Risk of Vehicle-Tree Accidents and Management of Roadside Trees

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Research conducted by the Michigan Department of Transportation has resulted in recommendations regarding both safety and environmental issues for management of roadside trees. Intended for local and state road authorities, recommendations resulted from research that included analysis of nearly 500 sites of vehicle-tree accidents across Michigan. Statistical analysis of vehicle-tree accidents in Michigan reveals, among other characteristics, that the typical driver may be intoxicated or unfamiliar with the road or both. Vehicle-tree accidents typically occur along winding rural roads and involve a vehicle that leaves the pavement on the outside of a curve. No single feature of the road environment accounts for all the accidents that occur and so can be used to determine the level of risk. The distance of the tree from the road is not sufficient by itself to determine the probability of a vehicle-tree accident. Treatment of locations should address both safety and environmental issues. High-risk locations should be identified for treatment first on the basis of both accident history and potential accident frequency. Accident profiles have been developed to identify high-risk locations while eliminating random accident sites from consideration. Tree removal is only one of many alternatives that should be considered depending on site-specific environmental and safety issues. Contact with adjacent property owners and judgment of professional engineers are essential in the treatment process rather than strict adherence to set clear-cut distances. Because it is expected that safety issues will continue to conflict with environmental issues associated with roadside trees, the management process offered will be useful in addressing the vehicle-tree accident problem.

The Michigan Department of Transportation (MDOT) has recently completed a *Guide to Management of Roadside Trees (1)*, which presents a step-by-step approach to identify and treat rural roadways that have a high risk of vehicle-tree accidents. It is intended for use by state highway personnel and local road authorities responsible for maintaining roads. Both safety and environmental issues are addressed, along with alternative treatments to reduce the risk of vehicle-tree accidents.

Prepared under an FHWA grant for national distribution, this guide is a result of more than 10 years of comprehensive research *(2–5)*. Defining the exact nature and extent of the vehicle-tree accident problem on a statewide and site-specific basis required supportive statistical analysis of accident data and field surveys of vehicle-tree accident sites.

Environmental and highway safety research consultants were employed to identify and evaluate the problem *(4,6)*. Following study of the state-of-the-art research, evaluation of five consecutive years of vehicle-tree accident data in Michigan, field surveys, and analysis of nearly 500 vehicle-tree accident sites across Michigan, a statistical basis for research findings and recommendations was developed. Subsequent evaluation and revisions by the MDOT were based on field testing by the Ingham County Road Commission (Michigan) and review by other Michigan county road agencies and transportation departments in other states *(2)*.

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DEFINING THE PROBLEM

Trees are valued as a resource along the roadways. However, they have come under scrutiny in recent years as posing a risk. In Michigan, for example, review of accidents for the 5-year period from 1981 through 1985 reveals that although tree-related accidents constitute only about 2.8 percent of all accidents, they represent 11.1 percent of all fatal crashes *(7)*. A review of fatal accident involvement from 1978 through 1985 reveals that although crashes involving trees vary significantly by year, the absolute number appears to stay relatively constant *(7)* (Figure 1).

Vehicle-tree accidents are not distributed evenly throughout a geographic area. In Michigan, for example, the vehicle-tree accident problem occurs with much greater frequency in the lower half of the lower peninsula. According to recent data on the cumulative number of vehicle-tree accidents for both local and U.S. or state roads (fatal, injury, and property damage) from 1979 to 1983, these accidents occurred with greater frequency in 13 counties *(7)*, which appear to include those associated with both higher population concentrations or density and greater vehicle miles traveled as well as areas having roadside trees.

Research devoted to identifying, ranking, and tabulating the risk potential of many characteristics of vehicle-tree accidents was completed as part of this study. These characteristics fall into three categories:

1. Driver characteristics;
2. The road design, or geometrics; and
3. Trees and the roadside environment.

Driver Characteristics

The discussion in this section is based on two studies *(3,6)*. Traffic-related research has drawn a profile of the driver most typically involved in run-off-road accidents. He is typically a young man between 20 and 25 years old. He is a weekend driver, out during the early morning hours between 2:00 and 4:00 a.m. He is driving faster than the posted speed limit and may also be intoxicated or unfamiliar with the road, or both.

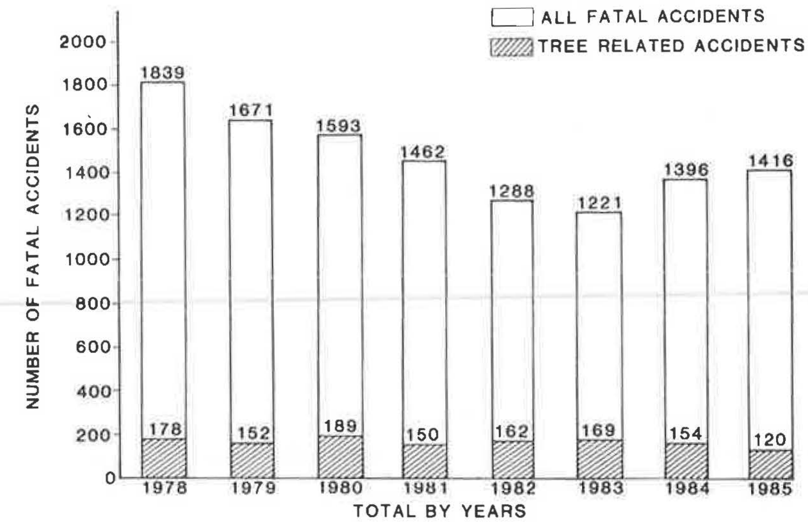

FIGURE 1 Fatal vehicle accidents in Michigan, total and tree related, from 1978 through 1985.

Drinking is a common ingredient in vehicle-tree accidents. More than 60 percent of the drivers killed in vehicle-tree crashes had been drinking; less than 30 percent of the drivers involved in property-damage-only accidents were reported to have been drinking.

More than two-thirds of vehicle-tree collisions occur on weekends. Most of these accidents occur on Friday and Saturday nights between 2:00 and 4:00 a.m. on the following day. Crashes are most frequent during the winter months, suggesting some correlation with longer periods of darkness and, perhaps, snow-covered or icy roads.

Many of the factors that correlate with speeding, such as nighttime hours and young drivers, are also typical of run-off-road accidents.

Design

Vehicle-tree accidents typically occur along winding rural roads on which a vehicle leaves the pavement on the outside of a curve *(6)*. The road type and various physical features (lane and shoulder width, traffic volume and direction, presence of curves, etc.), as well as the driver characteristics described earlier, determine the probability of running off the road.

Accidents involving trees are mainly a rural phenomenon, occurring most frequently on rural local roads *(3)*. Of the fatal accidents occurring during 1985, for example, 81.7 percent occurred on rural roads; 72.9 percent of the injury-producing and 70.7 percent of the property-damage-only vehicle-tree accidents occurred in unincorporated areas *(7)*.

Seventy-seven percent of tree-related accidents on curves occur on the outside of the curve, that is, to the right of a left curve or the left of a right curve *(6)*. Inside curves account for 23 percent of the crash frequency. Most vehicle-tree crashes on curves involve right departures on left curves.

This study addresses two road classifications, rural U.S. or state and rural local. Rural U.S.-state roads are identified as rural arterials and major collectors. These roads include all U.S. and state-designated routes. Rural local roads include the remaining ones, generally maintained by local road authorities (county, township, etc.). Because of lower traffic volumes, these roads also include gravel surfaces and are maintained to lower standards than higher volume arterials and some collectors.

Trees and the Roadside Environment

The typical vehicle-tree accident involves a larger tree within 30 ft (9.15 m) of the road edge. The tree is typically located in a drainage ditch or at the bottom of a downward grade. The target tree and its immediate surroundings (size, density, distance from the road, the presence of other obstructions, etc.) determine the probability that the vehicle will strike the tree.

Although trees involved in accidents have been as far from the pavement edge as 90 ft (27.45 m), 85 percent of the trees involved in vehicle-tree crashes were within 30 ft (9.15 m) of the road edge *(6)* (Figure 2).

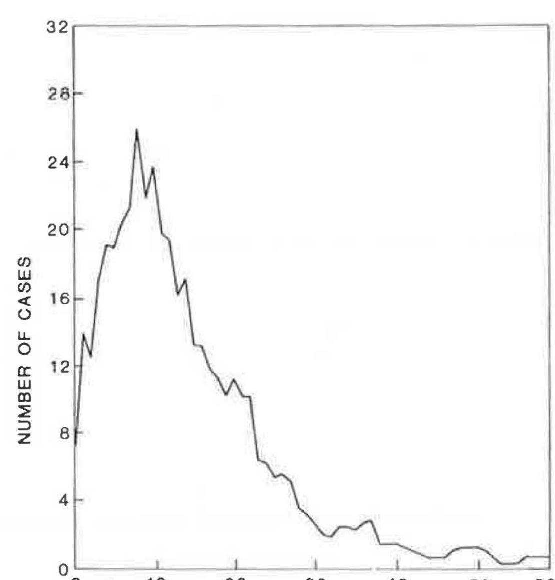

FIGURE 2 Distance of struck trees from road.

A number of other factors may reduce or increase the probability of striking a tree as well as affect the severity of the crash. For instance, the presence of guardrails may change the character of the accident; roadside edge slope design may reduce the speed of a vehicle before it strikes a solid object; a drainage ditch may guide the vehicle directly into a tree.

Accident Profiles

In the explanation of run-off-road accidents, no single feature of the road environment accounts for all the accidents that occur and thus the level of risk. For example, the distance of the tree from the road is not sufficient by itself to determine the probability of a vehicle-tree accident. Accidents involving trees have occurred in a wide range of distances from the pavement's edge. Employing such one-dimensional models limits the ability to understand and consequently to prevent vehicle-tree accidents.

Identifying and ranking nonhuman factors that contribute to the risk of vehicle-tree accidents is an essential task in developing guidelines. Two areas of the roadside environment must be considered: the actual roadway and the off-roadway environment.

Studies indicate that the various roadway and off-roadway characteristics of vehicle-tree accidents cluster in particular patterns associated with road type and alignment *(5,6)*. These accident profiles identify potential high-risk sites so they can be treated.

The accident profiles relate to the road types identified earlier. They include both rural U.S.-state roads and rural local roads, along with the horizontal alignment (curved or straight sections) of these roads. Curved rural local roads typically involve the higher risk, followed by curved rural U.S.-state roads, and then straight rural local roads and rural U.S.-state roads *(1)*.

A comparison of the number of fatal vehicle-tree accidents was made in this study for U.S.-state and local road classifications in Michigan *(7)* (Figure 3). Measured by the number of fatal vehicle-tree accidents per 100 million mi traveled, curved local road sections are by far the highest-risk areas. In 1985, for example, curved local roads, with 564.4 vehicle-tree accidents per 100 million mi traveled, had nearly 10 times the number of accidents as the next highest category, curved U.S.-state roads, with 57.9 accidents per 100 million mi. This is followed by straight local roads with some 21 vehicle-tree accidents and, finally, straight U.S.-state roads with 3.9 vehicle-tree accidents per 100 million mi traveled.

A program for the management of roadside trees should be focused on these road types. City streets have been excluded from the MDOT guide because of the difficulty of defining what they are and a lack of data on vehicle-tree accidents occurring along this road type *(1)*. Exceptions include rural U.S.-state and rural local roads that pass through city limits, but more closely resemble rural conditions (i.e., no curbs).

Curved Rural Local Roads

Curved rural local roads constitute a substantially higher-risk driving environment than do straight rural local roads. Most curved rural local road accident sites are found on left-hand turns with downhill grades following a series of curves. The likelihood of an accident increases with tree density near the outside of the curve *(6)*. The impacted tree is often 20 ft (6.1 m) or more from the road edge.

Curved Rural U.S.-State Roads

In every case studied, accidents along curved rural U.S.-state roads occurred on left-hand curves *(5)*. Most often, the fatal tree was in a grove of trees and was rarely the first tree struck. Typically, the vehicle ran down an embankment into a grove of trees. Almost half of the accidents studied occurred at the location of at least one previous serious vehicle-tree accident.

Treatment of curved rural U.S.-state roads is more difficult than treatment of curved rural local roads. The trees tend to be even farther from the road edge.

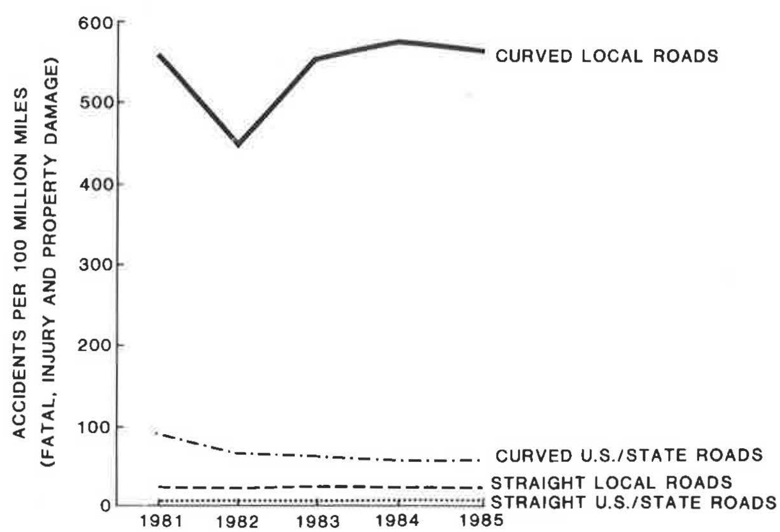

FIGURE 3 Vehicle-tree accidents per miles traveled by road type (curved or straight sections) in Michigan, 1981 to 1985.

As is the case with accidents on curved rural local roads, vehicles often miss a left turn and continue down a side slope into a tree. Slope of the road is a less critical factor on rural U.S.-state roads than on rural local roads.

Straight Sections of Rural Local Roads

Straight sections of rural local roads have accident profiles that are considerably different from those of curved sections. The distance of trees from the road edge tends to be appreciably less along straight rural local roads. Typically the vehicle enters a ditch from a narrow and often unstable (i.e., soft) shoulder and is then channelled into several trees.

Straight Sections of Rural U.S.-State Roads

The impacted trees along straight rural U.S.-state road sections are farther from the road edge than trees along rural local roads. The ditches are usually wider and less likely to direct the vehicle into a tree. Another tree is usually struck first; the vehicle then careens into the fatal one.

SOLVING THE PROBLEM

How does one solve the vehicle-tree accident problem? A method for examining roadside vehicle-tree accident risk is necessary in areas where roads are lined with trees.

Although a county or state may appear to have an existing vehicle-tree accident problem along specific road sections, many of these locations may simply reflect random accident occurrence. A policy to treat only sites that demonstrate accident risk (because of perceived legal or liability issues or because of limited funding, or both) is therefore likely to miss the majority of high-risk locations. Many sites where there have been no accidents will have a much higher potential risk, although it has not been demonstrated within the last 5 years.

Sufficient resources do not exist to remove all roadside trees, nor would this be desirable. Resources do not exist to upgrade all roads or easily modify driver behavior. Therefore, those road sections with a high risk for a serious accident involving a tree must be identified for treatment.

Accident profiles just discussed allow one to identify potential high-risk locations for treatment based on road type and alignment. Ranking by risk has been taken further to identify locations having vehicle-tree accidents that should not be considered random occurrences. To address this, average daily traffic (ADT) and the incidence of vehicle-tree accidents are taken into account. This allows one to more appropriately rank locations that are more frequently traveled first.

A more responsive approach, therefore, is to consider both expected accident occurrence and locations of significant accident frequency to determine priorities for field verification and treatment. This would both address long-term prevention (10 to 20 years) and be responsive to locations that have a significant accident history.

To do this, accident history over the last 3 to 5 years should be used to identify locations where particularly high vehicle-tree accident frequency has occurred. For example, when the actual vehicle-tree accident frequency along a road section is significantly higher than what is expected (based on both probability and local accident data), these should not be considered random accident locations. Instead, the number of accidents may indicate a real and statistically significant deviation from this expectation. The threshold, or the number of vehicle-tree accidents that represents a statistically significant deviation from the expected, can be calculated for each location. For those locations meeting or exceeding this threshold, the actual number of vehicle-tree accidents (equated per year) may be used to determine the priority for treatment. This will identify both straight road sections as well as curved road sections that have an unusually high vehicle-tree accident frequency (risk).

A method for examining roadside vehicle-tree accident risk was developed in this study and involves five tasks *(1,2)* (Figure 4). It enables the road engineer to identify road sections by risk for priority treatment. The method can be used to consider both potential risk and accident frequency for any location.

Developed for practical application, the methodology is presented as a step-by-step procedure. It can be completed manually or programmed for use with the aid of a computer as part of an already existing accident data system for analysis.

Along with both safety and environmental concerns, the procedure is based on driver characteristics, factors concerning the road environment, and characteristics of roadsides with trees (Figure 4).

Task 1: Prepare a Base Map and Plot Roadway Information

The first task is broken into six steps that create a base map or computer file for interactive use. Identified are rural roads by type (rural local or rural U.S.-state), ADT, curved road sections, locations of past vehicle-tree accidents, and locations of natural and cultural significance that may be affected along the roadside. These may include champion trees, locations of endangered plant species, and historic sites. The base map or computer file would exhibit or list this type of information.

Areas of natural and cultural significance in Michigan, for example, are available through an existing Natural Features Inventory from the Michigan Department of Natural Resources (MDNR). Similar inventory or heritage programs are available in other states.

Any particular county road system may include 400 or more locations with high vehicle-tree accident risk. However, less than half of these, and probably not more than the top 10 to 20 percent, would reasonably be considered part of a 3- to 5-year program of priority safety improvement. A computer-based file could, of course, accommodate a much more comprehensive inventory system.

Task 2: Assign Priorities for Field Verification

Divided into four steps, the second task determines the order in which to field check the high-risk road sections. The step-by-step approach allows one to consider both potential risk and actual accident frequency. A master county (or state) map (or computer listing) is developed that pinpoints locations of high risk. This is then used to identify sections rank ordered by risk for field review and treatment.

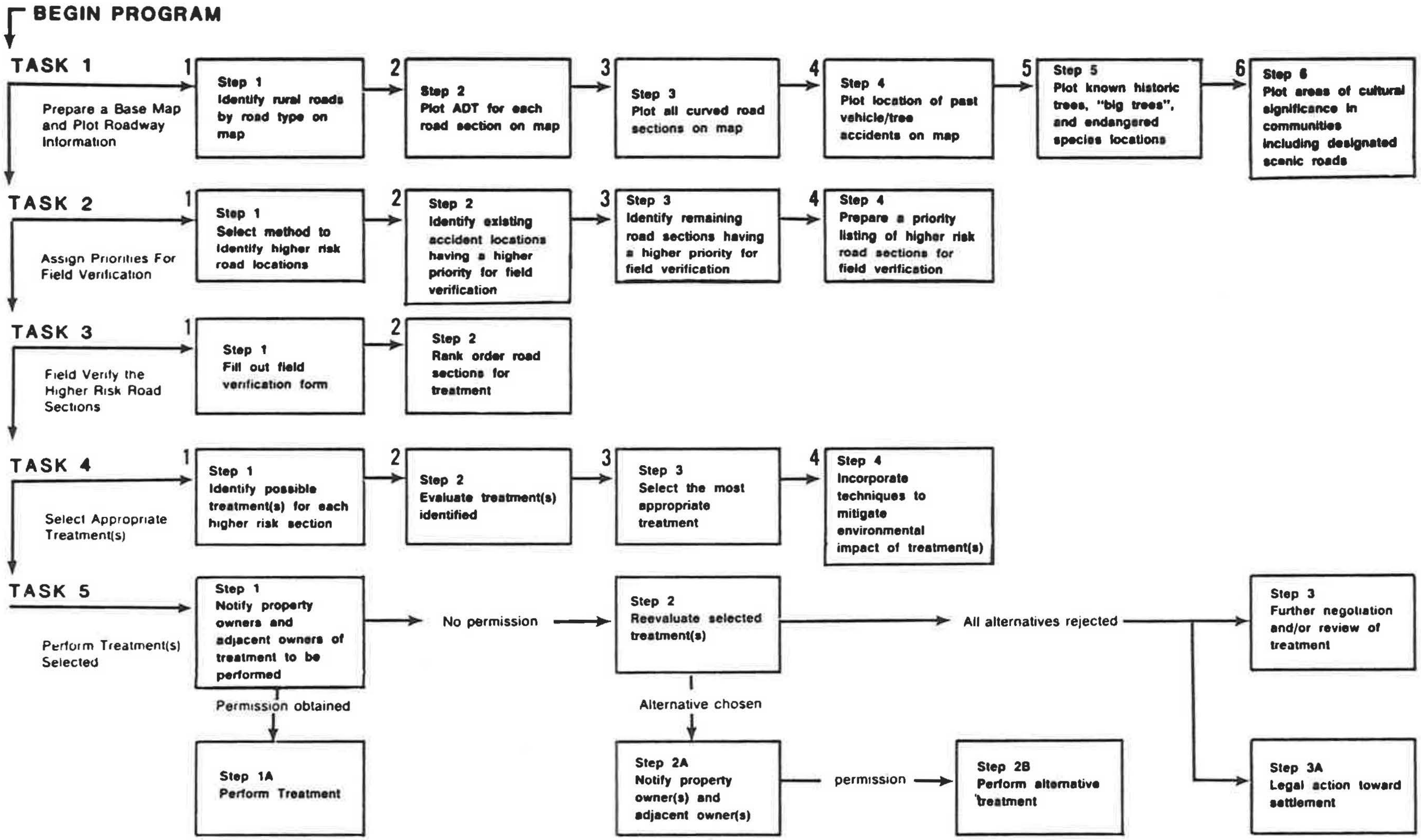

FIGURE 4 Method for evaluating higher-risk roadside environments.

Task 3: Field Verify High-Risk Road Sections

Using the priority listing established in Task 2, high-risk road sections should be field reviewed first. This provides a more cost-effective approach to confirm or eliminate potential road sections for treatment. It avoids a random approach of both field review and treatment.

A field verification form is filled out for each road section location identifying the location and recording all the pertinent safety, environmental, and other considerations that may have a bearing on the treatment to be selected. This may include discussion with the adjacent property owners concerning the location.

Task 4: Select Appropriate Treatments

Alternative treatments for each of the higher-risk road sections are next selected. This involves a review of the field verification forms and listing of higher-risk road sections to determine or confirm appropriate treatments. The treatments selected should be based on a simplified benefit/cost analysis of the alternatives considered for the sites.

Roadway and roadside treatments that may be considered to reduce the risk of vehicle-tree accidents include

- Pavement marking
- Installing delineators and advance warning signs
- Installing advisory speed signs
- Designating special-purpose roads
- Superelevating or modifying road cross-slope
- Widening and paving shoulders
- Removing trees
- Installing guardrails
- Regrading ditch sections
- Making slope alterations
- Using protective plantings
- Relocating or realigning road

The feasibility and effectiveness of any treatment, including tree removal, will depend on specific applications and whether treatments are used in combination or individually.

Alternatives that improve the design characteristics of the road should be investigated first. Such treatments as pavement marking, superelevation correction, and shoulder paving make it easier for motorists to stay on the road.

Improvements that should be considered next are those that involve the roadside. From a safety standpoint, the most effective treatment may be tree removal. This is generally the least costly and the simplest to accomplish. However, as will be discussed shortly, tree removal is sometimes not an appropriate treatment because of a number of environmental constraints.

Other treatments such as guardrails, ditch regrading, and slope alterations also provide a more forgiving roadside for motorists who inadvertently leave the road. These need to be considered as well and may provide suitable alternatives to tree removal. Combinations of alternatives that both improve the design characteristics of the road and create a more forgiving roadside would provide the most complete improvement.

When the appropriate treatment to alleviate the risk of run-off-road accidents is selected, it is important to keep in mind that the interaction of the driver, the vehicle, and the roadway is a complex relationship. Therefore, combinations of treatments, rather than one treatment used exclusively, are more likely to alleviate the risk of vehicle-tree accidents.

Environmental factors also need to be considered in the selection of treatment to reduce risk *(1,8,9)*. Following the consideration or application of various alternatives, it may then be appropriate to consider tree removal, grading and slope changes, and so on. If tree removal is an appropriate alternative to reduce the risk, certain environmental factors need to be considered before a final decision is made or action is taken. These considerations should include issues associated with ownership, endangered or threatened species and unique habitats, tree species size, historic vegetation, erosion and sedimentation, safety, and mitigation of environmental impacts. These factors are not to be taken lightly and may represent the most significant hurdle before any safety or maintenance program can be carried out.

Task 5: Perform Treatment or Treatments Selected

The last task involves contacting property owners and adjacent owners, securing property owners' permission to perform the selected treatment, and performing the treatment. This is particularly important in locations adjacent to residences, nature areas, plant preserves, parks or landscaped areas, and designated scenic roads.

This should be done not only to promote good public relations, but also to facilitate implementation of maintenance programs by helping to identify or avoid environmentally sensitive or controversial locations.

MAINTENANCE

Continued maintenance of cleared or treated higher-risk roadsides cannot be overemphasized. Maintenance of these higher-risk roadsides as clear zones is necessary to avoid future safety problems and an increase in vehicle-tree accident risk as vegetation naturally reestablishes itself along the roadside. Without a maintenance program, a much more costly tree-removal or treatment program, or both, would again have to be implemented. Brush and tree maintenance programs developed from this guide should be integrated into the responsible department's overall maintenance program.

CONCLUSIONS

It is expected that there will continue to be issues of safety versus environment and liability associated with roadside trees. These are serious issues and cannot easily be solved.

The vehicle-tree accident problem exists predominantly along curved rural local road sections. With limited resources available to improve roadside safety, it becomes important to focus these resources on a priority-risk basis. Treatment must take into account both safety and environmental issues for effective management of roadside trees.

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