Three Planting and Clearing Guidance with Consideration of Minimized Crash Risk

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This basic design philosophy has guided roadside designers for nearly 40 years and is the basis for all editions of AASHTO’s Roadside Design Guide (RDG) through the edition published in 2011 (4). Improvement projects along highways and streets are increasingly introducing landscape elements to add aesthetic appeal to the project. These landscape elements may include trees, shrubs, bushes, and other plantings; rocks and boulders; decorative walls; art work; signs or markers. Although it is effective for improving aesthetics, the introduction of trees and roadside elements places objects on the roadside that may conflict with collision zone design concepts and increase the risk of fatal and incapacitating crashes. Without specific engineering guidance, these placement issues frequently become divisive and political. Unfortunately, decisions are often made to include or exclude items without adequate knowledge of where, how, or how they can be incorporated into the design without introducing inappropriate levels of risk.

The concept of providing a forgiving roadside first emerged in the 1960s (7) and started to become regularly incorporated into highway designs in the 1970s, resulting in the 1974 AASHO Highway Design and Operational Practices Related to Highway Safety (i.e., the Yellow Book) (2) and the 1977 AASHTO Guide for Selecting Landscape Elements Along Highways (i.e., the Barrier Guide) (3). The 1974 Yellow Book was the first to formalize the forgiving roadside approach to roadside design. In forgiving roadside approach, designers are given the following priorities for designing the roadside:

1. Remove the obstacle.
2. Make the obstacle traversable.
3. Relocate the obstacle to a point where it is less likely to be struck.
4. Use breakaway devices to reduce the severity of striking the obstacle.
5. Shield the obstacle.
6. Delimitate the obstacle.

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Acceptable Risk Target

Single-vehicle tree crash data for Maine were collected from 1998 to 2006 and the crash severity distribution was determined. Maine has 22,882 miles of roadway, or about 50,000 edge miles of road (9). Table 2 provides the severity distribution of crashes with trees, tree crashes per year, and tree crashes per year per edge mile for each level of injury severity. Over the 20 years between 1989 and 2008, drivers in Maine experienced 0.906 fatal + 0.0026 incapacitating = 0.933 K-A crashes per edge mile per year on average. This existing risk of K-A crashes provides a benchmark against which improvements can be measured. For example, if an improvement project was suggested in Maine where the tree crash risk would increase from the current statewide level, more fatal and incapacitating crashes with trees would be expected as a result of that project. Conversely, if a project was suggested in which some trees remain in place but the risk of fatal and incapacitating crashes with trees is below the current statewide average, fewer crashes would be expected as a result of that project.

The cumulative binomial distribution function can be used to determine the probability of a crashes occurring for any tree location alternative. The analysis requires knowledge of the independent trials (o, i.e., vehicle encroachments) and possible variations in the tree locations that will affect the number of crashes (x) with a tree that has an EPCCR value above the thresholds established in Table 1. The established risk goals provide the benchmark used to determine when a tree has an unacceptable risk. These goals are used here for demonstration purposes. Each jurisdiction should determine its existing risk and establish its own goals.

Example of Tree Risk Analyses

The probability of a tree being struck was considered for a variety of placement alternatives using the RSAAPV3 (5). Figure 2 plots the existing risk of 0.0051 by tree line (i.e., continuous line of trees) at the range of offset from 0 to 30 ft from the travelway for a 55-mph divided highway. Trees were only considered on the roadside, not within the median, for this analysis. Any offset and encroachment combination that falls below the risk boundary line will have a risk below the current risk of K-A tree crashes in Maine. Any point that plots above the boundary exceeds the current risk.

Conversely, the undivided highway analysis considered two tree offsets from the roadway, as shown in Figure 3, and varied the spacing of individual trees from 20 to 200 ft in 20-ft increments (i.e., 20, 40, 60, ..., 200 ft). This analysis culminated in the two-part figure where the boundaries for existing risk of 0.0011 have been plotted in Figure 4. This figure is applicable to any 45-mph undivided highway. The spacing and encroachment combination that falls below the risk boundary line will have a risk below the current risk of K-A tree crashes in Maine. The spacing and encroachment combination that plots above the boundary will exceed the current risk. A less choppy chart could be achieved by more analyses of smaller tree-spacing increments.

TABLE 2 Maine Tree Crash Severity Levels, 1998–2006

<table>
<thead>
<tr>
<th>Severity Level</th>
<th>Number of Crashes</th>
<th>Number of Crashes/FY</th>
<th>Crashes/FY/Mile Edge Mile</th>
</tr>
</thead>
<tbody>
<tr>
<td>K</td>
<td>532</td>
<td>28.65</td>
<td>0.026</td>
</tr>
<tr>
<td>A</td>
<td>2,555</td>
<td>127.65</td>
<td>0.0026</td>
</tr>
<tr>
<td>B</td>
<td>9,254</td>
<td>462.70</td>
<td>0.0095</td>
</tr>
<tr>
<td>C</td>
<td>8,371</td>
<td>418.55</td>
<td>0.0084</td>
</tr>
<tr>
<td>O</td>
<td>25,837</td>
<td>1,291.85</td>
<td>0.0238</td>
</tr>
</tbody>
</table>

FIGURE 3 Tree location alternatives: (a) between road and side walk and (b) behind sidewalk. (b) = risk boundary line.

An example is a project that is considering planting trees on both sides of an undivided 45-mph roadway with spacing of 100 ft along the roadway. The traffic volume at this location is 5,000 vehicles/day and the road has a 5% horizontal curve and a 2% grade. The analyst would consult Figure 5 for annual average daily traffic of 5,000 vehicles/day and follow the line to where it intersects the curve representing encroachments on undevided roadways.

Figure 5 provides the estimate of the number of encroachments at this traffic volume if the road were straight and flat. There would be 1.3 encroachments/km/year expected for a traffic volume of 5,000 vehicles/day. The geometric characteristics of the roadway will affect the encroachments and should be accounted for in the risk analysis. There are many encroachment adjustment factors in the literature to account for roadway geometry. Many of these adjustment factors were summarized by Roy et al. in NCHRP 22-27 (5).

An encroachment adjustment for longitudinal curvature and vertical grade is shown for demonstration purposes in Figure 6. In the figure, positive values represent right-curving curves in the direction of travel.
To maintain a risk ≤ 0.003 for a K-A injury, the tree line should be at least 12 ft from the roadway on the increasing milepost right edge and at least 18 ft from the roadway on the decreasing milepost right edge.

CONCLUSION

Crash data and mileage logs were reviewed to determine that the current risk of fatal and incapacitating injury tree crashes in Maine is 0.0031. The RSA/PV risk process was used to generate the K-A risk associated with tree spacing and typical offsets. Risk boundaries were plotted to generate generic figures that can be used by decision makers to determine whether the tree-planting options being considered for any project are above or below the current average statewide tree crash risk. This methodology can be expanded to any jurisdiction by using tools that are currently available. As such, the procedure would follow the same steps:

1. Determine the current risk of fatal and incapacitating injury tree crashes by edge mile for the jurisdiction.

2. Simulate the risk of K-A crashes across the range of current planting and offsets typical in the jurisdiction using the RSA/PV risk analysis module or other tools available for 1-mi segments of road.

3. Plot the distributions of crashes and offsets exceeding the current risk (or set a goal) rather than the current risk.

4. Use the plots generated in Step 3 with Figures 5 through 7 of other encroachment adjustment factors that are available in the literature.

The primary advantage of this approach is that it allows departments of transportation to assess the risk (positive by tree locations against the tree jurisdictional risk. Implementation of this type of approach will necessitate identifying typical roadway designs and tree offsets for analysis and inclusion in a series of figures. Implementation of this approach provides a scientific method that quantifies the crash risk of trees and ensures that risk is explicitly considered.

REFERENCES


