Managing Risk in the Urban Forest

Part 2: Tree Risk Assessment

By Nelda Matheny and Jim Clark

This article is second in a series of four on the topic of risk management. The articles are adapted from ISA's upcoming Municipal Arborist Certification Study Guide.

CEU LEARNING OBJECTIVES

The arborist will be able to

- describe why it is important for arborists to perform tree risk assessments.
- identify the three major components of tree risk assessments.
- learn what field procedures and documentation are helpful in performing risk assessments.
- identify key defects that are commonly associated with tree failures.

Risk Versus Hazard

In the past, arborists and foresters have used the term *hazard assessment* to describe the process of inspecting and evaluating the structural condition of trees. In recent years, there has been concern that the term *hazard* has unnecessarily negative connotations. The trend now is to identify the process as tree *risk assessment*. So, what is the distinction between tree *risk* and *hazard*?

Risk: The potential for injury or damage due to tree failure.

Risk assessment: The process of evaluating the likelihood that a tree or tree part will fail and cause injury or damage.

Hazard: The presence of a condition that is likely to cause injury. In a risk assessment, a tree is hazardous when the potential for injury or damage due to tree failure exceeds a threshold that is defined by the tree owner or managing agency.

The first article in this series (April 2007 issue) discussed the general principles of risk management; communicating risk to clients, owners, and the public; and developing a risk management plan and policy. This article addresses tree failure risk assessments. The third article in this series will discuss risk rating systems, and the final installment will cover potential problems with tree litter and root conflicts with pavement and infrastructure.

Wherever trees are near people and property, the risk of damage or injury exists. Any tree, whether it has observable defects or not, will fail if forces are applied that exceed the material strength of the wood. Hurricane-force winds, for instance, can break defect-free branches. For this reason, it is impossible to maintain trees free of risk. Some level of risk must be accepted to experience the benefits trees provide. Fortunately, tree failure is a relatively infrequent occurrence.

Arborists have a duty to inspect and manage trees in a reasonable manner. It is unreasonable to expect that every tree will be managed in such a way as to eliminate any risk. Rather, a reasonable expectation is to take appropriate action to reduce risks that can be identified and that pose the greatest potential for harm. Actions are always limited by the resources of the managing agency or owner.

Trees cannot be neatly separated into hazardous and nonhazardous groups. We can, however, evaluate the structural condition of trees and convey the relative risk of failure to tree owners (see sidebar above). Together, the arborist and owner can determine which treatment options will reduce risk to an acceptable level.

Defining Tree Risk Assessment

Tree risk assessment is the systematic process of evaluating the potential for a tree or one of its parts to fail and, in so doing, injure people or damage property (see sidebar, next page). Most tree failures involve a combination of structural defects, such as the presence of decay or included bark at a branch attachment, and unusual or severe weather, such as strong winds and snow or ice loads.

The degree of risk will vary with the size of the tree or tree part, type and location of the defect, tree type, weather and site conditions, and the nature of the target. A tree in an area with no target poses no risk because nothing would be injured or lost if failure occurred (the only costs might be for cleanup). At the opposite end of the scale, a tree on the verge of structural collapse that is located at a busy

Three components of tree risk assessment:

- inspecting the tree and evaluating the tree's potential to fail
- considering the contribution of site conditions and weather to failure
- determining the likelihood that a person or object (that is, the target) would be injured or damaged by the failure

intersection or over a house or utility conductor poses a high risk. Most trees are somewhere between these two extremes.

Developing a Tree Risk Assessment Program

Developing a tree risk assessment program requires considerable planning before going into the field. Questions to answer and decisions to make include the following:

- When and how often will trees be inspected?
- Who will perform the inspections and how will they be trained?
- How will information be recorded?
- What procedures will be followed?
- In large populations of trees, which trees will be inspected (for example, only those with targets)?
- Will a risk-rating system be employed?

As discussed in the first article, the arborist should find the answers to most of these questions in the risk management policy and standard of care statement. If no such documents exist, the arborist should work with the client to determine the preferred procedures. The arborist may help the owner, agency, or managers create policy statements that frame the tree risk assessment program. Commercial and consulting arborists who work for many clients can define their own standards for risk assessments in an internal standard of care statement.

All arborists must consider the budget and staff realistically when designing a tree risk assessment program. It does no good to design a program that the owner or manager cannot implement because of insufficient funding or staffing.

Timing of Inspections

Because site character and tree development change over time, risk assessments must occur on a regular basis. Ideally, the evaluation cycle, or inspection interval, should be every one to two years, although some agencies, due to budget constraints, inspect on a five-year cycle.

Timing the inspection to a specific season can aid the assessment (Figure 1). For instance, deciduous trees are more easily assessed in the winter than in the summer when in full leaf. If a particular decay fungus produces annual conks at specific times of the year, identification of that decay will be easier if the inspection is scheduled to correspond with the conk emergence.

The inspector will see the tree in different seasons if intervals are uneven, perhaps in 8- or 16-month cycles. For the utility arborist, assessments can be combined with periodic inspection for clearance. The commercial arborist can inspect while monitoring for a Plant Health Care program.

Who Is Qualified?

The selection of the individual to perform the evaluation may be the most significant decision of all. As discussed in the first article, arborists with responsibility for tree risk assessments must be knowledgeable about tree biology, patterns of failure, site conditions analysis, and related topics. This knowledge comes only with experience and specialized training.

Documentation

Because tree risk assessment is a process that considers a wide range of information, the arborist needs a systematic method for recording observations and measurements. There are several ways to record observations: handwritten notes, specially designed forms, and handheld electronic devices.

The type of information to record includes date of inspection, tree species, size, location, description of defects present, targets, and site conditions that could contribute to failure. While the arborist should observe and assess characteristics of the root collar, trunk and branches, and site, how much of that information to record may vary depending on the client's needs and project scope.

Figure 1. Timing is everything. (a) Deciduous trees are more easily inspected in the winter than in the summer. (b) Sulfur fungus (*Laetiporous* spp.) conks are present for a few months during the year. Inspections should be timed accordingly when the fungus contributes to tree failure.

Performing a Tree Risk Assessment

It is not yet possible to quantify the risk of failure ►

Figure 2. The standard for evaluating defects in trees is a visual inspection from a ground survey.

associated with trees. We lack the quantitative data necessary to develop such statistics. The standard for evaluating risk of tree failure is the application of the arborist's experience and training to evaluate in an objective manner the structural condition of the tree, the site in which it grows, and weather conditions to which it is exposed. The inspection is qualitative, performed as the inspector observes conditions and characteristics 360 degrees around the tree (Figure 2).

One outcome of the inspection may be to recommend further inspection of specific parts of a tree. Additional inspections may be warranted when the arborist needs more information to assess the risks to high-value targets. Examples are decay testing, root collar excavation, and aerial inspection of the crown. Several tools and devices are available to assist the arborist in those inspections. Examples are the Resistograph, PICUS, and TreeRadar for decay evaluation, and the Elastometer and Inclinometer to measure movement in Statics Integrated Method pull tests. While use of these tools can provide more information about defects, determining their significance to tree failure remains the judgment of a qualified assessor. Because these additional inspections are time consuming to perform, the equipment is relatively expensive, and specialized skill is needed, additional inspections are employed only as needed.

Species Failure Profiles

For most species and sites, there are recurring patterns of tree failure (Figure 3). In some species, branch failure occurs more frequently than either root or trunk failure. Specific structural defects, such as decay or weak branch attachments, may be more commonly associated with failure for a species (see sidebar, next page). Environmental conditions, such as wind and site disturbance, may or may not be significant contributing factors.

Species failure profiles consider the following information:

- type of failure (root, trunk, branch) and relative frequency
- typical growth patterns associated with each (for example, poorly tapered limbs, multiple branch attachments)
- structural defects
- environmental conditions associated with failure
- management factors associated with failure (for example, excessive pruning and irrigation)

Arborists need to know about the growth and failure patterns of individual species when performing risk assessments. Species failure patterns are observed from looking at how trees fail. Arborists' observations of tree failures are being catalogued in the International Tree Failure Database.

Species failure patterns provide clues for assessing likely failures within the inspection period. The arborist must keep in mind, however, that specific defects in individual trees can result in "nontypical" failures. The evaluator must consider all defects present, not just those that are most common for the species.

Inspection Procedures

When assessing trees, the arborist should work in a systematic manner to ensure that all trees within the designated area are inspected thoroughly. Perhaps the most important aspect of training is to develop consistent evaluation procedures, among inspectors and over time.

Figure 3. Italian stone pine (*Pinus pinea*) is a round-headed tree that tends to develop multiple trunks and heavy lateral branches. (a) In California, where trees are planted from containers, circling roots are commonly associated with tree failure (b).

Species Failure Profile

Arborists can improve their ability to assess the potential for tree failure by studying failed trees, much like doctors learn about the human body by performing autopsies after death. What we have learned is that there are common themes in how trees of the same species fail.

Species failure profiles describe how, where, and when trees of a given species commonly fail. Arborists can develop species failure profiles for the species common to their region based on their and other arborists' experience, and from the International Tree Failure Database (ITFD). The ITFD is a web-based collection, operated by the U.S. Forest Service, of tree failure records submitted by trained cooperators. The Web site can be accessed at http://ftcweb.fs.fed.us/natfdb.

Following is a species failure profile for Italian stone pine (*Pinus pinea*). It was developed from 104 records of tree failures reported by trained cooperators to the California Tree Failure Report Program (now merged into the ITFD).

Average tree in dataset

41 years old (> 50% between 26 and 50 years)
31 inches (78.7 cm) in diameter
45 feet (13.7 m) tall; 43-foot (13.1 m) spread

Location of failure

Trunk—32%, most often at ground level or below 5 feet (1.5 m)
Root—39%
Branch—30%, most often at attachment

Most common defects associated with failure (> 10%)

Multiple trunks/codominant stems
Dense crown
Heavy lateral limbs
Kinked/girdling roots
Decay present in 22% of failures

Weather at time of failure

Wind speed
<5 mph (8 km/h)—37%
5–25 mph (8–40.2 km/h)—29%
>25 mph (40.2 km/h)—35%
More root failures with precipitation
Trunk failure most frequent with no wind
Branch failure most frequent with wind 5–25 mph (8–40.2 km/h)

Following is an example of typical tree inspection procedures:

1. Tag each tree and map its location (if there are many trees).
2. Describe tree type and condition.
3. Describe the site conditions as they relate to the tree.
4. Describe the target(s) associated with the tree.
5. Going around the tree, describe all significant tree defects, beginning at the root crown and working upward.
6. Determine whether additional evaluation is needed, such as root crown inspection and/or aerial inspection by a climber.
7. Determine treatments, if any, to reduce potential for failure, including those requiring immediate action.
8. Record results of assessment and recommendations.
9. Proceed to next tree.

Evaluating Structural Stability

Examination of the entire tree structure for defects begins with a visual assessment of overall vitality. Then it focuses on an examination of the root collar (to the extent it is visible), trunk, scaffold limbs, and branches. Some key characteristics to look for are illustrated in Figure 4.

If the inspector identifies a tree in imminent danger of failing, immediate action must be taken. This includes informing appropriate personnel, restricting access to the target area, and implementing abatement treatments (pruning, removal, moving the target, etc.) as soon as possible.

Some structural defects are more critical and significant than others. Ranking the problem as low, moderate, or high severity will help discern the significance. Furthermore, seemingly small defects can become worrisome when other aggravating or contributing factors are present. For instance, multiple branch attachments in a small tree may not be of great concern. In a large tree, however, with branches that have narrow angles of attachment with included bark and heavy ends, the defect becomes much more significant. Similarly, a tall tree with little trunk taper in a forest stand is less likely to fail than a similar tree recently exposed to wind when adjacent trees are cleared for construction.

Evaluating Site Conditions

Site factors have a significant influence on the potential for tree failure. Most failures occur during storm events with unusual winds, saturated soils, or snow and ice loads. Knowledge of regional and local climate, soils, and topography is critical in assessing failure potential. Site factors to consider include the following:

- general climate and seasonal precipitation patterns
- site management history
- soil and drainage conditions
- history of failure of other trees in the area
- site changes (root injury, grade changes, recent exposure)
- obstructions to tree development (pavement, utilities, structures)

Evaluating Targets

The safety of potential targets is the major reason for a tree risk management program. Two components of a target are use and occupancy.

Use describes the activity associated with the area, such as parking, buildings, and recreation. The chance that a tree failure will strike a target increases as occupancy of a site increases. Risk is greater for targets that are in constant use than for targets that are infrequently occupied. For example, houses are ranked higher than garages because the potential loss is greater. Electrical conductors such as

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Figure 4. Tree characteristics that may be associated with tree failure:

a. **Unusual storm event** with strong wind, rain, snow, or sleet. Even defect-free trees can fail under these conditions.

b. **Weak branch attachment.** Attachments of stems of similar size or those with included bark are more likely to fail than attachments in which the branch is smaller than the stem and there is no included bark.

c. **Decay.** Loss of structural strength due to decay can lead to failure.

d. **Excessive end weight.** This problem can be created by poor pruning such as excessive crown raising or lion tailing. Potential for failure is increased by wind and poor branch/trunk taper. Branches separated from the canopy are one indicator.

e. **Excessive structural root loss.** When structural roots are damaged, die, or are deformed by kinks or circling, trees are more prone to failure, especially in wind.

f. **Lean.** Leaning trees are more likely to fail than upright trees, especially when soil is wet.

g. **Dead branches.** For most species, dead wood decays quickly, becoming prone to failure.

h. **Crown decline.** Declining trees often have diseased or compromised root systems that make them prone to failure.

power lines are stationary, constant targets. When evaluating them, consider the consequences of damage such as power outages, electrocution, or fire.

Occupancy considers how frequently and intensely the location is used. Target occupancy can be viewed as either mobile or stationary, and long term or short term. Targets

Inspection Before and During Tree Care Operations

Arborists must consider the safety of coworkers, employees, and subcontractors as well as their own. Inspecting the tree before working on it is one of the keys. Arborists must assess the tree's ability to support their weight and the stresses of rigging. Put another way, the arborist must answer the question, "Is this tree going to fall over while I'm in it?"

In the United States, the American National Standards Institute (ANSI) Z133.1 standard defines the safety requirements associated with tree care operations. In the United Kingdom, the Arboricultural Association's *Guide to Good Climbing Practice* describes safety requirements. Both these standards mandate a pre-climbing inspection and that the climber continue the inspection while in the tree.

How does the arborist go about making the assessment? Dead trees and limbs present the most obvious concern, along with a lack of basal flare and buttress roots. The root collar must be assessed, even if soil, weeds, or other material must be cleared from the base of the trunk. Higher in the tree, cracks, cavities (with and without wildlife), hangers, and other defects may not be visible from the ground but obvious to a climber.

Is the pre-climbing inspection the same as a risk assessment? Certainly. The tree inspection also assesses structural stability, but the pre-climbing inspection focuses on climber safety while at work. Potential impacts to all possible targets and the effects of weather and site conditions over a period of time (as determined by the inspection cycle) are not part of a pre-climbing inspection.

that are stationary and long term have higher risk of damage should tree failure occur than those that are mobile and short term. Although there may be no targets present at the time of inspection, site use and occupancy at different times of the day or season should be considered.

In some cases, risk can be effectively reduced by moving a mobile target, such as a picnic table. Excluding use beneath a tree also will reduce the risk associated with possible failure, although it may be necessary to erect barriers to restrict access.

Risk Abatement Treatments

Abatement treatments are those that, when applied, reduce the risk for tree failure and damage. In most cases, the arborist identifies at the time of assessment what action or actions could be taken to reduce the risk. Possible actions include the following (also see Table 1):

- prune to remove or reduce weight on parts likely to fail
- cable, brace, or prop to provide support for weak areas
- remove tree (and replace where appropriate)
- modify site to improve conditions for tree (for example, provide drainage to reduce failure in wind)
- eliminate or restrict use within tree fall zone
- inspect further to better assess potential for failure (for example, decay testing, aerial inspection, root collar excavation)

Following an inspection, the arborist might determine, for example, that pruning the tree would reduce the risk

Table 1. Abatement options for specific tree defects.

For this type of defect	*Consider this action*
Trunk or root decay	With low to moderate decay, prune to reduce the weight and extension of the crown, to reduce the stress placed on the weak area. Where decay is extensive, removal may be reasonable. Cabling typically will not abate this defect. Propping may be feasible if the tree is leaning strongly.
Branch crack or decay	For low to moderate decay, prune to reduce the weight and extension of the branch. Where damage is extensive, cable into solid wood or remove the branch. Cabling in decayed wood is not advised.
Horizontal branch with poor taper and excessive end weight	The first choice is to prune to reduce the weight and extension of the branch. If pruning is inadequate to reduce stress on the branch, propping or cabling could be considered for high-value trees.
Poorly tapered trunk with high height:diameter ratio and low live crown ratio, recently exposed	Remove the tree or move the target. Thinning will seldom abate this condition. Over time, vigorous trees will develop taper and branching suitable for edge conditions, and risk will decrease.
Leaning tree	Where top has grown vertically (self-correcting), no treatment may be needed. For moderate leans, prune to reduce weight and extension. For recent leans with mounded or cracked soil behind the lean, removal usually is warranted. For high-value trees, propping or guying could be coupled with pruning to reduce weight and extension.
Weak branch attachment due to included bark	Prune to reduce weight on weakly attached branches, subordinate one of the stems, or remove one of the stems. Consider installing a cable/brace system.
Previously topped tree with regrowth weakly attached	Prune to reduce weight and extension of regrowth. Subordinate and thin to provide spacing, retaining shoots with the best attachments.
Roots severed near trunk	Prune to reduce weight and extension in crown (crown reduction). If root loss is significant and tree is exposed to strong winds, consider removal.
Dead branches and/or hangers	Prune to clean the crown.

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to a moderate level, and cabling would reduce it more. The arborist and tree owner should discuss potential treatments and identify the preferred option. The owner must balance his or her tolerance for risk with the tree's benefits Given those options, the owner decides which is preferable given the costs, the benefits, and the acceptable level of risk. The only treatment that will eliminate individual tree risk is removing the tree, roots and all, or eliminating the targets, because even after abatement, unusual storm events could result in tree failure.

If further inspections are needed to assess the tree's structural condition and evaluate failure potential, the arborist may defer abatement recommendations until those procedures are completed. If the tree owner or manager is unwilling to fund further inspection, the arborist must make the best recommendations possible from the visual assessment.

Key Ideas About Risk Assessment

- The primary goal in risk assessment is safety. Arborists are not omniscient nor do their clients have unlimited funds. However, arborists and owners can reduce future injuries by inspecting trees and taking action in a reasonable manner to reduce risk.
- There are three components to tree risk assessment: (1) inspecting the tree and evaluating the tree's potential to fail; (2) considering the contribution of site conditions and weather to failure; and (3) determining the likelihood that a person or object (the target) would be injured or damaged by the failure.
- The standard for evaluating risk for tree failure is the application of the arborist's experience and training to evaluate the structural condition of the tree, the site in which it grows, and weather conditions to which it is exposed. The basic inspection is visual, performed as the inspector walks around the tree.
- One outcome of the assessment may be that the arborist needs additional information to assess tree stability and recommend action. Examples are decay test, root collar excavation, or aerial inspection by a climber.
- Once the arborist assesses the risk, action should be taken, if needed, to reduce the risk to a level acceptable to the owner and/or manager.
- Do not miss the forest for the trees. Risk assessments may be only one factor in determining action. For instance, tree removal may be the preferred action because of tree health, potential longevity, or placement in the landscape, even if not required specifically to reduce risk.

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Photos courtesy of the authors.

CEU TEST QUESTIONS

To receive continuing education unit (CEU) credit (1.0 CEU) for home study of this article, after you have read it, darken the appropriate circles on the answer form of the insert card in this issue of *Arborist News*. (A photocopy of the answer form is ***not*** acceptable.) A passing score for this test is 16 correct answers.

Next, complete the registration information, ***including your certification number***, on the answer form and send it to ISA, P.O. Box 3129, Champaign, IL 61826-3129. Answer forms for this test, **Managing Risk in the Urban Forest, Part 2: Tree Risk Assessment**, may be sent for the next 12 months.

You will be notified only if you do not pass. If you do not pass, ISA gives you the option of re-taking the quiz until you do achieve a passing score.

1. Any tree will fail if
   a. structural defects are severe
   b. the risk rating is 9 or greater
   c. defects are not abated
   d. forces exceed wood strength
2. A tree is hazardous if or when
   a. it has more than one aggravating defect
   b. the target, appraisal, and size ratings are high
   c. damage potential exceeds a threshold
   d. removal is the most reasonable option
3. Most tree failures involve a combination of
   a. included bark and wet soils
   b. root rot and sandy soils
   c. a lack of pruning and other arboricultural treatments
   d. structural defects and severe weather
4. Tree risk assessment involves
   a. evaluating the tree's potential to fail
   b. considering site conditions and weather
   c. determining the likelihood of damage
   d. all of the above
5. The degree of risk will vary with
   a. the size and species of the tree or tree part
   b. type, severity, and location of the defect
   c. weather and site conditions, and the target
   d. all of the above
6. Tree risk assessments must be done regularly because
   a. arboriculture must be a growth industry
   b. budget and staff considerations demand it
   c. tree defects always get worse over time
   d. site character and tree development change
7. The evaluation cycle, or inspection interval, should be
   a. every one to two years
   b. two to five years
   c. evenly spaced for budgeting and staffing
   d. staggered to occur in different seasons

8. Tree risk assessors must be knowledgeable about
   a. tree biology and patterns of failure
   b. site analysis and expert witness reports
   c. tree physiology and meteorology
   d. all of the above
9. An effective way to record observations is
   a. handwritten notes
   b. specially designed forms
   c. handheld electronic devices
   d. all of the above
10. The risk of failure associated with trees can be
   a. quantified exactly
   b. abated partially
   c. eliminated totally
   d. all of the above
11. If advanced testing is not in the budget, the arborist must
   a. recommend options based on all the information
   b. recommend conserving the tree if it is valuable
   c. recommend removal, erring on the side of caution
   d. recommend crown cleaning branches 1 inch diameter or larger
12. The structure of deciduous trees is most easily assessed in
   a. summer
   b. fall
   c. winter
   d. spring
13. A tree in an area with no target poses ___ risk.
   a. no
   b. some
   c. great
   d. variable
14. The standard for evaluating risk of tree failure is the application of
   a. the arborist's experience and training
   b. the urban forester's university training
   c. the 12-point tree risk rating system
   d. pruning paint to prevent wilt infection
15. Advanced decay-testing tools and devices include
   a. rubber hammer, tile probe, and tape measure
   b. Resistograph, PICUS, and TreeRadar
   c. Resistograph, tile probe, and rubber hammer
   d. Resistograph, PICUS, and GPS
16. Observations of tree failures are being catalogued in the
   a. National Tree Failure Database
   b. International Tree Failure Database
   c. International Tree Risk Catalog
   d. National Tree Risk Catalog
17. The most important aspect of training is to
   a. develop formal evaluation procedures
   b. develop painstaking evaluation procedures
   c. develop consistent evaluation procedures
   d. all of the above
18. The major reason for a tree risk management program is
   a. elimination of liability concerns
   b. prioritizing arboricultural treatments
   c. the safety of potential targets
   d. all of the above
19. The two components of target evaluation are
   a. infrequent or constant occupancy
   b. people and vehicles
   c. use and occupancy
   d. economic and aesthetic value
20. Branches with weak attachments can be
   a. pruned to reduce weight and extension
   b. subordinated or removed
   c. supported with a cable/brace system
   d. all of the above