CONTINUING EDUCATION UNIT

Qualitative Tree Risk Assessment

By E. Thomas Smiley, Nelda Matheny, and Sharon Lilly

Editor's Note: The following article is the second in an extensive series of CEU items on tree risk assessment. Future articles will look at the various levels of assessment, mitigation, reporting, and factors that affect tree risk.

LEARNING OBJECTIVES

The arborist will be able to

- explain the differences between quantitative and qualitative tree risk assessment methods and discuss the advantages and limitations of each.
- describe the factors that must be considered in the categorization of risk.
- discuss the factors that affect likelihood of failure and those that affect likelihood of a tree failure impacting a target.
- explain how likelihood of failure and impact are combined with consequences of failure to yield a rating of risk.
- discuss how risk tolerance varies with individuals and what implication that can have on tree risk management.

CEUs for this article apply to Certified Arborist, Utility Specialist, Municipal Specialist, Tree/Worker Climber, and the BCMA management category.

Before a tree risk assessment takes place, it is important to establish the context of the assignment. Context defines the parameters of the risk assessment, including objectives, how risk will be evaluated, communication flow, applicable policies or legal requirements, and limitations of the risk assessment. The context will be one factor in deciding what method of tree risk assessment is appropriate. Tree risk assessment is the systematic process to identify, analyze, and evaluate tree risk. By its nature, tree risk assessment involves a significant amount of uncertainty that must be acknowledged and managed. Understanding the advantages and limitations of various approaches is important for selecting a method and properly applying it.

Approaches to Risk Assessment

The two primary approaches to risk assessment are *quantitative* and *qualitative*. Each has advantages and limitations, and each may be appropriate with different objectives, requirements, resources, and uncertainties. Both the quantitative and qualitative approaches are valid when applied properly and with reliable data and valid assumptions. With training and experience, reliability can be improved for each approach.

Quantitative Risk Assessment

Quantitative risk assessment estimates numeric values for the probability and consequences of events, and then produces a numeric value for the level of risk, typically using the formula:

Risk = Probability × Consequences

An advantage of quantitative assessment is that tree risk can be compared not only to other trees but also to other types of risk, as might be necessary for municipal decisions in which resources must be allocated among departments, for example. The calculations can vary from simple to complex because risks are analyzed independently or in combination. Even if complex statistical analyses are carried out, users must remember that the calculations are estimates and must ensure that the accuracy and precision are consistent with the data and methods employed. Our ability to quantify probability is often limited when applied to trees because they are natural structures, and we have little systematically collected data on which to base probabilities. Since numeric data are not always available and both systematic and statistical uncertainties can be high, full quantitative analysis is often not warranted or practical for tree risk assessment.

Qualitative Risk Assessment

Qualitative risk assessment is the process of using ratings of the likelihood and consequences of an event to determine a risk level and evaluate the level of risk against qualitative criteria. Often, ratings

Basic Definitions

There are a number of key definitions required for understanding tree risk assessment concepts. Here is a partial list of these definitions.

Risk is the combination of the likelihood of an event and the severity of the potential consequences.

In the context of trees, risk is the likelihood of a conflict or tree failure occurring and affecting a target; and the severity of the associated consequences—personal injury, property damage, or disruption of activities.

Tree risk assessment is the systematic process to identify, analyze, and evaluate tree risk.

Tree risk evaluation is the process of comparing the assessed risk against given risk criteria to determine the significance of the risk.

Risk is evaluated by categorizing or quantifying both the *likelihood* (probability) of occurrence and the *severity* of consequences. The magnitude of risk can be categorized or calculated and compared to the client's tolerances to determine if the risk is acceptable.

Targets (risk targets) are people, property, or activities that could be injured, damaged, or disrupted by a tree.

Failure (tree failure) is the breakage of stem, branches, roots, or loss of mechanical support in the root system.

Likelihood is the chance of an event occurring.

In the context of tree failures, the term likelihood is used in three places to specify: 1) the chance of a tree failure occurring, 2) the chance of impacting a specific target, and 3) the combination of the likelihood of a tree failing and the likelihood of impacting a specific target.

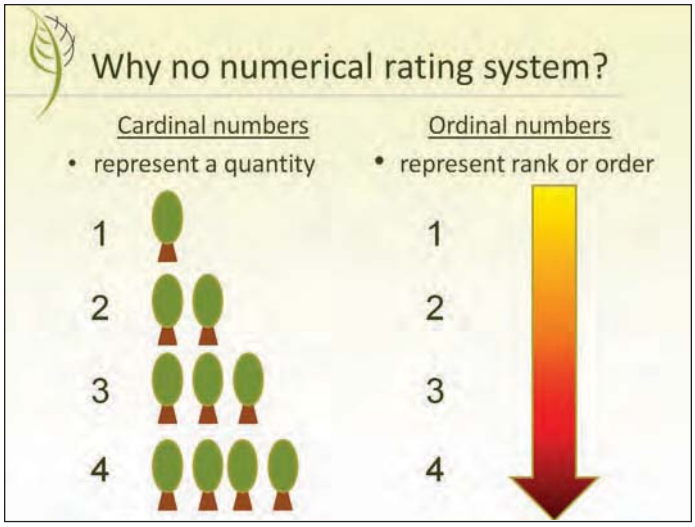
Consequences are the effects or outcome of an event.

In tree risk assessment, consequences include personal injury, property damage, or disruption of activities due to the event.

are combined in a matrix to categorize risk. Inherent subjectivity and ambiguity are limitations of the qualitative approach. In order to increase reliability and consistency of application, it is important to provide clear explanations of the terminology and significance of the ratings defined for likelihood, consequences, and risk. This approach is a recognized and respected method of risk assessment used internationally by many governments and businesses.

E. THOMAS SMILEY

Tree failures usually occur when there is a critical combination of tree defect(s), conditions, and contributing environmental factors.



NELDA MATHENY

Because ordinal numbers represent rank or order, they cannot be added or multiplied.

There are several qualitative numerical tree risk assessment systems in use throughout the world that assign numbers to certain factors to derive an estimate or ranking of relative risk. The rankings are sometimes used to prioritize work. The assigned numbers, which are actually categorizations and are not quantifiable, are either added or multiplied to develop an overall relative level of risk.

Risk professionals caution that addition or multiplication of ordinal numbers is mathematically incorrect. Some of these systems were designed to estimate level of risk for individual trees and others to prioritize work within a population of trees. If a qualitative numeric system is employed, it should be used only for the intended purpose and with an understanding of its limitations.

Assessment Appropriateness

The selected methodology of the risk assessment should be appropriate to the situation and should consider the goals and the resources

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available. With the context defined, the specific techniques should be selected based upon:

- the needs of the decision makers and the level of detail required
- the resources available and what is reasonable for the potential consequences
- the availability of information and data
- the expertise required

A matrix-based, qualitative approach to tree risk assessment has been selected for expanded explanation in this article, but quantitative assessments are not precluded from best management practices. Whichever technique is chosen, the users should recognize the limitations as well as the nature and degree of uncertainty in the data and information available.

Typically, there is a considerable level of uncertainty associated with tree risk assessment due to our limited ability to predict natural processes (e.g., rate of progression of decay, response growth), weather events, traffic and occupancy rates, and potential consequences of tree failure. Sources of uncertainty should be understood and communicated to the risk manager/tree owner.

Risk Categorization

Most tree risk assessment reports include a rating of risk posed by the tree. In a qualitative tree risk assessment, assessors can use a matrix to help categorize risk. The risk category is then compared to the level of risk that is acceptable to the client, controlling authority, or societal standards. If the risk category defined for the tree exceeds the level of acceptable risk, mitigation options should be presented.

The likelihood of a tree failure impacting a target and the consequences of the failure are the factors to consider when categorizing tree risk. The likelihood of a tree failure impacting a target is determined by considering two additional factors. First is the likelihood of a tree failure occurring within a specified period of time. The likelihood of tree failure is determined by examining structural conditions, defects, response growth, and anticipated loads. Second is the likelihood of the failed tree or branch impacting the specified target. Impact may be the tree directly striking the target, or it may be a disruption of activities due to the failure.

These two factors are evaluated and categorized using a matrix to estimate the likelihood of the combined event: a tree failure occurring, and the tree impacting the specified target. The likelihood of that combined event is then compared with the expected consequences of a failure impacting the target to determine a level of risk.

Likelihood of Failure

Judgment about the significance of defects, conditions, and response growth can be guided by the information available in various professional resources, as well as through species failure profiles, site conditions, and tree risk assessor experience. It is essential to consider all of the compounding factors, as well as any response growth in the tree, which may have compensated for the condition. Guidelines should be considered a starting point and should be modified as needed so that they are appropriate for the tree and site. Significant deviation from these guidelines or other standards that are used should be noted and presented in a detailed report.

When more than one defect or condition is present in a tree, the impact of the combination must be considered. Not all conditions and defects have a significant impact on tree structure. For example, a trunk lean of 10 degrees may not be of great concern on many trees, but if there is a large, decayed root on the side opposite the lean, then the likelihood of failure increases if significant loads are likely to occur and the tree did not compensate for the defect with adaptive growth. Assessing each condition with regard to its likelihood of failure or level of risk will help discern the significance of each condition relative to the entire tree.

Tree failures usually occur when there is a critical combination of tree defect(s), conditions, and contributing environmental factors, such as wind, rain, freezing rain, or snow. With the exception of sudden branch drop, calm-day tree failures are very rare and usually result from extreme defects. Most tree failures occur when wind speed exceeds the seasonal norm for the site.

In discussing likelihood of failure, a time period should be referenced to put the likelihood in context. Often, the time period is the inspection interval (the time recommended for the next inspection); however, some inspectors base all assessments on a one-year time interval. Either method is acceptable, as long as the time period is specified and is reasonable. This time period should not be considered a "guarantee period" for the risk assessment. The assessment states the conditions found at the time of the inspection, weather, and activities in and around the tree can have a significant impact on tree condition and the likelihood of failure.

The likelihood of failure can be categorized using the following guidelines:

Improbable—the tree or branch is not likely to fail during normal weather conditions and may not fail in many severe weather conditions within the specified time period.

Possible—failure could occur, but it is unlikely during normal weather conditions within the specified time period.

Probable—failure may be expected under normal weather conditions within the specified time period.

Imminent—failure has started or is most likely to occur in the near future, even if there is no significant wind or increased load. This

Response Growth

Response growth is new wood produced in response to damage or loads to compensate for higher strain (deformation) in marginal fibers. This includes reaction wood (compression and tension) and woundwood.

Properties that show the potential for, or presence of, response growth:

- Crown healthy, vigorous, good color, good growth, and few pests.
- Bark healthy and intact.
- Woundwood well developed around cuts, cracks, and openings.
- Local increases in wood growth near a structural defect—ribs and bulges.
- Enlargement in diameter in areas weakened by internal decay.
- Distinct demarcations between healthy and damaged tissue.
- Well developed, wide root flare.
- Corrected trunk lean.

is a rare occurrence for a risk assessor to encounter, and may require immediate action to protect people from harm.

Likelihood of Impacting a Target

The second factor to be considered is the likelihood of the failed part impacting the target. To estimate this likelihood, the arborist should attempt to determine the occupancy rate of any targets within the target zone, and any factors that could affect the failed tree as it falls toward the target.

Likelihood of impacting a target can be categorized using the following guidelines:

Very Low—the chance of the failed tree or branch impacting the specified target is remote. This is the case in a rarely used site that is fully exposed to the assessed tree, or an occasionally used site that is partially protected by trees or structures. Examples include a rarely used trail or trail head in a rural area, or an occasionally used area that has some protection against being struck by the tree failure due to the presence of other trees between the tree being assessed and the targets.

Low—it is not likely that the failed tree or branch will impact the target. This is the case in an occasionally used area that is fully exposed to the assessed tree, a frequently used area that is partially exposed to the assessed tree, or a constant target that is well protected from the assessed tree. Examples are a little-used service road next to the assessed tree, or a frequently used public street that has a street tree between the street and the assessed tree.

Medium—the failed tree or branch may or may not impact the target, with nearly equal likelihood. This is the case in a frequently used area that is fully exposed on one side to the assessed tree, or a constantly occupied area that is partially protected from the assessed tree. Examples include a suburban street next to the assessed street tree or a house that is partially protected from the assessed tree by an intermediate tree.

High—the failed tree or branch will most likely impact the target. This is the case when a fixed target is fully exposed to the assessed tree or near a high-use road or walkway with an adjacent street tree.

Categorizing Likelihood of a Tree Failure Impacting a Target

After determining the likelihood of failure and the likelihood of impacting a target, the combined likelihood of a failure impacting a target can be categorized. Table 1 can be used to guide the arborist in relating these likelihood factors within a given time period. The resulting terms (unlikely, somewhat likely, likely, and very likely) are defined by their use within the table and are used to represent this combination of occurrences in Table 2, the Risk Matrix.

An example of determining the likelihood of a failure impacting a target is as follows:

A large tree with a large, dead branch is growing next to a one-story house. The dead branch is on the side of the tree away from the house. The likelihood of a dead branch failure within the next year was classified by a tree risk assessor as "probable." The house is a static target with a "constant" occupancy rate. However, the likelihood of the branch falling from the opposite side of the tree through the rest of the tree to the house is "very low." This results in a likelihood of impacting the house rating of "unlikely."

On the other hand, there is a car parking area located directly under the branch and there are no lower branches that would mitigate the fall of the branch. A car is parked under the tree for 14 hours each day, and the driver is present for a few minutes each day as she walks between the house and the car. Thus the human occupancy rate in the target zone is "rare" and the car occupancy rate is "frequent." There are no factors that would affect the fall of the branch on this side of the tree, so the "rare" human occupancy rate translates to a "low" likelihood of impacting the driver. When that is combined with a failure likelihood of "probable," the combination results in the likelihood of a failure impacting the driver of "unlikely."

The car occupancy rate is "frequent," making the likelihood of the branch striking it "medium." Combining the medium likelihood of impact, with the "probable" likelihood failure of the branch, the likelihood of failure and impact for the car becomes "somewhat likely." As illustrated in this example, it is not unusual to have multiple targets with different values and occupancy rates. All the main risk targets should be considered when conducting a risk assessment.

Categorizing Consequences of Failure

Consequences are estimated based on the value of the target and the harm that may be done to it. The consequences depend on the part size, fall characteristics, fall distance, and any factors that may protect the risk target from harm. The significance of target values—both monetary and otherwise—is subjective and relative to the client. Values should be assessed from the client's perspective.

Consequences of failures can be categorized using the following guidelines:

Negligible consequences are those that involve low-value property damage or disruption that can be replaced or repaired, and do not involve personal injury. Examples of negligible consequences include:

- a small branch striking a fence
- a medium-sized branch striking a shrub bed
- a large part striking a structure and causing low monetary damage
- disruption of power to landscape lighting

Minor consequences are those involving low to moderate property damage, small disruptions to traffic or a communication utility, or very minor injury. Examples of minor consequences include:

- a small branch striking a house roof from a high height
- a medium-sized branch striking a deck from a moderate height
- a large part striking a structure and causing moderate monetary damage

Table 1. The matrix used to estimate the likelihood of a tree failure impacting a specified target.

Likelihood of Failure	Likelihood of Impacting Target			
	Very low	Low	Medium	High
Imminent	Unlikely	Somewhat likely	Likely	Very likely
Probable	Unlikely	Unlikely	Somewhat likely	Likely
Possible	Unlikely	Unlikely	Unlikely	Somewhat likely
Improbable	Unlikely	Unlikely	Unlikely	Unlikely

- short-term disruption of power at a service drop to a house
- temporary disruption of traffic on a neighborhood street

Significant consequences are those that involve property damage of moderate to high value, considerable disruption, or personal injury. Examples of significant consequences include:

- a medium-sized part striking an unoccupied new vehicle from a moderate or high height
- a large part striking a structure and resulting in high monetary damage
- disruption of distribution primary or secondary voltage power lines, including individual services and street-lighting circuits
- disruption of traffic on a secondary street

Severe consequences are those that could involve serious personal injury or death, damage to high-value property, or disruption of important activities. Examples of severe consequences include:

- injury to a person that may result in hospitalization
- a medium-sized part striking an occupied vehicle
- a large part striking an occupied house
- serious disruption of high-voltage distribution and transmission power lines
- disruption of arterial traffic or motorways

Continuing the example from the prior section, the consequences of a medium-sized dead branch striking a house would be "minor," the consequences of that branch striking an unoccupied new car would be "significant," and the consequences of impacting the driver would be "severe." These consequences are combined with the likelihood of failure and impact to determine risk ratings.

E. THOMAS SMILEY

Consequences, which depend on many different tree and site characteristics, are estimated based on the value of the target and the harm that may be done to it.

E. THOMAS SMILEY

To estimate the likelihood of impacting a target, determine the occupancy rate of any targets within the target zone and any factors that could affect the failed tree as it falls toward the target.

Tree Risk Rating

Tree risk assessment reports typically include a rating of risk. A risk matrix (Table 2) is a means of combining ratings of likelihood and consequence factors to determine a level or rating of risk. The matrix approach was selected for use in this guide because of its broad acceptance, ease of use, and effective application for rating risk. This matrix was designed specifically for the evaluation of risk posed by tree failures. The limitations associated with using a matrix include the inherent subjectivity associated with the selection of both the likelihood and consequence factors, and the lack of comparability to other types of risk assessed using other means.

Most trees have more than one potential failure mode and may have multiple risk targets. For example, a tree with excessive root decay may also have several dead branches; the whole tree could fail from root decay, and dead branches may fail. Similarly, the whole tree may fall on a house, while the dead branches would fall only on the driveway. When evaluating individual trees, it is appropriate to evaluate each factor as independent events and to recommend mitigation options along with estimated residual risks for each factor.

Risk aggregation is the consideration of multiple risks in combination, and is difficult to do even with complex mathematical analyses. Therefore, the tree risk assessor *cannot* simply add or multiply

Steps to Developing a Tree Risk Rating

1. Identify possible targets.
2. Identify tree part(s) that could strike target.
3. Evaluate likelihood for each part to fail.
   a. improbable
   b. possible
   c. probable
   d. imminent
4. Evaluate likelihood of tree/part impacting target.
   a. very low
   b. low
   c. medium
   d. high
5. For each failure mode, identify likelihood for tree failure impacting a specified target (Table 1).
   a. very unlikely
   b. unlikely
   c. somewhat likely
   d. likely
   e. very likely
6. For each failure mode, estimate consequences of failure
   a. negligible
   b. minor
   c. significant
   d. severe
7. For each failure mode, designate the risk (Table 2).
   a. low
   b. moderate
   c. high
   d. extreme

the risk ratings for the individual failure modes to reach a whole-tree risk rating.

What the tree risk assessor *can* do is identify—among all the failure modes and consequences assessed—the failure mode having the greatest risk, and report that as the tree risk rating. Assigning a tree risk rating for a tree may be useful, especially when assessing a population of trees. For example, in a given situation, whole-tree failure may be unlikely, but could have significant consequences if it occurs; using Table 2, the risk rating is "low." At the same time, failure of a dead branch may be very likely, but with minor consequences; the risk rating is "moderate." The risk rating may be reported as "moderate," the higher of the two ratings. This rating often is presented as the single risk level for the tree, especially when dealing with populations of trees and limited visual assessments. It is important to note, however, that if measures are taken to mitigate the highest risk, there still is residual risk associated with that tree, including the remaining risk factors. The risk rating for that tree may or may not change based upon the remaining risk factors.

In the tree risk assessment matrix, four terms are used to define levels of risk: low, moderate, high, and extreme. These risk ratings are used to communicate the level of risk and to assist in making recommendations to the owner or risk manager for mitigation and inspection frequency. The priority for action depends upon the risk rating and risk tolerance of the owner or manager.

Low. The low-risk category applies when consequences are "negligible" and likelihood is "unlikely"; or when consequences are "minor" and likelihood is "somewhat likely." Some trees with this level of risk may benefit from mitigation or maintenance measures, but immediate action is not usually required. Tree risk assessors may recommend retaining and monitoring these trees, as well as mitigation that does not include removal of the tree.

Moderate. Moderate-risk situations are those for which consequences are "minor" and likelihood is "very likely" or "likely"; or when likelihood is "somewhat likely" and consequences are "significant" or "severe." The tree risk assessor may recommend mitigation and/or retaining and monitoring. The decision for mitigation and timing of treatment depends upon the risk tolerance of the tree owner or manager. In populations of trees, moderate-risk trees represent a lower priority for mitigation than high- or extreme-risk trees.

High. High-risk situations are those for which consequences are "significant" and likelihood is "very likely" or "likely," or when consequences are "severe" and likelihood is "likely." This combination of likelihood and consequences indicates that the tree risk assessor should recommend mitigation measures be taken as soon as is practical. The decision for mitigation and timing of treatment depends upon the risk tolerance of the tree owner or risk manager. In populations of trees, the priority of high-risk trees is second only to extreme-risk trees.

Extreme. The extreme-risk category applies in situations in which failure is "imminent" and there is a high likelihood of impacting the target, and the consequences of the failure are "severe." The tree risk assessor should recommend that mitigation measures be taken as soon as possible. In some cases, this may mean immediate restriction of access to the target zone area to avoid injury to people.

Continuing the example from the sections on likelihood and consequence: for the house, the risk of a medium-sized, dead branch with a likelihood of failure an impact rating of "unlikely," and consequences rating of "minor," would result in a risk rating of "low." For the parked car, the likelihood is "somewhat likely" and the consequences are "significant," so the risk is "moderate." For the driver of the car, the likelihood is "unlikely" and the consequences "severe," so the risk is also "low." Overall, the tree risk rating would be "moderate," the highest of these three individual ratings. Whether the client chooses to mitigate the risk depends on their perception of risk and what level of risk they find acceptable, as well as the cost, aesthetics, and inconvenience of mitigation.

Table 2. Risk rating matrix showing the level of risk as the combination of likelihood of a tree failing and impacting a specified target, and severity of the associated consequences.

Likelihood of Failure and Impact	Consequences			
	Negligible	Minor	Significant	Severe
Very likely	Low	Moderate	High	Extreme
Likely	Low	Moderate	High	High
Somewhat likely	Low	Low	Moderate	Moderate
Unlikely	Low	Low	Low	Low

Risk Perception and Acceptable Risk

Tree risk assessors assess and categorize an individual tree's risk. How people perceive risk and their need for personal safety is inherently subjective; therefore, risk tolerance and action thresholds vary among tree owners/managers. What is within the tolerance of one person may be unacceptable to another. It is impossible to maintain trees completely free of risk—some level of risk must be accepted to experience the benefits that trees provide.

Acceptable risk is the degree of risk that is within the owner, manager, or controlling authority's tolerance, or that which is below a defined threshold. Municipalities, utilities, and property managers may have a risk management plan that defines the level of acceptable risk. Safety may not be the only basis used by the risk manager to establish acceptable levels of risk; budget, a tree's historical or environmental significance, aesthetics, and other factors may also come into the decision-making process. Tree risk assessors may also assess risk within a population of trees and use that information to prioritize remedial action.

For extreme-risk trees, the tree risk assessor should notify the owner/manager as soon as possible and, in some cases, immediately restrict access to the target zone to avoid injury. For lower levels of risk, however, some discussion is usually required to understand the client's risk tolerance and determine appropriate mitigation treatments. In considering risk and mitigation measures, tree risk assessors should communicate the benefits of trees as well as the consequences of losing them.

The next article in this series will define and describe three levels of tree risk assessment, and will discuss how and when each is used.

E. Thomas Smiley is a Board-Certified Master Arborist. He is an arboricultural researcher at the Bartlett Tree Research Laboratory (Charlotte, NC). Nelda Matheny is president of HortScience, Inc. She is a Board-Certified Master Arborist and Registered Consulting Arborist. Sharon Lilly is the ISA Director of Educational Goods & Services. She is a Board-Certified Master Arborist.

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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, **Qualitative Tree Risk Assessment**, may be sent for the next 12 months.

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1. It is important to establish the context of a tree risk assessment to define
   a. the objectives of the assignment and communication flow
   b. how risk will be evaluated
   c. the limitations of the risk assessment
   d. all of the above
2. An advantage of quantitative assessment is that
   a. tree risk can be compared to other trees and to other types of risk
   b. the assessment results are inherently more precise
   c. the likelihood of failure of the tree is irrelevant
   d. it does not require training or expertise to be used
3. A limitation of quantitative tree risk assessment can be that
   a. it is not possible to mathematically calculate the risk
   b. quantitative data for probability and consequences may not be available
   c. probabilities are too variable for use with living organisms
   d. there are no ways of estimating consequences of failure
4. A limitation of qualitative tree risk assessment is that
   a. it is not possible to categorize likelihood factors
   b. probabilities are too variable for use with living organisms
   c. the process holds inherent subjectivity and ambiguity
   d. there are no ways of estimating consequences of failure
5. A caution related to the categorization of risk factors into numeric values is that
   a. addition or multiplication of ordinal numbers is mathematically incorrect
   b. quantitative values for probability and consequences cannot be multiplied
   c. risk cannot be determined based on categories
   d. all of the above
6. Choice of risk assessment methods should be based on the
   a. needs of the decision makers and the level of detail required
   b. resources available and what is reasonable for the potential consequences
   c. availability of information and data
   d. all of the above
7. Uncertainty in tree risk assessment can be due to the limited ability to predict
   a. decay progression
   b. weather events
   c. traffic and occupancy rates
   d. all of the above
8. Sources of uncertainty in risk assessment should be
   a. eliminated by using proper methodology and equipment
   b. minimized through careful measurement and calculations
   c. understood and communicated to the risk manager
   d. all of the above
9. Most tree failures are associated with
   a. structural defects or conditions and an extraordinary loading event
   b. tension wood or compression wood failures in the trunk
   c. uncompartmentalized fungal decay in the heartwood
   d. senescent wood tissues in the root collar or buttress roots