TREES IN HIGHWAY MEDIANS

An Interactive Qualifying Project Report

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by

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Abstract

A study was conducted to determine the economic benefit of trees in unprotected highway medians. A representative segment of highway median on Interstate-290 in Central Massachusetts was chosen for analysis. Several years of accident reports involving collisions with trees located within the project site were collected, and a field survey was conducted to gather physical data. Using models that estimate societal losses due to accidents and the value of trees respectively, the economic benefit of trees in unprotected medians was determined.

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1. Introduction

Determining whether trees in interstate highway medians, like those shown in Figure 1, are a net benefit or hazard to society is the objective of this project. Safety issues, such as the probability of an automobile striking a tree off the road and the consequences of the collision are a major concern among highway engineers when dealing with trees in the median. In addition to the possible hazardous characteristics of trees, potential benefits (i.e., safety advantages, environmental and aesthetic values, and economic values) must also be considered when placing a societal value on trees.

Figure 1. Trees in a highway median

Hazards of roadside trees

In 1998, there were almost 11,000 fatal car crashes in the U.S. in which an automobile struck a fixed object. About 8 percent of these fatal accidents involved trees on the roadside. [1] Of these collisions, 8.6 percent resulted in severe injury or death in 1998.

Much research has been done to profile the drivers and types of roads most commonly involved in run-off-road collisions. Results indicate that typical drivers involved in run-off-road collisions are 20-25 year old males driving with excessive speed in the dark, early morning hours. Intoxication, unfamiliarity with the road, and inexperienced driving are also often contributing factors. [2]

The most common type of road where these accidents take place are curved, rural roads, where trees are located within 30 feet from the edge of the road. [2] According to Zeigler, rural roads may be grouped into two categories: local roads, which are owned and maintained by cities, towns and counties, and U.S. and state routes, which are owned and maintained by the States. [2] This project will be concerned with the latter, specifically Route I-290 in central Massachusetts. It will focus on trees located in the median along I-290 from approximately Exit 21 to the end of I-290.

Benefits of Roadside Trees

Safety

Trees in highway medians serve a major role in separating opposing traffic flow. A car crossing a highway median into oncoming traffic could create a devastating accident, possibly involving numerous automobiles and people. Trees are an effective way to prevent such crossovers, although the vehicle striking the tree would be involved

in a serious collision. Also, drivers can use high beam headlights at night and at high speeds because of the visual shielding provided by trees. [6] Trees in highway medians can reduce headlight glare from opposing traffic that would otherwise blind motorists in the opposing lanes. Trees, therefore, have both positive and negative impacts on highway safety.

Environmental and Aesthetic

When houses and neighborhoods are located near busy highways, the issue of noise control must be addressed. Noise from heavy traffic flow, especially from trucks, are an annoyance to nearby communities and several methods of reducing highway noise have been developed like building soundwalls. [3]

Although the insulation of houses and the reduction of noise emitted from the automobile itself have been examined as methods of reducing traffic noise, the construction of some type of barrier (i.e., houses, walls, trees, etc.) has been found to be the most cost efficient. [4] Among those barriers mentioned, trees have been found to be effective noise barriers.

The psychological effect of the barrier is just as important as the actual reduction in noise levels. [4] Trees are much more aesthetically pleasing than a row of houses or concrete walls and, in this regard, are important aesthetic features of highway medians and roadsides.

In addition to these important features of roadside trees is their aesthetic value. Trees create a friendly environment for drivers and for passengers. The more pleasant the driving experience is, the less hassle the drive seems to be, and motorists and society as a whole benefit.

Another benefit of roadside trees is that they create habitat for various wildlife species. [5] A study conducted by the West Virginia University Division of Forestry examined the nesting frequency of songbirds in 554 trees (along I-79 in West Virginia) of various species over a period of seven years. [5] Two hundred thirty seven nests were discovered throughout this period clearly indicating the environmental and biological importance of roadside trees.

Along with providing shelter for numerous species of wildlife, trees have many other environmental benefits. Trees affect the environment by moderating climate, improving air quality, and conserving water. They control the climate by moderating the effects of the sun, wind, and rain. Trees improve the quality of the air we breathe. Leaves filter the air by removing dust and other particles and absorb other air pollutants such as ozone, carbon monoxide, and sulfur dioxide, and give off oxygen in the process of photosynthesis. [7] Trees provide food and shelter for many living things, as well as preserving the land by reducing soil erosion by holding the soil together. [8] Trees are a major factor of the ecosystem and removing them should be carefully considered and only done if absolutely necessary.

Economic

While often overlooked, trees have economic value, something that is made obvious by the positive affect trees have on things such as property value. This monetary value can be appraised using several different methods. The major methods discussed by the Council of Trees and Landscape Appraisers are the Trunk Formula Method, the Cost of Repair Method, the Cost of Cure Method, and the Replacement Cost Method, along with income and market approaches to appraisal. [10] Each method of appraisal has its

own procedure that must be used, and each of these methods are useful in different scenarios. Every appraisal varies, and after assessing the situation the most reasonable approach should be chosen. [10]

The economic cost of accidents will be compared with the cost of benefits of the trees. The two important factors involved in accident costs are injury severity and vehicle damage. The outcome of this study is to determine if the cost of accidents associated with trees in highway medians exceed the monetary benefits of trees on the environment.

II. Methodology

The benefits and hazards of trees in the highway medians will be evaluated by studying a particular section of highway in Central Massachusetts, Route I-290. Figure 5 shows a location map of the project site.

Literature Review

A literature review for this project will focus on the roadside safety hazards and environmental benefits of trees in highway medians. The most important outcome of the literature search will be finding appropriate economic models of the benefits and safety consequences of trees in medians so that a cost in dollars can be estimated when placing a societal value on trees.

Collision Reports

The Massachusetts State Police in Holden, MA provided three years of accident reports. These reports were individually examined in order to identify collisions with trees in the median in the project study section. The following information was collected from the selected accident reports:

- Location of accident (nearest mile marker, exit #, etc),
- Brief description,
- Approximate damage to automobile, and
- Severity of the injury.

These accident reports will serve as a guide to identifying possible areas of high risk along the study section.

Survey the Road

After reviewing several years of accident reports and locating approximate areas of accident frequency, the median study section was surveyed. The first objective of surveying the road was simply to locate unprotected medians within the approximately 8-

mile section of interest. Data from these unprotected medians included the width and length of the median strip, the location of the trees within the median, the density of trees, the maximum height and diameter of the trees, etc. (For a more complete list of the data collected, see Appendix 2). Careful examination of the sites for precise locations of accident occurrences will be the most important feature of the survey. Pictures will be taken of any site of a suspected accident.

Guidelines for surveying highway medians

A major part of this project involved collecting site information by surveying the placement and condition of trees located in the highway medians along I-290. Before actually going out on the roadside and collecting such data, it was important to have a basic idea of what types of information would be collected and how they would be used.

- First, determine a way in which to distinguish one site from another, such as observing the area in order to identify mile markers, nearby exit numbers, structures with numbers or anything to identify the specific median being surveyed.
- Second, note the population of trees. Does this area have a high tree density, scattered trees, or a mixture of trees, shrubs, rocks, etc?
- Measure how far from the roadside the trees are located. Also, is the median flat, or does it dip into a valley (i.e., road and median characteristics)?
- Study the condition of the trees. Do they appear to have been involved in any accidents? Does the bark appear to be scratched or worn away? If so, how severe does the injury to the tree appear to be?

The most efficient way to survey the median was to develop data collection forms or checklist so that information could be recorded easily. This allowed for more efficient surveying and for focusing on the specific points of interest. The database was broken into sections of related information, so quick check marks and numbers could be written where appropriate on the forms. Once the median was surveyed, the data were used in

cost analysis by comparing the cost of the damage to trees to the cost associated with the accidents.

Apply Cost Models

The final portion of the project is to apply any cost models to the trees or locations of trees that have been involved (or possibly involved) in accidents and determine the net benefit of these trees in dollars. Possible variables in these cost models could include the cost of median maintenance (e.g., mowing) removal or trees, or delineation, versus the cost of accidents (damage to automobile and tree), injuries, environmental costs and consequences, etc. It is desirable that these cost models be applicable to the collected data in order to get accurate, tangible results.

III. Literature Review

Trees, the Road, and the Roadside Environment

An excellent method for evaluating the hazards of various roadside trees has been developed by the Michigan Department of Transportation (MDOT). [2] The Field Survey Data Form (Appendix 2) being used in this project was adapted from the MDOT forms. Although most of the data in the MDOT forms focuses on roadside trees, the general principles may be applied to trees in the median.

As stated in the introduction, this project will focus on a segment of Interstate 290 in central Massachusetts. The study section of I-290 is a rural primary arterial interstate. Along with the driver profiles discussed previously, the road environment itself (i.e., grade, curves, traffic volume, etc.) contributes to the probability of an automobile leaving the road. [9]

Grade, which is the ascent or descent in elevation of the road, affects accident rates. [9] Depending on the grade, the speed of a vehicle may increase or decrease before hitting an object, thereby affecting the severity of the impact. It has been reported that sites with grades over three percent experience above average accident frequencies. [9]

As expected, the presence of curves in the road increases the probability of an automobile leaving the road. The majority of accidents occurring on curved roads occur on the outside of the curve. [9] Although accidents involving the inside of curves do occur, they are less frequent as shown in Figure 2.

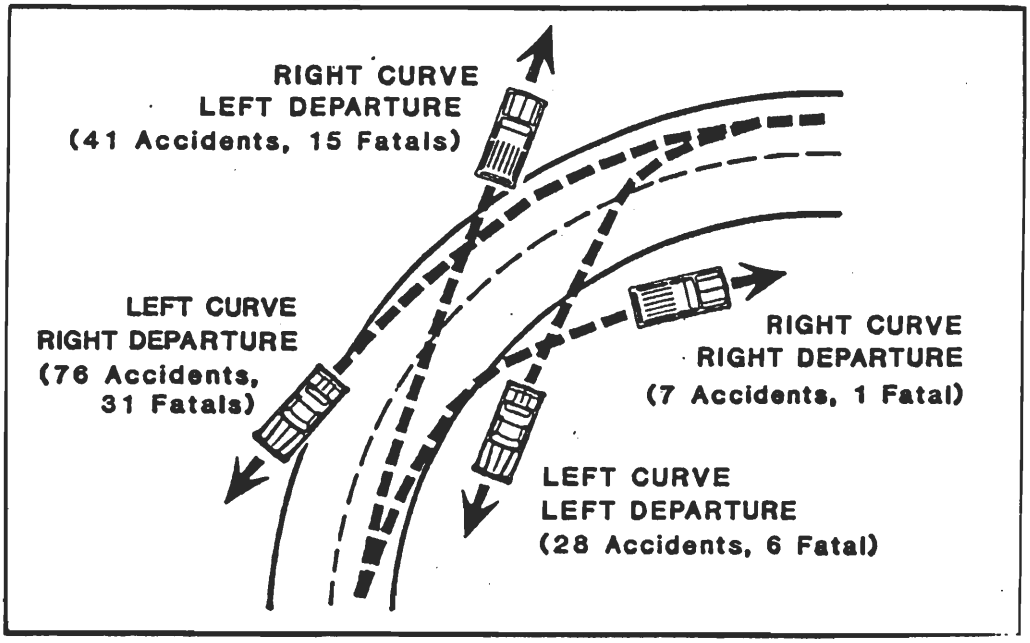

Figure 2. Curve direction and accident frequency [9]

It has also been found that traffic volume is a variable in accident probability. It has been documented that the number of tree related accidents are inversely proportional to the average daily traffic (ADT) for traffic volumes of 4000 or above. This means that an ADT of over 4000 corresponds to a lower accident frequency. Accidents occur more frequently when the ADT is under 4000. Reasons for these phenomena have been attributed increased driver awareness at higher traffic volumes and the reduction of speeds due to traffic congestion. [9]

Along with the road environment, the roadside environment (including the trees themselves) affects the probability of a vehicle/tree accident. Tree size, distance of trees from the road, tree density, and other roadside characteristics are considered.

As expected, larger trees are involved in fatal vehicle/tree accidents more often than smaller ones. It has been reported that median tree diameters of 20 inches are associated with fatal accidents while a median diameter of 15 inches are associated with non-fatal accidents. [9]

The distance of trees from the edge of the road is a factor that can determine crash frequency. Although trees with various distances from the road may be involved in a collision, 85 percent of trees involved in collisions are within 30 feet of the road, as shown in Figure 3. [9]

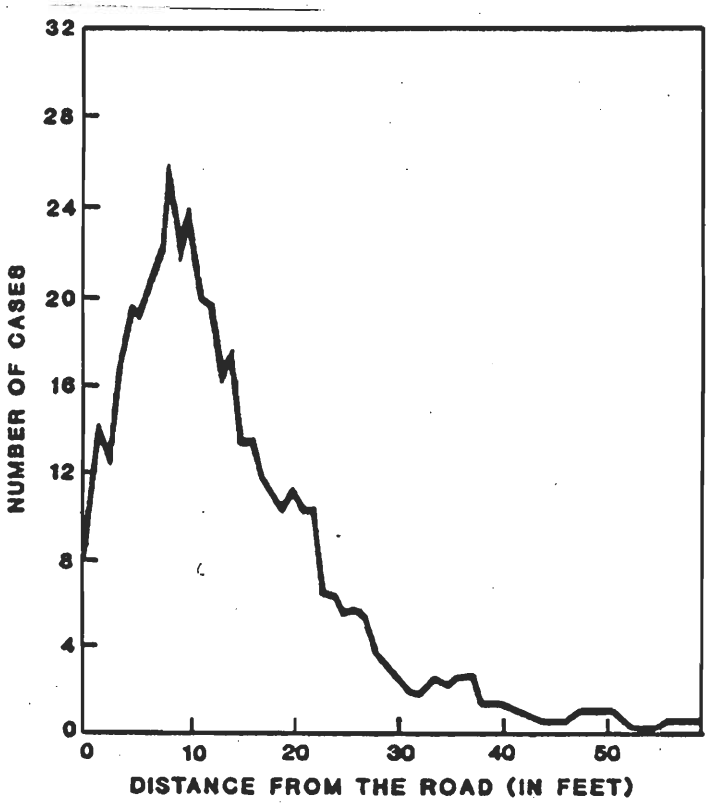

Figure 3. Distance of trees struck from road [9]

Tree density is also a factor in accident probability and severity where a large tree density is attributable to a higher accident frequency and a smaller tree density is attributable to lower accident frequency. [9]

Other roadside conditions that affect vehicle/tree accident probabilities and severity are the presence or absence of guardrails and the slope of the roadside (i.e., sloped up or down). The focus of this project is trees in unprotected highway medians

(e.g., medians not shielded by guardrails); therefore the slope of the median is the most important factor.

Tree Appraisals

When appraising the value of trees in the median, we must take into consideration four key factors must be considered:

- A rating of the species of the tree must be applied (i.e., a rating of 100 percent could be considered for a plant that can tolerate the harshness of its native environment; therefore 100 percent would be considered a good rating). This information is normally kept up to date by the appropriate Regional Plant Appraisal Committee.
- Tree size plays a major role in assigning a monetary value to trees. If the tree is going to be replaced, the difference in size from the original tree to the replacement tree must be considered. Otherwise, the size merely refers to a cross-sectional area of the tree (with different guidelines that must be followed concerning how to measure/where to measure the trunk).
- Tree condition will be shown to be a major factor in this project as well, since this will show the connection between automobile accidents and collisions with trees. When evaluating the 'condition' of trees, one must not only observe the present well being of the trees, but also estimate the previous condition (in this case, before being involved in an automobile accident). Condition not only refers to the state that the trunk of the tree is in, but also takes into consideration any damage done to the roots and branches of the tree.
- Location is the other major factor in tree appraisal that also ties in with this project. This factor looks at the actual location of the tree, along with the contribution it makes to society (functional as well as aesthetic), and the effectiveness of its placement.

These three ratings are averaged to give the overall location rating for a particular tree. On a scale of 1 to 100 percent, the higher the percentage rating, the higher the relative market value considered for that particular location.

It is important to examine each appraisal method to ensure that the method most suited for the situation is chosen. The first possible method is the Trunk Formula Method; this method appraises the value of a tree that is thought to be too large to be replaced by another tree. While this is a viable option, it is not suited for this project

because the trees in the median are mainly located on the periphery of the median, and are not large enough to be evaluated by the above method. Next is the Cost of Repair Method which focuses on whether a damaged tree can be treated and returned back to a healthy state. Again, this has a connection with this project, but is not the best method to be used because this project is not concerned with repairing damaged trees.

The Cost of Cure Method determines the cost for replacement and/or repair of the appraised tree, as well as the restoration of the surrounding property. Again, this method is not the best method to be used because this project is not concerned with repairing damaged trees, or damage to the surrounding locations. There is also an Income Approach Method for situations where the property produces income benefits, and a Market Approach Method taken from the landscape's influence on property sale, both of which do not apply to this research because the trees being studied are not involved in typical real estate transactions.

Finally, there is the Replacement Cost Method, which determines the appraised value of landscape trees based on how much it would cost to replace the tree in question with a tree of equal value with respect to species, condition and size. Since this method appears to be most closely related to the topic (dealing with damaged trees used in landscaping), it will be applied to this study. Once the replacement value of the tree is obtained, it needs to be determined if it is more beneficial to have the tree(s) replaced or removed totally. If this is so, there is a need to add the cost for removal and cleanup of the original tree, as well as the cost of the replacement tree and it's planting. The following is a brief description of the steps that are taken in determining tree value. This same procedure was used in the fieldwork for this project.

Replacement Cost Method Procedure

Field studies: After identifying the species of tree, one would note the condition of the tree being appraised (i.e., if damage is present, one would also assess the condition prior to this damage). From here, one would measure, or estimate if necessary, the size of the tree(s) being observed, and make note of the location, as well as the contribution that the tree makes in this location. Finally, if the tree will be replaced, estimate the costs associated with removal and cleanup. Figure 4 is an example of the form used to calculate the appraised value using the Replacement Cost Method. [10]

Appraised Value =

[Installed Plant Cost × Species % × Condition % × Location %] + Removal and Cleanup Cost (if needed)

Installed Plant Cost = Replacement Plant Cost + Installation Cost

Case # _____ Property _____ Date _____

Appraiser _____

Field Observations

1. **Species** _____
2. **Condition** _____%
3. **Trunk Circumference** _____ in./cm and/or **Diameter** _____ in./cm or **Shrub** or **Vine Size** (height/spread/volume) _____
4. **Location** % = [**Site** ___% + **Contribution** ___% + **Placement** ___%] ÷ 3 = ___%
5. **Removal and Cleanup Costs** for appraised plant or plant that will be replaced = $_____

Regional Plant Appraisal Committee and/or Appraiser-Developed or -Modified Information

6. **Species** rating _____%
7. **Replacement Plant Size** (diameter) _____ in./cm
8. **Replacement Plant Cost** = $_____
9. **Installation Cost** = $_____
10. Other Regional Information_____

Calculations by Appraiser Using Field and/or Regional Information

11. **Installed Plant Cost** = **Plant Cost** (#8) $ _____ + **Installation Cost** (#9) $ _____ = $_____
12. **Adjusted Installed Plant Cost** = **Installed Plant Cost** (#11) $_____ × **Species** rating (#6) _____% × **Condition** (#2) _____% × **Location** (#4)____% = $_____
13. Add **Removal and Cleanup Costs** (#5) (if appraised plant is replaced). $_____ = $_____
14. The **Appraised Value** is either #12 or #13. = $_____
15. If the **Appraised Value** (#14) is $5,000 or more, round it to the nearest $100; if it is less, round to nearest $10.
16. **Appraised Value** (#14) = $_____.

Figure 4. Replacement cost method worksheet

IV. Observations

Accident Reports

Accident reports from 1998,1999, and 2000 were gathered and examined at the State Police barracks in Holden, MA. They are summarized in Appendix 1. Each report was carefully examined to determine the location of the accident. If the accident occurred on Interstate 290, it could have been at a site of interest to this project. The report was then examined more closely for the nearest exit, nearest mile marker, town, or any other evidence that the accident occurred in the project site area. Some reports were clearer and gave more information than others.

If it could be determined that the accident occurred at the site of interest, the report was then analyzed for the nature of the accident (i.e., did the vehicle(s) stay on the road, go off to the roadside, or end up in the median?). If the vehicle did go into the median, whether or not it hit a tree had to be determined. This information was obtained first by examining the drawing of the accident scene. If it looked like the vehicle was in the median and hit a tree, the typed or written description of the accident was read to confirm and to obtain any additional insight.

Finally, each accident report corresponding to the project site was examined to determine the injuries to occupants and damage to the vehicle. This information was listed directly on the police report, with the injuries listed as none, minor, moderate, severe, or fatal. The damage to the vehicle was listed as under $1000, over $1000, or totaled. This information provided an approximate societal cost of the accidents. The data was collected on three separate trips to the police barracks. (A summary of the accident data is shown in Appendix 1.)

	Collisions		Damage		
Injuries	Number	Percent	+ $1000	- $1000	Totaled
None	22	71	21	1	0
Minor	8	26	6	1	1
Moderate	0	0	0	0	0
Severe	0	0	0	0	0
Fatal	1	3	0	0	1
Total	31	100	27	2	2

Table 1. Summary of accident report data

Table 1 summarizes the accident occurrences on the study segment. There were 31 accidents involving trees in the project site between 1998, 1999, and 2000. There was one fatal collision (3 percent), eight minor injury collisions (26 percent) and 22 property damage collisions (71 percent). This data suggests that approximately 10 accidents occur each year that involve trees in the median. Most do not involve fatalities or severe injuries although a fatal collision occurs occasionally.

Road Survey

After collecting the accident report data and determining an average annual accident rate of 10 collisions per year, a survey of the median was conducted. Four main points were emphasized in the survey:

- Location of the trees
- Number and physical properties of the trees
- Road and median characteristics and
- Identifying accident sites

A field survey data collection form was developed and is included in Appendix 2.

The study section is 7.4 miles long beginning 0.3 miles west of exit 22 and ending at exit 25B. To simplify identifying the different sites, mile zero was assigned to the beginning of site one. There were 22 different sites along study section therefore, the end of site 22 was designated as mile 7.4 (Figure 5).

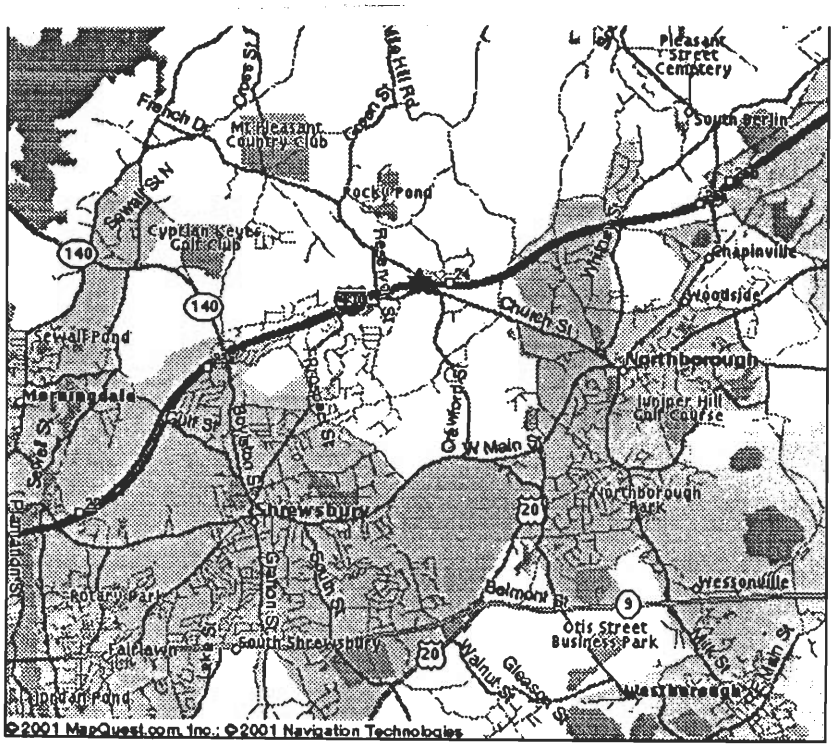

Figure 5. General map of the site (roughly from exits 22 – 25B)

Several pieces of information were obtained for the "Location of trees" and "Road and median characteristics" portion of the survey (Appendix 2). With the exception of measuring the average distance from the trees to the edge of the road, all of the data collected for the above items were done travelling along the highway. Mile zero was set on the odometer at the beginning of site one. Every time the median type changed (i.e.,

from a flat median to a hilly median to a valley median etc.) the mileage on the odometer was recorded. For example, site one starts at mile zero and is a hill-type median. At mile 0.2 the median type changes to a valley and continues to mile 0.35 where it changes again. Therefore, site one goes from mile zero to mile 0.2 and is about 1050 feet long. It is a hill type median and consists of a large grove of trees. All of the sites were characterized in this fashion.

The road characteristics were also determined while driving along the study section. Whenever any one of the six variables changed (i.e., left curve, right curve, straight, flat, sloped up, or sloped down) the mileage was recorded. Therefore, several road and median characteristics were recorded without having to go on the median. Several drive by surveys were conducted to assure accuracy and reproducibility.

The "Number and physical properties of the trees" and "Indicating accident sites" sections of the survey were conducted in the median. Starting at mile zero and walking down the length of the median as far as possible, sites of previous accidents were examined. Upon discovering an accident site, several pieces of information were recorded including the condition of the trees (e.g., bark on the trees, broken trees, etc.), skid marks in the median, automobile fragments in the median, etc. Most accident sites were identified because of automobile fragments in the area. Pictures were taken to illustrate typical tree damage, broken trees in the accident site, automobile fragments, etc.

Figure 6. Fender fragment at a possible accident site (site 1).

Figure 7. Skid marks leading into median (site 13).

Figure 8. Skid marks and broken trees in median (site 10).

Figure 9. Signs of bark disruption due to accident (site 10).

Figure10. Hubcap and broken trees at probable accident site (site 13).

Figure 11. Broken tree (site 1).

After identifying the accident sites, the tree-roadside distance was measured along with the approximate tree density, maximum tree diameter, and maximum tree height. A representative square yard in the median was chosen in each site to approximate the tree density, and maximum tree height was approximated. Note that the tree diameter values are maximum values. They do not represent the sizes of the trees in the median as a whole but rather the largest and oldest trees in each median section. The trees involved in accidents better depict the average sizes of the trees in the median. It will be these trees (which are generally smaller than the maximum size trees and appear to be fairly old due to their brittle nature) that will undergo cost analyses. The approximate diameters of these trees can be obtained form pictures of the site.

With all of this information at hand, a net worth of the trees in a seven and a half mile segment of median on I-290 can be approximated by comparing the cost of the trees to the cost of the accidents.

V. Cost Analysis

Cost of Trees

A simplified form of the "replacement cost method" will be used to appraise the value of the trees in the median. [10] Estimates for accident costs will be adopted from "Motor Vehicle Accident Costs" from the U.S. Department of Transportation Federal Highway Administration. [11]

Because of the extremely large number of trees in the study section, a representative tree size must be chosen for cost analysis. A tree circumference of 15 inches (approximately five-inch diameter) was chosen because this size best represents the typical size of trees located on the periphery of the median where the majority of accidents happens.

From the "Guide for Plant Appraisal" workbook, a value of $760 was obtained for the replacement cost of a five-inch diameter tree (estimated by several nurseries). An installation cost of $1800 and removal and cleanup costs of $90 per tree were also obtained.

According to the "Guide for Plant Appraisal", the appraised value of a plant or tree is:

[installed plant cost x species % x condition % x location %] + removal & cleanup costs

where,

installed plant cost = replacement plant cost + installation cost

Here, a species, condition, and location rating will be arbitrarily chosen as 75 percent for each. Out of 100 percent total, 75 percent can be thought of as an average value, and is a fair approximation considering the condition and location of the trees in the study section.

So, an appraised value can be made as follows:

- Installation cost = $1800
- Replacement plant cost = $760
- Installed plant cost = $2560
- Removal and cleanup cost = $90

So from the above formula:

$$[\$2560 \times 0.75 \times 0.75 \times 0.75] + \$90 = \$1170/tree \quad \text{(appraised tree value)}$$

Assuming an average tree density of three trees/yd^2 the cost in dollars per square yard is:

$$3\ trees/yd^2 \times \$1170/tree = \$3510/yd^2$$

or

$$\$3510/yd^2 = \$390/ft^2$$

Note that a tree density of three trees/yd^2 does not coincide with values given in the Field Survey Forms for tree densities. As maximum tree circumference does not represent actual tree size, tree density values do not accurately predict average tree densities. Considering that, along with large groves of trees, there are scattered trees and

random isolated trees along the project site, the average tree density of the site as a whole will be lower than most isolated tree densities.

With a project site of 7.4 miles, and approximately one mile of it being protected (i.e., guardrails), the length of unprotected median can be estimated to be approximately six miles long and an average of 30 feet wide. So,

$$6 \text{ miles} \times 5280\text{ft.} \times 30\text{ft.} = 950{,}400\text{ft}^2 \text{ of unprotected median}$$

Therefore, at $\$390/\text{ft}^2$, the replacement cost method yields,

$$\$390/\text{ft}^2 \times 950{,}400\text{ft}^2 = \$370{,}656{,}000$$

This value approximates the cost of removing every tree from the study section and replanting equivalent trees somewhere else. If tree densities of two trees/yd^2 or four trees/yd^2 were used, the replacement cost method would yield \$247,104,000 and \$494,208,000, respectively. And if values of 50 percent were used for species, condition, and location ratings with all other variables held constant, we would get a value of \$129,888,000, a value still in the hundreds of millions of dollars. We can conservatively estimate the replacement value of the trees in the study section to be:

$$\text{Tree replacement cost } (P_{TRC}) = \$250{,}000{,}000$$

Societal Costs

Motor vehicle accident costs have been reported to be the following [11]:

Accident severity	Cost per injury (dollars)	Accidents from '98, '99, & 2000 in the project site	Totals (dollars)
Fatal	2,600,000	1	2,600,000
Incapacitating	180,000	0	0
Evident	36,000	0	0
Possible	19,000	8	152,000
PDO	2,000	22	44,000
Total		31	$2,796,000

Table 2. Motor vehicle accident costs.

The total societal cost for three years of accidents involving impacts with trees in the study section is $2,796,000. Therefore, the annual accident cost (AAC) is =

$$AAC = \$2,796,000 / 3\ years = \$932,000$$

Using present worth analysis at a rate of four percent over 20 years gives the present worth of the annual accident cost of:

$$P_{AAC} = (P/A)_{4,20} \times \$932,000$$

$$= 13.59 \times \$932,000 = \$12,665,880$$

Comparing annual accident cost (P_{AAC}) to the tree replacement cost (P_{TRC}), we find

$$\$250,000,000 >> \$12,665,800$$

and

$$P_{TRC} >> P_{AAC}$$

Completely removing the trees from all median sections would save approximately $12.6 million in accident costs but doing so would cost $250 million. Clearly, removing all trees is not a cost-beneficial solution if the trees must be replaced with equivalent trees.

On the other hand, if trees were simply cleared from the median, it would cost approximately $90,000 to clear and grub all the unprotected medians. [13] If P_{TRC} = $90,000 and P_{AAC} = $12,665,000, the benefit cost ratio would be 140; well worth doing. This alternative, however, does not include the environmental benefits of trees in the median whereas the replacement cost method probably over-values the environmental benefits of the trees.

VI. Conclusions

After using two models for estimating the societal costs due to motor vehicle accidents and the economic value of trees and applying those models to data obtained from accident reports and field surveys, a conclusion may be drawn about the net benefits of trees in them median from an economic viewpoint.

It is clear from the cost analysis that tree replacement costs far outweigh societal costs due to accidents in the study section of this project. These results indicate that the societal benefits (i.e., environmental and aesthetic) of having trees in highway medians outweigh the safety costs.

Tree replacement costs will vary among the many types of highway medians consisting of various tree densities, sizes, and species. However, as shown in the cost analysis section, even with a very low tree density, the tree replacement cost far exceeds the annual accident cost (assuming a given stretch of unprotected median has a fairly low accident rate, or more importantly, low accident severity).

It could be argued that a "clear 'n grub" cost (the cost of removing all trees and shrubs) of $4000/acre can be used to significantly decrease society's loss due to collisions with trees in the median. [13] For this project site of 21.8 acres, the clear 'n grub cost would be approximately $87,000. However, this does not include the environmental, aesthetic, and safety features trees possess. For example, if all the trees were removed from a given segment of median, automobiles could be susceptible to cross the median and get involved in accidents with oncoming traffic. If this happened, the money saved by clearing the median of trees would soon be lost again to large societal costs.

It is the conclusion of this project that trees in highway medians are an essential part of highway design from an economic, environmental, aesthetic, and safety standpoint.

VII. References

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3) Cook, David I. Role of Plant Materials in Traffic Noise Control. Transportation Research Record 789.

4) Birnie, et al. Effectiveness of Shielding in Reducing Adverse Impacts on Highway Traffic Noise. Transportation Research Record 686.

5) Michael, Edwin D. Use of Roadside Plantings by Songbirds for Nesting. Transportation Research Record 1075.

6) Ricker, ER. Effect of Planting in Median Strip on Night-Visibility Distances. Highway Research Board Bulletin, 1954.

7) "Benefits of Trees". The International Society of Arboriculture [database online]. 1995- [cited February 23, 2001]. Available from http://www.isa-arbor.com/consumer/benefits.html.

8) "Our Ecosystem". [database online] 1997- [cited February 23, 2001]. Available from http://tqjunior.thinkquest.org/3646/earth/ecosystem/index.html.

9) "Guide to Management of Roadside Trees." U.S. Department of Transportation. Report No. FHWA-IP-86-17. December, 1986.

10) Gooding, Richard F., et al. Council of Tree & Landscape Appraisers: Guide for Plant Appraisal, 9th ed. (Champaign, IL: International Society of Arboriculture, 2000), 11, 57-58.

11) "Motor Vehicle Accident Costs." U.S. Department of Transportation Federal Highway Administration. Technical Advisory. October 31, 1994.

12) Newman, Donald. Engineering Economic Analysis. Engineering Press. 1977: Ch. 5.

13) "Safety Cost – Effectiveness of Incremental Changes in Cross Section Design – Informational Guide." U.S. Department of Transportation Federal Highway Administration. Publication no. FHWA/RD – 87/094. December, 1987.

Appendix 1. **Accident Report Data From 1998, 1999, and 2000**

1998

Location (direc., town, nearest exit, etc.)	Nearest M. M.	Injuries	Damage
290W; Marlboro	19.6	N/A	$1000 +
290W; Shrewsbury	11	Minor	$1000 +
290W; Shrewsbury	12	N/A	$1000 +
290W; Northboro	15	N/A	$1000 +
290; Shrewsbury	2000ft. W. Church St.	Minor	$1000 +
290W; Northboro	15.6	N/A	$1000 +
290W; Shrewsbury	10	N/A	$1000 +
290W; Shrewsbury	N/A	Minor	$1000 +
290W; Shrewsbury	by intersec. with 140	N/A	$1000 +

1999

290E; Northboro	N/A	N/A	$1000 +
290E; Northboro	16	1 Killed	totaled
290W; Northboro	17.5	Minor	$1000 -
290E; Shrewsbury	11	N/A	$1000 +
290W; Northboro	14	N/A	$1000 +
290W; Northboro	N/A	N/A	$1000 +
290E; Marlboro	intersec. at Sol. Pond	Minor	$1000 +
290E; Northboro	.5 miles W. of ex 24	N/A	$1000 +
290W; Northboro	.5 miles W. of mall	N/A	$1000 +
290E; Northboro	14	N/A	$1000 +
290E; Northboro	15.2	N/A	$1000 +
290W	10.6	N/A	$1000 -
290E; Northboro	15	N/A	$1000 +

2000

290W; Shrewsbury	11	N/A	$1000 +
290N; Marlboro	19	N/A	$1000 +
290W; Shrewsbury	13	N/A	$1000 +
290E; Northboro	18	Minor	$1000 +
290E; Marlboro	by 290E/495N exit	N/A	$1000 +
290E; Shrewsbury	13	1-Minor; 2-N/A	$1000 +
290W; Shrewsbury	13	N/A	$1000 +
290W; Northboro	1 mile E. exit 24	Minor	totaled

Appendix 2

Field Survey Data Form

All trees in the study section are located within an approximate 7 mile stretch of median on I-290, beginning about 0.3 miles west of exit 22 (mile 0) in Worcester, MA and ending at exit 25B (mile 7.4) in Northboro, MA.

Site Number: ____

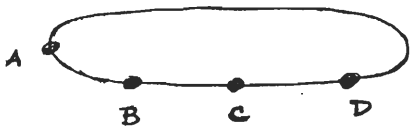
1. Location of trees:
   From mile ____ to mile ____
   Length of the stretch of trees _____ (ft)
   Average distance from roadside EB lane ___(ft) WB lane ___(ft)

2. Number and physical properties of the trees:
   Approximate tree density _____(trees/yd^2)
   Maximum tree diameter _____(inches)
   Maximum tree height (approx.) _____(ft)
   Characterize site (circle one) Large grove
   Scattered clusters
   Random isolated trees

3. Road and median characteristics (circle one):
   Is the road curved straight
   Is the road flat slope up slope down
   Median type

   Other comments:

4. Indicating accident sites (circle one):
   Is this a possible site of a previous accident? Yes No
   Approx. position in median A B C D



Is there any sign of tree disruption?	Yes	No
Is the bark on the trees intact?	Yes	No
Are any trees broken?	Yes	No
Are there any skid marks in the median?	Yes	No
Are there any automobile fragments in the area?	Yes	No
Other comments:		

5. Insert picture(s) of the site

Appendix 3

Field Survey Data Form

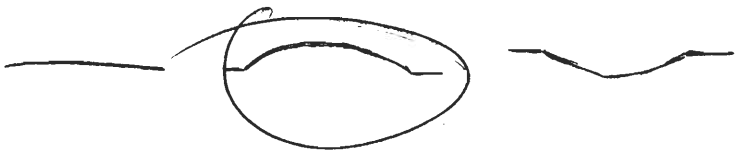
All trees in the study section are located within an approximate 7 mile stretch of median on I-290, beginning about 0.3 miles west of exit 22 (mile 0) in Worcester, MA and ending at exit 25B (mile 7.4) in Northboro, MA.

Site Number: 1

1. Location of trees:
   - From mile 0 to mile 0.2
   - Length of the stretch of trees 1050 (ft)
   - Average distance from roadside EB lane 10 (ft) WB lane 10 (ft)

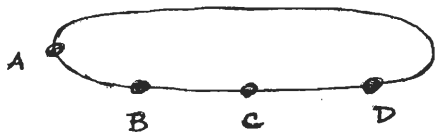
2. Number and physical properties of the trees:
   - Approximate tree ~~density~~ circum. 8 [redacted] (trees/yd^2)
   - Maximum tree diameter 32 (inches)
   - Maximum tree height (approx.) 25 (ft)
   - Characterize site (circle one): (Large grove) / Scattered clusters / Random isolated trees

3. Road and median characteristics (circle one):
   - Is the road (curved) straight
   - Is the road flat / slope up / (slope down)
   - Median type



   - Other comments:

4. Indicating accident sites (circle one):
   - Is this a possible site of a previous accident? (Yes) No
   - Approx. position in median A (B) C D



Is there any sign of tree disruption?	Yes	No
Is the bark on the trees intact?	Yes	No
Are any trees broken?	Yes	No
Are there any skid marks in the median?	Yes	No
Are there any automobile fragments in the area?	Yes	No
Other comments:		

5. Insert picture(s) of the site

Field Survey Data Form

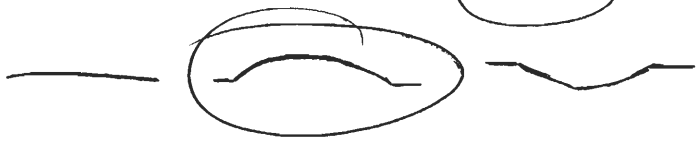
All trees in the study section are located within an approximate 7 mile stretch of median on I-290, beginning about 0.3 miles west of exit 22 (mile 0) in Worcester, MA and ending at exit 25B (mile 7.4) in Northboro, MA.

Site Number: 3

1. Location of trees:
   - From mile 6.35 to mile 6.5
   - Length of the stretch of trees 800 (ft)
   - Average distance from roadside EB lane 10 (ft) WB lane 10 (ft)

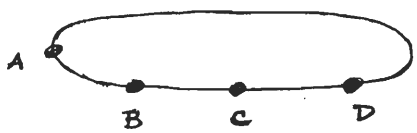
2. Number and physical properties of the trees:
   - Approximate tree density 10 (trees/yd^2)
   - Maximum tree ~~diameter~~ circum. 25 (inches)
   - Maximum tree height (approx.) 30 (ft)
   - Characterize site (circle one) (Large grove) / Scattered clusters / Random isolated trees

3. Road and median characteristics (circle one):
   - Is the road (curved) / straight
   - Is the road flat / slope up / (slope down)
   - Median type



   - Other comments:

4. Indicating accident sites (circle one):
   - Is this a possible site of a previous accident? (Yes) / No
   - Approx. position in median A (B) C D



Is there any sign of tree disruption?	(Yes)	No
Is the bark on the trees intact?	Yes	(No)
Are any trees broken?	(Yes)	No
Are there any skid marks in the median?	Yes	(No)
Are there any automobile fragments in the area?	(Yes)	No

Other comments:

5. Insert picture(s) of the site

Field Survey Data Form

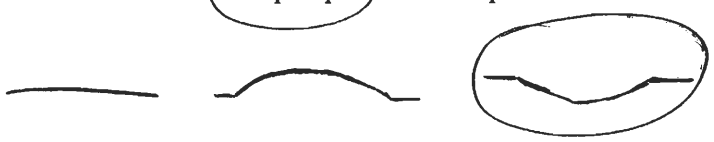
All trees in the study section are located within an approximate 7 mile stretch of median on I-290, beginning about 0.3 miles west of exit 22 (mile 0) in Worcester, MA and ending at exit 25B (mile 7.4) in Northboro, MA.

Site Number: 5

1. Location of trees:
   From mile 1.4 to mile 1.9
   Length of the stretch of trees 2600 (ft)
   Average distance from roadside EB lane 15 (ft) WB lane 5 (ft)

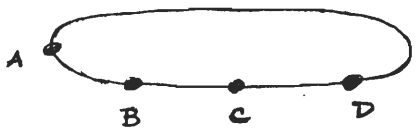
2. Number and physical properties of the trees:
   Approximate tree density 6 [redacted] (trees/yd^2)
   Maximum tree ~~diameter~~ circum. 30 (inches)
   Maximum tree height (approx.) ~30 (ft)
   Characterize site (circle one) (Large grove) Scattered clusters Random isolated trees

3. Road and median characteristics (circle one):
   Is the road (curved ?) straight
   Is the road flat (slope up) slope down
   Median type



   Other comments:

4. Indicating accident sites (circle one):
   Is this a possible site of a previous accident? (Yes) No
   Approx. position in median A B (C) D



Is there any sign of tree disruption?	Yes	No
Is the bark on the trees intact?	Yes	No
Are any trees broken?	Yes	No
Are there any skid marks in the median?	Yes	No
Are there any automobile fragments in the area?	Yes	No

Other comments:

5. Insert picture(s) of the site

Field Survey Data Form

All trees in the study section are located within an approximate 7 mile stretch of median on I-290, beginning about 0.3 miles west of exit 22 (mile 0) in Worcester, MA and ending at exit 25B (mile 7.4) in Northboro, MA.

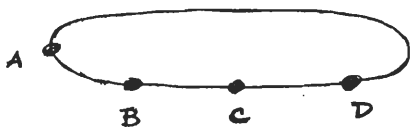
Site Number: 6

1. Location of trees:
   From mile 1.95 to mile 2.1
   Length of the stretch of trees 3100 (ft)
   Average distance from roadside EB lane 15 (ft) WB lane 15 (ft)

2. Number and physical properties of the trees:
   Approximate tree density 10 (trees/yd^2)
   Maximum tree ~~diameter~~ circum. 23 (inches)
   Maximum tree height (approx.) ~30 (ft)
   Characterize site (circle one) (Large grove) Scattered clusters Random isolated trees

3. Road and median characteristics (circle one):
   Is the road (curved ?) straight
   Is the road flat (slope up) slope down
   Median type 
   Other comments:

4. Indicating accident sites (circle one):
   Is this a possible site of a previous accident? (Yes) No
   Approx. position in median A (B) C D



Is there any sign of tree disruption?	Yes	No
Is the bark on the trees intact?	Yes	No
Are any trees broken?	Yes	No
Are there any skid marks in the median?	Yes	No
Are there any automobile fragments in the area?	Yes	No

Other comments:

5. Insert picture(s) of the site

Field Survey Data Form

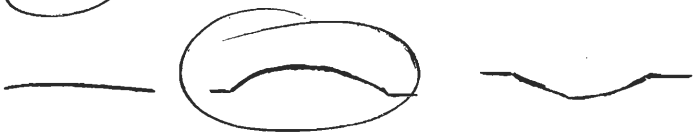
All trees in the study section are located within an approximate 7 mile stretch of median on I-290, beginning about 0.3 miles west of exit 22 (mile 0) in Worcester, MA and ending at exit 25B (mile 7.4) in Northboro, MA.

Site Number: 10

1. Location of trees:
   - From mile 2.6 to mile 2.8
   - Length of the stretch of trees 1000 (ft)
   - Average distance from roadside EB lane 10 (ft) WB lane 10 (ft)

2. Number and physical properties of the trees:
   - Approximate tree density 6 (trees/yd^2)
   - Maximum tree ~~diameter~~ circum. 27 (inches)
   - Maximum tree height (approx.) ~30 (ft)
   - Characterize site (circle one) (Large grove) / Scattered clusters / Random isolated trees

3. Road and median characteristics (circle one):
   - Is the road (curved R) / straight
   - Is the road (flat) / slope up / slope down
   - Median type



   - Other comments:

4. Indicating accident sites (circle one):
   - Is this a possible site of a previous accident? (Yes) / No
   - Approx. position in median A B (C) D

Is there any sign of tree disruption?	Yes	No
Is the bark on the trees intact?	Yes	No
Are any trees broken?	Yes	No
Are there any skid marks in the median?	Yes	No
Are there any automobile fragments in the area?	Yes	No

Other comments:

5. Insert picture(s) of the site

Field Survey Data Form

All trees in the study section are located within an approximate 7 mile stretch of median on I-290, beginning about 0.3 miles west of exit 22 (mile 0) in Worcester, MA and ending at exit 25B (mile 7.4) in Northboro, MA.

Site Number: 13

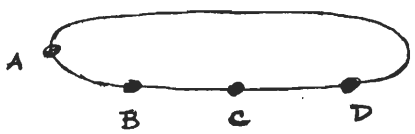
1. Location of trees:
   - From mile 3.9 to mile 4.2
   - Length of the stretch of trees 1600 (ft)
   - Average distance from roadside EB lane 15 (ft) WB lane 15 (ft)

2. Number and physical properties of the trees:
   - Approximate tree density 8 (trees/yd^2)
   - Maximum tree ~~diameter~~ circum. 39 (inches)
   - Maximum tree height (approx.) ~30 (ft)
   - Characterize site (circle one)
     - (Large grove)
     - Scattered clusters
     - Random isolated trees

3. Road and median characteristics (circle one):
   - Is the road (curved R) straight
   - Is the road (flat) slope up slope down
   - Median type

   - Other comments:

4. Indicating accident sites (circle one):
   - Is this a possible site of a previous accident? (Yes) No
   - Approx. position in median A B (C) D



Is there any sign of tree disruption?	Yes	No
Is the bark on the trees intact?	Yes	No
Are any trees broken?	Yes	No
Are there any skid marks in the median?	Yes	No
Are there any automobile fragments in the area?	Yes	No

Other comments:

5. Insert picture(s) of the site

Field Survey Data Form

All trees in the study section are located within an approximate 7 mile stretch of median on I-290, beginning about 0.3 miles west of exit 22 (mile 0) in Worcester, MA and ending at exit 25B (mile 7.4) in Northboro, MA.

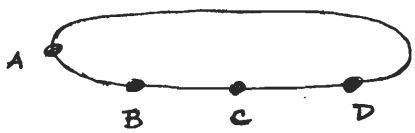
Site Number: 16

1. Location of trees:
   - From mile 5.5 to mile 5.75
   - Length of the stretch of trees 1300 (ft)
   - Average distance from roadside EB lane 15 (ft) WB lane [illegible] (ft)

2. Number and physical properties of the trees:
   - Approximate tree density 3 (trees/yd^2)
   - Maximum tree ~~diameter~~ circum. 32 (inches)
   - Maximum tree height (approx.) 15 (ft)
   - Characterize site (circle one) Large grove / (Scattered clusters) / Random isolated trees

3. Road and median characteristics (circle one):
   - Is the road curved (straight)
   - Is the road flat (slope up) slope down
   - Median type 
   - Other comments:

4. Indicating accident sites (circle one):
   - Is this a possible site of a previous accident? (Yes) No
   - Approx. position in median A (B) C D



Is there any sign of tree disruption?	Yes	No
Is the bark on the trees intact?	Yes	No
Are any trees broken?	Yes	No
Are there any skid marks in the median?	Yes	No
Are there any automobile fragments in the area?	Yes	No

Other comments:

5. Insert picture(s) of the site

Field Survey Data Form

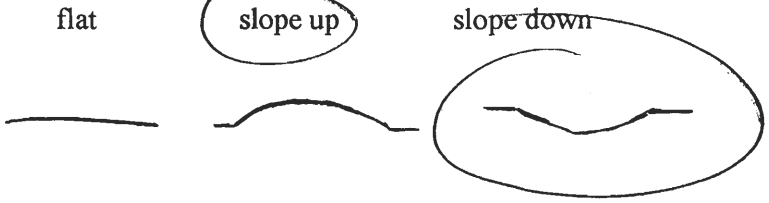
All trees in the study section are located within an approximate 7 mile stretch of median on I-290, beginning about 0.3 miles west of exit 22 (mile 0) in Worcester, MA and ending at exit 25B (mile 7.4) in Northboro, MA.

Site Number: 19

1. Location of trees:
   - From mile 6.1 to mile 6.3
   - Length of the stretch of trees 1100 (ft)
   - Average distance from roadside EB lane 15 (ft) WB lane 15 (ft)

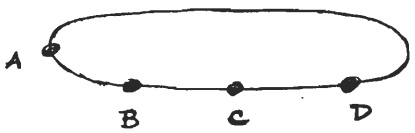
2. Number and physical properties of the trees:
   - Approximate tree density 7 (trees/yd^2)
   - Maximum tree ~~diameter~~ circum. 35 (inches)
   - Maximum tree height (approx.) 25 (ft)
   - Characterize site (circle one)
     - (Large grove)
     - Scattered clusters
     - Random isolated trees

3. Road and median characteristics (circle one):
   - Is the road (curved R.) straight
   - Is the road flat (slope up) slope down
   - Median type



   - Other comments:

4. Indicating accident sites (circle one):
   - Is this a possible site of a previous accident? (Yes) No
   - Approx. position in median A (B) C D



Is there any sign of tree disruption?	Yes	No
Is the bark on the trees intact?	Yes	No
Are any trees broken?	Yes	No
Are there any skid marks in the median?	Yes	No
Are there any automobile fragments in the area?	Yes	No
Other comments:		

5. Insert picture(s) of the site

Field Survey Data Form

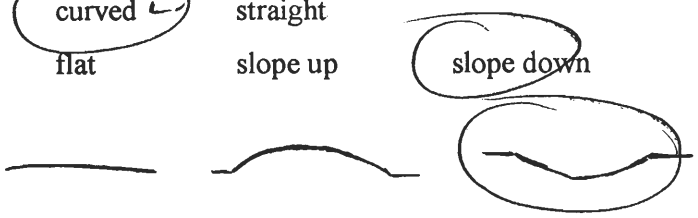
All trees in the study section are located within an approximate 7 mile stretch of median on I-290, beginning about 0.3 miles west of exit 22 (mile 0) in Worcester, MA and ending at exit 25B (mile 7.4) in Northboro, MA.

Site Number: 21

1. Location of trees:
   From mile 6.75 to mile 7.1
   Length of the stretch of trees 1900 (ft)
   Average distance from roadside EB lane 15 (ft) WB lane 15 (ft)

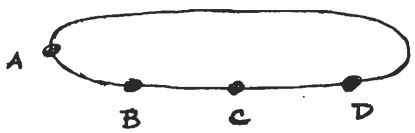
2. Number and physical properties of the trees:
   Approximate tree density 9 (trees/yd^2)
   Maximum tree ~~diameter~~ circum. 45 (inches)
   Maximum tree height (approx.) 30 (ft)
   Characterize site (circle one) (Large grove)
   Scattered clusters
   Random isolated trees

3. Road and median characteristics (~~circle one~~):
   Is the road (curved) straight
   Is the road flat slope up (slope down)
   Median type



   Other comments:

4. Indicating accident sites (circle one):
   Is this a possible site of a previous accident? (Yes) No
   Approx. position in median A B (C) D



Is there any sign of tree disruption?	Yes	No
Is the bark on the trees intact?	Yes	No
Are any trees broken?	Yes	No
Are there any skid marks in the median?	Yes	No
Are there any automobile fragments in the area?	Yes	No

Other comments:

5. Insert picture(s) of the site

Field Survey Data Form

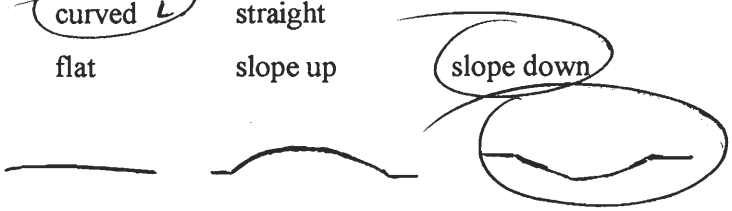
All trees in the study section are located within an approximate 7 mile stretch of median on I-290, beginning about 0.3 miles west of exit 22 (mile 0) in Worcester, MA and ending at exit 25B (mile 7.4) in Northboro, MA.

Site Number: 2

1. Location of trees:
   From mile 0.2 to mile 0.35
   Length of the stretch of trees 800 (ft)
   Average distance from roadside EB lane ___(ft) WB lane ___(ft)

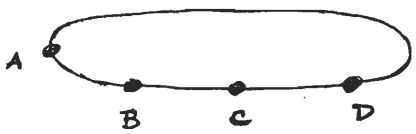
2. Number and physical properties of the trees:
   Approximate tree density _____(trees/yd^2)
   Maximum tree diameter _____(inches)
   Maximum tree height (approx.) _____(ft)
   Characterize site (circle one) (Large grove)
   Scattered clusters
   Random isolated trees

3. Road and median characteristics (circle one):
   Is the road (curved L) straight
   Is the road flat slope up (slope down)
   Median type



   Other comments:

4. Indicating accident sites (circle one):
   Is this a possible site of a previous accident? Yes No
   Approx. position in median A B C D



Is there any sign of tree disruption?	Yes	No
Is the bark on the trees intact?	Yes	No
Are any trees broken?	Yes	No
Are there any skid marks in the median?	Yes	No
Are there any automobile fragments in the area?	Yes	No
Other comments:		

5. Insert picture(s) of the site

Field Survey Data Form

All trees in the study section are located within an approximate 7 mile stretch of median on I-290, beginning about 0.3 miles west of exit 22 (mile 0) in Worcester, MA and ending at exit 25B (mile 7.4) in Northboro, MA.

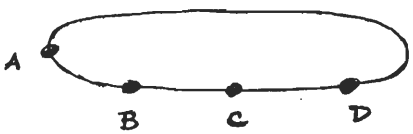
Site Number: 4

1. Location of trees:
   From mile 1.35 to mile 1.4
   Length of the stretch of trees 260 (ft)
   Average distance from roadside EB lane ___(ft) WB lane ___(ft)

2. Number and physical properties of the trees:
   Approximate tree density _____(trees/yd^2)
   Maximum tree diameter _____(inches)
   Maximum tree height (approx.) _____(ft)
   Characterize site (circle one) (Large grove) Scattered clusters Random isolated trees

3. Road and median characteristics (circle one):
   Is the road curved L. straight
   Is the road flat slope up slope down
   Median type
   Other comments:

4. Indicating accident sites (circle one):
   Is this a possible site of a previous accident? Yes No
   Approx. position in median A B C D



Is there any sign of tree disruption?	Yes	No
Is the bark on the trees intact?	Yes	No
Are any trees broken?	Yes	No
Are there any skid marks in the median?	Yes	No
Are there any automobile fragments in the area?	Yes	No

Other comments:

5. Insert picture(s) of the site

Field Survey Data Form

All trees in the study section are located within an approximate 7 mile stretch of median on I-290, beginning about 0.3 miles west of exit 22 (mile 0) in Worcester, MA and ending at exit 25B (mile 7.4) in Northboro, MA.

Site Number: 7

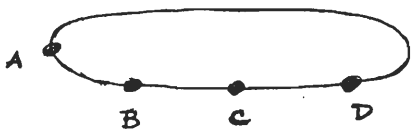
1. Location of trees:
   From mile 2.1 to mile 2.2
   Length of the stretch of trees 530 (ft)
   Average distance from roadside EB lane ___(ft) WB lane ___(ft)

2. Number and physical properties of the trees:
   Approximate tree density _____(trees/yd^2)
   Maximum tree diameter _____(inches)
   Maximum tree height (approx.) _____(ft)
   Characterize site (circle one) (Large grove) Scattered clusters Random isolated trees

3. Road and median characteristics (circle one):
   Is the road (curved ?) straight
   Is the road flat (slope up) slope down
   Median type

   Other comments:

4. Indicating accident sites (circle one):
   Is this a possible site of a previous accident? Yes No
   Approx. position in median A B C D



Is there any sign of tree disruption?	Yes	No
Is the bark on the trees intact?	Yes	No
Are any trees broken?	Yes	No
Are there any skid marks in the median?	Yes	No
Are there any automobile fragments in the area?	Yes	No

Other comments:

5. Insert picture(s) of the site

Field Survey Data Form

All trees in the study section are located within an approximate 7 mile stretch of median on I-290, beginning about 0.3 miles west of exit 22 (mile 0) in Worcester, MA and ending at exit 25B (mile 7.4) in Northboro, MA.

Site Number: 8

1. Location of trees:
   From mile 2.3 to mile 2.45
   Length of the stretch of trees 800 (ft)
   Average distance from roadside EB lane ___(ft) WB lane ___(ft)

2. Number and physical properties of the trees:
   Approximate tree density _____(trees/yd^2)
   Maximum tree diameter _____(inches)
   Maximum tree height (approx.) _____(ft)
   Characterize site (circle one) (Large grove)
   Scattered clusters
   Random isolated trees

3. Road and median characteristics (circle one):
   Is the road (curved R) straight
   Is the road (flat) slope up slope down
   Median type

   Other comments:

4. Indicating accident sites (circle one):
   Is this a possible site of a previous accident? Yes No
   Approx. position in median A B C D

Is there any sign of tree disruption?	Yes	No
Is the bark on the trees intact?	Yes	No
Are any trees broken?	Yes	No
Are there any skid marks in the median?	Yes	No
Are there any automobile fragments in the area?	Yes	No
Other comments:		

5. Insert picture(s) of the site

Field Survey Data Form

All trees in the study section are located within an approximate 7 mile stretch of median on I-290, beginning about 0.3 miles west of exit 22 (mile 0) in Worcester, MA and ending at exit 25B (mile 7.4) in Northboro, MA.

Site Number: 9

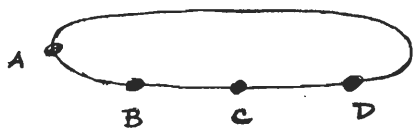
1. Location of trees:
   From mile 2.5 to mile 2.6
   Length of the stretch of trees 530 (ft)
   Average distance from roadside EB lane ___(ft) WB lane ___(ft)

2. Number and physical properties of the trees:
   Approximate tree density _____(trees/yd^2)
   Maximum tree diameter _____(inches)
   Maximum tree height (approx.) _____(ft)
   Characterize site (circle one) Large grove / (Scattered clusters) / Random isolated trees

3. Road and median characteristics (circle one):
   Is the road (curved R) straight
   Is the road (flat) slope up slope down
   Median type

   Other comments:

4. Indicating accident sites (circle one):
   Is this a possible site of a previous accident? Yes No
   Approx. position in median A B C D



Is there any sign of tree disruption?	Yes	No
Is the bark on the trees intact?	Yes	No
Are any trees broken?	Yes	No
Are there any skid marks in the median?	Yes	No
Are there any automobile fragments in the area?	Yes	No
Other comments:		

5. Insert picture(s) of the site

Field Survey Data Form

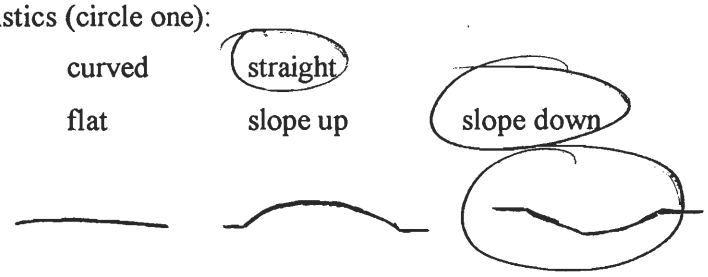
All trees in the study section are located within an approximate 7 mile stretch of median on I-290, beginning about 0.3 miles west of exit 22 (mile 0) in Worcester, MA and ending at exit 25B (mile 7.4) in Northboro, MA.

Site Number: 11

1. Location of trees:
   From mile 3 to mile 3.4
   Length of the stretch of trees 2100 (ft)
   Average distance from roadside EB lane ___(ft) WB lane ___(ft)

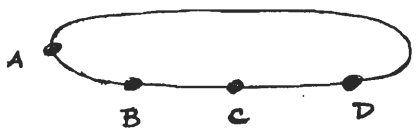
2. Number and physical properties of the trees:
   Approximate tree density _____(trees/yd^2)
   Maximum tree diameter _____(inches)
   Maximum tree height (approx.) _____(ft)
   Characterize site (circle one) (Large grove) Scattered clusters Random isolated trees

3. Road and median characteristics (circle one):
   Is the road curved (straight)
   Is the road flat slope up (slope down)
   Median type



   Other comments:

4. Indicating accident sites (circle one):
   Is this a possible site of a previous accident? Yes No
   Approx. position in median A B C D



Is there any sign of tree disruption?	Yes	No
Is the bark on the trees intact?	Yes	No
Are any trees broken?	Yes	No
Are there any skid marks in the median?	Yes	No
Are there any automobile fragments in the area?	Yes	No
Other comments:		

5. Insert picture(s) of the site

Field Survey Data Form

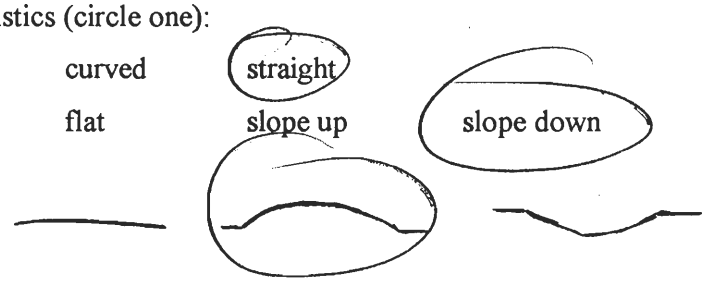
All trees in the study section are located within an approximate 7 mile stretch of median on I-290, beginning about 0.3 miles west of exit 22 (mile 0) in Worcester, MA and ending at exit 25B (mile 7.4) in Northboro, MA.

Site Number: 12

1. Location of trees:
   From mile 3.4 to mile 3.6
   Length of the stretch of trees 1100 (ft)
   Average distance from roadside EB lane ___(ft) WB lane ___(ft)

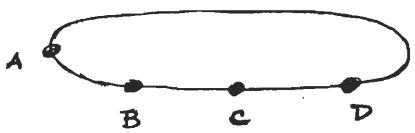
2. Number and physical properties of the trees:
   Approximate tree density _____(trees/yd^2)
   Maximum tree diameter _____(inches)
   Maximum tree height (approx.) _____(ft)
   Characterize site (circle one) (Large grove) Scattered clusters Random isolated trees

3. Road and median characteristics (circle one):
   Is the road curved (straight)
   Is the road flat slope up slope down
   Median type



   Other comments:

4. Indicating accident sites (circle one):
   Is this a possible site of a previous accident? Yes No
   Approx. position in median A B C D



Is there any sign of tree disruption?	Yes	No
Is the bark on the trees intact?	Yes	No
Are any trees broken?	Yes	No
Are there any skid marks in the median?	Yes	No
Are there any automobile fragments in the area?	Yes	No
Other comments:		

5. Insert picture(s) of the site

Field Survey Data Form

All trees in the study section are located within an approximate 7 mile stretch of median on I-290, beginning about 0.3 miles west of exit 22 (mile 0) in Worcester, MA and ending at exit 25B (mile 7.4) in Northboro, MA.

Site Number: 14

1. Location of trees:
   - From mile 4.6 to mile 4.65
   - Length of the stretch of trees 260 (ft)
   - Average distance from roadside EB lane ___(ft) WB lane ___(ft)

2. Number and physical properties of the trees:
   - Approximate tree density _____(trees/yd^2)
   - Maximum tree diameter _____(inches)
   - Maximum tree height (approx.) _____(ft)
   - Characterize site (circle one) Large grove / (Scattered clusters) / Random isolated trees

3. Road and median characteristics (circle one):
   - Is the road curved (straight)
   - Is the road (flat) slope up slope down
   - Median type 
   - Other comments:

4. Indicating accident sites (circle one):
   - Is this a possible site of a previous accident? Yes No
   - Approx. position in median A B C D

Is there any sign of tree disruption?	Yes	No
Is the bark on the trees intact?	Yes	No
Are any trees broken?	Yes	No
Are there any skid marks in the median?	Yes	No
Are there any automobile fragments in the area?	Yes	No
Other comments:		

5. Insert picture(s) of the site

Field Survey Data Form

All trees in the study section are located within an approximate 7 mile stretch of median on I-290, beginning about 0.3 miles west of exit 22 (mile 0) in Worcester, MA and ending at exit 25B (mile 7.4) in Northboro, MA.

Site Number: 15

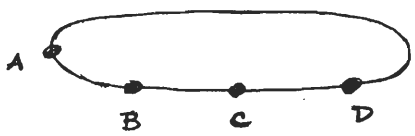
1. Location of trees:
   - From mile 5.1 to mile 5.3
   - Length of the stretch of trees 1100 (ft)
   - Average distance from roadside EB lane ___(ft) WB lane ___(ft)

2. Number and physical properties of the trees:
   - Approximate tree density _____(trees/yd^2)
   - Maximum tree diameter _____(inches)
   - Maximum tree height (approx.) _____(ft)
   - Characterize site (circle one)
     - Large grove
     - (Scattered clusters)
     - Random isolated trees

3. Road and median characteristics (circle one):
   - Is the road (curved) straight
   - Is the road (flat) slope up slope down
   - Median type

   - Other comments:

4. Indicating accident sites (circle one):
   - Is this a possible site of a previous accident? Yes No
   - Approx. position in median A B C D



Is there any sign of tree disruption?	Yes	No
Is the bark on the trees intact?	Yes	No
Are any trees broken?	Yes	No
Are there any skid marks in the median?	Yes	No
Are there any automobile fragments in the area?	Yes	No
Other comments:		

5. Insert picture(s) of the site

Field Survey Data Form

All trees in the study section are located within an approximate 7 mile stretch of median on I-290, beginning about 0.3 miles west of exit 22 (mile 0) in Worcester, MA and ending at exit 25B (mile 7.4) in Northboro, MA.

Site Number: 17

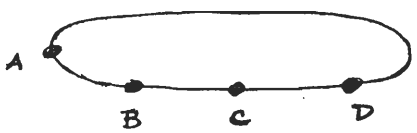
1. Location of trees:
   From mile 5.75 to mile 5.9
   Length of the stretch of trees 800 (ft)
   Average distance from roadside EB lane ___(ft) WB lane ___(ft)

2. Number and physical properties of the trees:
   Approximate tree density _____(trees/yd^2)
   Maximum tree diameter _____(inches)
   Maximum tree height (approx.) _____(ft)
   Characterize site (circle one) Large grove / (Scattered clusters) / Random isolated trees

3. Road and median characteristics (circle one):
   Is the road (curved R-) straight
   Is the road flat (slope up) slope down
   Median type

   Other comments:

4. Indicating accident sites (circle one):
   Is this a possible site of a previous accident? Yes No
   Approx. position in median A B C D



Is there any sign of tree disruption?	Yes	No
Is the bark on the trees intact?	Yes	No
Are any trees broken?	Yes	No
Are there any skid marks in the median?	Yes	No
Are there any automobile fragments in the area?	Yes	No
Other comments:		

5. Insert picture(s) of the site

Field Survey Data Form

All trees in the study section are located within an approximate 7 mile stretch of median on I-290, beginning about 0.3 miles west of exit 22 (mile 0) in Worcester, MA and ending at exit 25B (mile 7.4) in Northboro, MA.

Site Number: 18

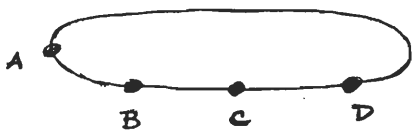
1. Location of trees:
   From mile 5.95 to mile 6.1
   Length of the stretch of trees 800 (ft)
   Average distance from roadside EB lane ___(ft) WB lane ___(ft)

2. Number and physical properties of the trees:
   Approximate tree density _____(trees/yd^2)
   Maximum tree diameter _____(inches)
   Maximum tree height (approx.) _____(ft)
   Characterize site (circle one) Large grove / (Scattered clusters) / Random isolated trees

3. Road and median characteristics (circle one):
   Is the road (curved R.) straight
   Is the road flat (slope up) slope down
   Median type

   Other comments:

4. Indicating accident sites (circle one):
   Is this a possible site of a previous accident? Yes No
   Approx. position in median A B C D



Is there any sign of tree disruption?	Yes	No
Is the bark on the trees intact?	Yes	No
Are any trees broken?	Yes	No
Are there any skid marks in the median?	Yes	No
Are there any automobile fragments in the area?	Yes	No
Other comments:		

5. Insert picture(s) of the site

Field Survey Data Form

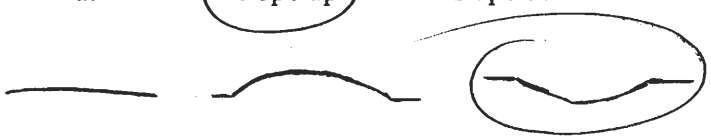
All trees in the study section are located within an approximate 7 mile stretch of median on I-290, beginning about 0.3 miles west of exit 22 (mile 0) in Worcester, MA and ending at exit 25B (mile 7.4) in Northboro, MA.

Site Number: 20

1. Location of trees:
   From mile 6.3 to mile 6.35
   Length of the stretch of trees 260 (ft)
   Average distance from roadside EB lane ___(ft) WB lane ___(ft)

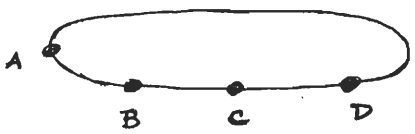
2. Number and physical properties of the trees:
   Approximate tree density _____(trees/yd^2)
   Maximum tree diameter _____(inches)
   Maximum tree height (approx.) _____(ft)
   Characterize site (circle one) Large grove / (Scattered clusters) / Random isolated trees

3. Road and median characteristics (~~circle one~~):
   Is the road (curved R.) straight
   Is the road flat (slope up) slope down
   Median type



   Other comments:

4. Indicating accident sites (circle one):
   Is this a possible site of a previous accident? Yes No
   Approx. position in median A B C D



Is there any sign of tree disruption?	Yes	No
Is the bark on the trees intact?	Yes	No
Are any trees broken?	Yes	No
Are there any skid marks in the median?	Yes	No
Are there any automobile fragments in the area?	Yes	No
Other comments:		

5. Insert picture(s) of the site

Field Survey Data Form

All trees in the study section are located within an approximate 7 mile stretch of median on I-290, beginning about 0.3 miles west of exit 22 (mile 0) in Worcester, MA and ending at exit 25B (mile 7.4) in Northboro, MA.

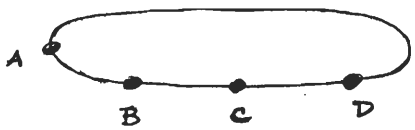
Site Number: 22

1. Location of trees:
   From mile 7.2 to mile 7.4
   Length of the stretch of trees 1100 (ft)
   Average distance from roadside EB lane ___(ft) WB lane ___(ft)

2. Number and physical properties of the trees:
   Approximate tree density _____(trees/yd^2)
   Maximum tree diameter _____(inches)
   Maximum tree height (approx.) _____(ft)
   Characterize site (circle one) Large grove / (Scattered clusters) / Random isolated trees

3. Road and median characteristics (circle one):
   Is the road (curved L.) straight
   Is the road (flat) slope up slope down
   Median type 
   Other comments:

4. Indicating accident sites (circle one):
   Is this a possible site of a previous accident? Yes No
   Approx. position in median A B C D



Is there any sign of tree disruption?	Yes	No
Is the bark on the trees intact?	Yes	No
Are any trees broken?	Yes	No
Are there any skid marks in the median?	Yes	No
Are there any automobile fragments in the area?	Yes	No
Other comments:		

5. Insert picture(s) of the site