchers collected crash data at ten study locations for 3–5 year periods to test for any change of crash rate in sections with landscape treatments. Multiple cases at different times and different locations are selected to enhance statistical validity and minimize the unknown threats and the 'uniqueness' of a particular treatment location. Conceptual explanation of crash data collection and unknown research threats for the comparison period at each study location is delineated in Fig. 2. The number of crashes was converted into the crash rate based on the number of crashes per one million Vehicle Miles Traveled (VMT) because in most cases traffic tended to increase over the study period. The calculation formula of crash rate per one million VMT is as follows:

$$\text{Crash rate (CR)} = \frac{\text{Number of crashes} \times 1000000}{\text{Traffic volume} \times \text{Section length} \times \text{Time period (years)} \times 365}$$

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; traffic volume: average of average annual daily traffic (AADT) volume at a study road section in a period of time; section length: length of a study road section; time period (years): at least 3–5 year periods before and after landscape treatments at the 10 study road sections between the years 1984 and 1999.

The difference in landscape characteristics at study sites before and after landscape treatments constitutes independent variable and the crash rate constitutes the dependent variable. Control variables were constituted during data filtering and analyses. The traffic volume before and after landscape treatments at the study sections was controlled through

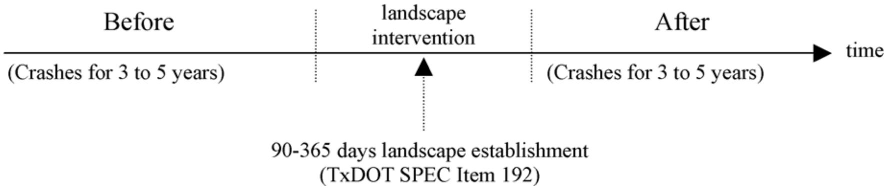

Fig. 2. Concept diagram of data collection before and after landscape intervention.

the calculation of crash rates in order to bring the sections to a standardized comparison study. Crashes within construction/maintenance zones were ruled out to control construction zone bias. In addition, data filtering controlled data recording change in the Texas accident dataset. Property damage only (PDO) crashes were ruled out from the dataset to control data recording bias because PDO recording threshold was changed on July 1st, 1995. According to TxDOT Standard Specifications Item 192 (TxDOT, 1993), roadside planting or landscape establishment period in Texas is 90–365 days. Crashes in the year of landscape construction are ruled out to control for fluctuations in the landscape form immediately post installation.

The number of tree collisions in the research was compared by a reduction factor. The reduction factor method is commonly used in 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:

$$\text{Reduction factor} = \frac{X_b - X_a}{X_b} \times 100$$

where X_b is the number of tree collisions before the landscape treatments at the study sections, X_a is the number of tree collisions after the landscape treatments at the study sections.

4. Results

4.1. Crash rate before and after landscape treatments

Eight of 10 study sites showed a decrease in crash rate and two sites showed an increase in crash rate after

Table 2
Number of crashes and crash rates before and after landscape improvements

Locations	Number of crashes[a,b,c]			Crash rates		
	Before	After	Difference[d]	Before	After	Difference[d]
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	−1740			
Average				1.0250	0.7811	−0.2439

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

Study location No. 1 in Austin

Study location No. 6 in Houston

Fig. 3. Photos of interchange landscape treatments.

the landscape treatment (Table 2). Both of the sites that showed increases in crash rate were complex grade separated interchanges (see Fig. 3). There were also two outstanding positive sites, study locations nos. 3 and 9 (see Fig. 4) 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 (mean: −0.2439, standard deviation: 0.4023). It suggests that these two are not an extreme or anomalous. This static has shown an approximately normal distribution.

Difference in crash rate calculated by analyzing 5874 crashes at 10 study sites for 3–5 year periods before and after landscape intervention was tested by one-sided paired *t*-test because crashes were independent before and after landscape intervention. The results show that there was a significant decrease in crash rate after landscape improvements at the 95% confidence level (p-value: 0.0437, $N = 10$). It could be statistically valid even if the number of sample sites is 10 but the crash rates were calculated by analyzing 5874 crashes based on the control of traffic volume and section length.

Interestingly, two negative sites reflect landscape treatments 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

Study location No. 3 in Dallas
Landscape improved section along US 75 North (Note: CTB existed prior to landscape development)

Study location No. 9 in Austin
Median landscaped section at Airport Blvd.

Fig. 4. Photos of two outstanding positive sites (study location nos. 3 and 9).

Table 3
Number of tree collisions before and after landscape improvements

Location number (treatment types)	Number of tree collisions[a,b,c]		
	Before	After	Difference[d]
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	$\frac{24-7}{24} \times 100 = 70.83\%$		

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

of ramps and bridges in interchange areas need a number of bridge columns or roadside vertical objects. On these sites detailed data analysis revealed that about 50% of vehicle crashes at this location were related to roadside fixed objects, such as median barriers, concrete traffic barriers, guardrails, and sides of bridges.

4.2. Tree collisions

The calculated reduction factor of tree collisions shows a decrease of about 70.83% of tree collisions after landscape treatments at ten study locations (Table 3). As shown in Table 3, there were no extreme changes in tree collisions before and after landscape treatments except for location no. 3. This site is on a four lane divided section of US 75 North in Dallas (see Fig. 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 (see Fig. 5). The change may also be explained by TxDOT landscape design guidelines which brought the site into compliance with clear zone rules and planting setback rules; trees should not be placed forward of any light standard and retaining wall (TxDOT, 2001).

5. Discussions

The findings in this research seem to support earlier work by Topp (1990), Bahar and Naderi (1997) 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

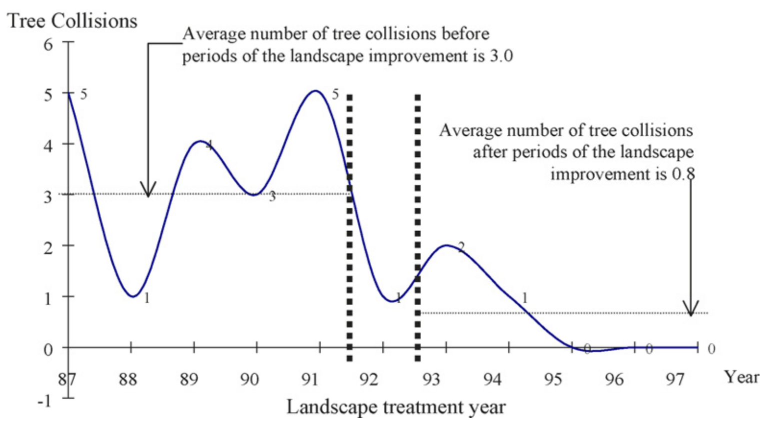

Fig. 5. Number of tree collisions at study location no. 3 (US 75 North in Dallas).

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. This single treatment may account for much of the improvement in accident rates.

5.1. 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 crash rates and therefore may contribute to better safety performance of our urban highways and streets. The findings from this research suggest that the setting of urban highways or streets characterized by landscape improvements does have impact on overall performance which may be a result of the effect of greening on human performance as suggested by environmental psychologists, such as Berlyne (1971), Wohlwill (1976), and Parsons et al. (1998).

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.

In the further research, crash data associated with roadside treatments will be investigated to identify properties that result in serious injuries. Field investigation at each accident location within project sections can give more specific information, which crash data and roadway inventory data do not have. Researchers verify often struck roadside objects at the project sites, check the types of struck objects, and measure the distance of clear zone, struck object size, and slope of roadside/embankment, etc. The data obtained from site investigation and community survey will be used to update or recommend urban roadside landscape design guidelines to enhance aesthetics and safety of landscape project sites.

6. Conclusions

The findings suggest that the use of roadside landscape is having a positive affect on overall performance and can be used as a tool to improve the safety performance of urban streets if the specifics of the affect on driver performance can be identified. There is a correlation between certain types of landscape treatments and reduction in crash rates, indicating that the landscape along the roadside is having a positive affect on driver behavior and perception. Further study into the effect of the specific treatments on driver attentiveness or alertness is required to begin to develop more specific safety-outcome design guidelines. In this regard several findings seem to be relevant to the design and development of urban highways and streets. When developing urban corridors, consideration should be given to the development of the landscape as an integral part of the safety management within the corridor. The landscape not only contributes to greater aesthetic compatibility between the urban environment and the highway but may 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. Many of the standards governing road design have been developed from sound research in driver perception, behavior and response to cues from the environment. While this research indicates that tree planting may not always be bad along a road and may in fact have a positive effect on safety in certain contexts, standards which are restrictive regarding planting of trees need to applied site specifically. These needed restrictions are often criticized by well meaning community leaders and other members of the design professions. Because of the complexity of the transportation design problems, experience in the application of AASHTO guidelines and newer FHWA context sensitive design recommendations are needed to encourage effective use of landscape for safety purposes. 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.

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.

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