# WHAT IS TREE FAILURE RISK ASSESSMENT?

Presented by Mike Ellison to the TreeNet Symposium in Adelaide, South Australia in September 2007.


## SUMMARY

Tree risk assessment is currently a hot topic amongst arboriculturists, urban foresters and land managers with responsibility for trees. However, although the language of tree safety management has developed considerably over the past decade, understanding of tree-failure risk assessment and the concepts that underpin it is by no means universal. Development of the Quantified Tree Risk Assessment (QTRA) method has moved the language of tree safety management forward but represents a paradigm shift for tree managers in both the public and private sectors.

Tree safety management is a matter of limiting the risk of significant harm from tree failure whilst maintaining the benefits conferred by trees. Although it may seem counter intuitive, the condition of trees should not be the first consideration. Instead, tree managers should first consider the usage of land upon which trees stand and this in turn will inform the process of assessing trees.


## INTRODUCTION

Whether in the public, corporate or private sectors, land managers have a legal duty to take reasonable care in managing the risks associated with trees in their control. But tree safety management goes beyond simply reducing the risks from trees, and requires consideration and optimisation of the benefits conferred by trees. In addition to the immediately apparent economic value of timber and their aesthetic beauty, trees confer many benefits such as moderating global and local climate, providing shade and shelter, intercepting storm water and providing wildlife habitats. There are even opportunities for the responsible tree manager to optimise the conservation benefits from collapsing and dying trees whilst managing the associated risks at a reasonable level that is acceptable to wider society.

To provide an adequate defence in the event of harm resulting from tree failure, it is usually necessary for the land manager to demonstrate that they have not been negligent but have acted reasonably in the management of their trees and have therefore discharged the duty of care. In most circumstances, to do absolutely nothing is probably unreasonable. Conversely expenditure on tree safety management should not be excessive or disproportionate to the risk being managed. After all, every dollar spent on tree safety is a dollar not spent elsewhere and in local government this means taking resources away from the provision of other services. In law, tree managers are generally expected to manage risks associated with trees to maintain them as low as is reasonably practicable and it will usually be sufficient to demonstrate that this has been achieved through a structured system.

## THE PRINCIPLES OF TREE FAILURE RISK ASSESSMENT

Tree failure risk assessment is quite literally the process of assessing risks from the failure of trees. The process can be as simple or as complicated as the tree manger wishes to make it. Too simple a method of risk assessment and the outcomes will have limited value in the management of the risks, too complicated and application of the method will be onerous and impractical.

Following the emergence of QTRA in the mid 1990s, the term ‘tree risk assessment’ has come into common parlance in the management of tree safety and there has been a move away from the term ‘hazard assessment’. It is apparent that what Wagener (1963), Paine (1971) and

Matheny and Clark (1994) have referred to as 'hazard assessment and 'hazard evaluation' are in fact 'risk assessment and 'risk evaluation'. The terms 'hazard' and 'risk are not interchangeable and it is perhaps helpful to clarify their meanings. A 'hazard' is the disposition of a thing, a condition or a situation to produce injury (Health and Safety Executive 1995). A tree-failure hazard is present when a tree has potential to cause harm to people or property. 'Risk' is the probability of something adverse happening; the likelihood that the hazard will cause harm. Quantified risk assessment is a risk assessment which incorporates numerical estimates (op. cit.). Correct usage of these terms and the language of risk will enable arboriculturists engage in the multidisciplinary risk management debate.

Assessment of tree-failure hazards requires consideration of the mechanical integrity of the tree and the likelihood that the tree or part of it will fail within a given period. Here again terms are often confused by inappropriately describing the assessment of the tree and its defects as 'risk assessment' when the tree represents only part of the risk. For a tree hazard to represent a significant risk there must be something of significance (a target) exposed to harm and this is the essence of tree-failure risk assessment. After all, if resources are to be allocated to tree risk management, it is reasonable to expect that there would be risks of significance and not risks with consequences so minor that the average person would not give them a second thought.

It is usual to consider risks in two parts. Firstly, how likely is it that an adverse event will occur and secondly, what is the likely consequence of the adverse event. The likelihood of the event is considered in terms of both potential for tree failure and the likelihood that something of significance (target) will be present at the time of failure. The consequence is considered in terms of how large is the tree or branch and how susceptible to harm is the target.

## RISK ASSESSMENT METHODS

There are several methods of tree risk assessment, the majority of which provide a ranking of risks on a simple scale and some of which provide arbitrary thresholds for action. Norris (2007) reviewed fifteen of these methods including Quantified Tree Risk Assessment in a paper presented at the International Society of Arboriculture Australia Chapter Annual Conference, Perth, 2007.

Norris (op. cit) concluded "*The 12 experienced arborists who assessed eight trees using eight different methods, produced the most interesting results. The hypothesis was that experienced arborists would apply similar values in similar circumstances and hence the differences produced by each method would be evident. However, it appears that the differences in arborist applied assessment values to these eight trees across all methods was so diverse that the influence of each method is not obvious and that the variation produced by the arborists is the greatest influence on the risk output values created by each method*." When the 12 arborist were asked how well they thought each of the methods worked, one of the simplest methods scored the highest but the range of results using this method, as with all others, was highly variable and it is clear that outputs in any tree-failure risk assessment are highly assessor dependant.

Probably the most widely used and indeed misused method of risk assessment is the ISA tree hazard evaluation method developed by Matheny and Clark (1994) in which the tree failure risk is assessed in three components; 1) failure potential, 2) size of part, 3) target rating. Each component is scored a value of between 1 – 4 (Table 1) and the sum of the three equally weighted scores is termed the 'Hazard Rating'. A Hazard Rating of 12 represents the most severe hazard and 3 the least severe. The system enables comparative ranking of failure risk in a tree population but has little value when assessing the risk from a lone tree because there is nothing with which to make a comparison. The method is used by some to define a numerical line for action, which is explicitly advised against by the authors of the method. Despite the severe limitations, the method is widely used but is often applied in a modified form.

**Table 1. Matheny and Clark Hazard Rating Categories**

| Component / Score | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| **Failure Potential** | low | medium | high | severe |
| **Size of Part** | <150mm | 150-450mm | 450-900mm | >900mm |
| **Target Rating** | occasional | intermittent | frequent | constant |

## QUANTIFIED TREE RISK ASSESSMENT

The Quantified Tree Risk Assessment system was developed in 1996 and formed the foundation for tree risk management training delivered by the author from the late 1990s through to 2005 when a technical paper describing the method was published. The QTRA system applies established and accepted risk management principles to tree safety management. Firstly, the targets (people and property) upon which trees could fail are assessed and quantified, thus enabling tree managers to determine whether or not and to what degree of rigour a tree survey or inspection is required. Where necessary, the tree or branch is considered in terms of both 'impact potential' (size) and 'probability of failure'. Values derived from the assessment of these three components (target, impact potential and probability of failure) are combined and their product is expressed as the 'risk of (significant) harm'.

The QTRA system moves the management of tree safety away from labeling trees as either 'safe' or 'unsafe', which requires definitive statements of tree safety from either tree surveyors or tree managers. Instead, QTRA allows tree assessors to quantify the risk of harm from tree failure in a way that enables managers to balance safety with tree value and operate to a predetermined threshold of acceptable risk.

### QTRA Target Evaluation

A target is anything of value that could be harmed in the event of tree failure. Frequent assessment of trees and of associated risks may be essential in areas of high public access or where trees are within striking range of people or valuable property. Conversely, in locations without property and having very low public access, the survey and assessment of tree hazards may be unnecessary. Therefore, the nature of the target beneath or adjacent to a tree should dictate the level of risk assessment that is required.

Vehicle and pedestrian targets and the value of damage to property are combined in Table 2. In the case of vehicles, probability of occupation may relate either to the tree part striking the vehicle or the vehicle striking the fallen tree part. Both types of impact are influenced by vehicle speed. The faster the vehicle travels the less likely it is to be struck by the falling tree, but the more likely it is to strike a fallen tree. 'Stopping distances' and an average vehicle length are used in the calculation of vehicle occupation of highways. The probability of a vehicle occupying any point in the road is the ratio of the time a point in the road is occupied by vehicles -including safe stopping distance - to the time in a day.

The probability of pedestrians occupying a target is calculated on the basis that an individual will spend, on average, five seconds occupying the average target area, unless a longer occupation is likely as with a habitable structure, outdoor café or park bench. For example, ten pedestrians per day each occupying the target for five seconds is a daily occupation of fifty seconds, by which the total seconds in a day are divided to give a probability of target occupation (50/86,400 = 1/1,728).

When evaluating target property, QTRA considers the approximate cost of repairs or replacement that might be required if the tree or branch under consideration should fail. The property values in Table 1 represent the likely cost of repair or replacement. Quantified Tree Risk Assessment Ltd. provides licensed users of the system with annual monetary conversion rates that enable application of the system internationally. The ranges of monetary value for property used in Table 1 are derived from a value of "hypothetical life" of £1,000,000. For example, Target Range 2 represents a probability of pedestrian occupation up to 1/20; £1,000,000 ÷ 20 = £50,000. Thus, property likely to incur a repair cost of £50,000, which is one-twentieth the value of a hypothetical life, is apportioned a ratio of 1/20.

Targets will ordinarily be recorded in the survey as a range (1-6 Table 1), but may be more accurately calculated and recorded as a ratio where circumstances dictate.

| Target Range | Property (repair or replacement costs)* | Pedestrian Frequency | Vehicular Frequency examples | Probability Ratio (of occupation or fraction of value of £1,000,000) |
|---|---|---|---|---|
| 1 | Very high value >£50,000 - £1,000,000 | >36 per hour - constant | 26,102 vehicles @ 110kph (68mph)<br>32,359 vehicles @ 80kph (50mph)<br>46,702 vehicles @ 50kph (32mph) | 1/1 |
| 2 | High value >£13,888 - £50,000 | >10 per hour - 36 per hour | 1,305 vehicles @ 110kph (68mph)<br>1,617 vehicles @ 80kph (50mph)<br>2,335 vehicles @ 50kph (32mph) | 1/20 |
| 3 | Moderate - high value >£1,388 - £13,888 | >1 per hour - 10 per hour | 363 vehicles @ 110kph (68mph)<br>449 vehicles @ 80kph (50mph)<br>649 vehicles @ 50kph (32mph) | 1/72 |
| 4 | Moderate value >£57.87 - £1,388 | >1 per day - 1 per hour | 36 vehicles @ 110kph (68mph)<br>45 vehicles @ 80kph (50mph)<br>65 vehicles @ 50kph (32mph) | 1/720 |
| 5 | Low value >£8.60 - £57.87 | > 1 per week - 1 per day | 1.5 vehicles @ 110kph (68mph)<br>1.87 vehicles @ 80kph (50mph)<br>2.7 vehicles @ 50kph (32mph) | 1/17,280 |
| 6 | Very low value ≤ £8.60 | ≤ 1 per week | None | 1/120,960 |

**Table 2. 'Target' ranges for property, pedestrians and vehicles.**

Vehicular, pedestrian and property targets are categorised by their frequency of use or their monetary value. For example, the probability of a vehicle or pedestrian occupying a target area in 'Target' range 4 is between the lower and upper limits of >1/17,280 and 1/720. Using the value of a 'Hypothetical Life' of £1,000,000 the structure value within the 'Target' range 4 is >£57.87-£1,388.

Vehicular frequency examples for 'Target' range 1 are calculated on the basis of the stopping distance for a given road speed providing a duration of occupation for the average vehicle on that road. The total time in a day is divided by the duration of occupation with the quotient being the number of vehicles per day required to produce constant occupation. All other 'Target' ranges are calculated as a proportion of the 'Target' range 1 value e.g. 'Target' range 2 (probability ratio 1/20) 26,102/20 = 1305.1.

* Property values represent the likely cost of repair or replacement.

## QTRA and the Effects of Weather

Often the nature of the defect is such that probability of failure is greater during windy weather, whilst the probability of the site being occupied during such weather conditions is considerably reduced, e.g. woodland, park or private garden, thus reducing the risk of harm from tree failure. Conversely risks may be increased by weather such as in case of the phenomenon known as 'Sudden Branch Drop', which is the shedding of branches in some tree species during hot dry weather when in some settings the likelihood of people being beneath the tree might be increased. In both of these situations we might apply a 'Weather Factor' to our calculation, which is a fraction that represents the combined effects of weather on site usage and on tree failure in reducing or increasing the 'Risk of Significant Harm' e.g. a 'Weather Factor' of 1/2 has the effect of reducing the 'Risk of Significant Harm' by half.

## QTRA Impact Potential

A small dead branch of less than 10mm diameter is unlikely to cause significant harm even in the case of direct contact with a target, whilst on average a falling branch with a diameter greater than 150mm is likely to cause harm in the event of contact with all but the most robust target. The increased potential for injury in relation to the size of tree or branch is proportional to a degree, yet the tree or branch will reach a size where the increased severity of injury is no longer proportional to the increase in size. Similarly, most property likely to be affected by tree failure can incur only a limited level of damage before further damage is likely to be inconsequential, i.e. when it is beyond economic repair.

The system categorises 'Impact Potential' by the diameter of tree stems and branches. A biomass equation derived from weight measurements of trees of different stem diameters is used to produce a data set of comparative weight estimates of trees and branches ranging from 10 to 600mm diameter. An upper limit of 600mm has been selected to represent a 1/1 'Impact Potential' on the premise that impact from a tree with a stem diameter of 600mm has a 1/1 probability of causing maximum possible damage to most frequently encountered targets. From this point, the Impact Potential reduces to 1/23,500 for a 10mm branch or tree. For initial assessments the probabilities are grouped into ranges 1-5 (Table 3).

| Impact potential range | Size of part likely to impact target | Impact Potential |
|---|---|---|
| 1 | > 450mm (18") dia. | 1/1 |
| 2 | > 250mm (10") dia.- 450mm (18") dia. | 1/2 |
| 3 | >100mm (4") dia.- 250mm (10") dia. | 1/8.6 |
| 4 | > 25mm (1") dia.- 100mm (4") dia. | 1/82 |
| 5 | 10mm (2/5") dia.- 25mm (1") dia. | 1/2500 |

**Table 3. Impact Potential.**
* Range 1 is based on a diameter of 600mm.

### QTRA Probability of Failure

The 'Probability of Failure' component of the system provides five ranges. Each range represents a range of probability of failure occurring within a year, expressed as a ratio calculated from the upper value of that range. Probability of failure will ordinarily be recorded in the tree survey schedules as a range (1-5 Table 4), but may be more accurately evaluated and recorded as a ratio where circumstances dictate.

| Probability of failure range | Probability of failure percentage | Probability ratio |
|---|---|---|
| 1 | >10% - 100% | 1/1 |
| 2 | > 1% - 10% | 1/10 |
| 3 | > 0.1% - 1% | 1/100 |
| 4 | >0.01% - 0.1% | 1/1,000 |
| 5 | ≤ 0.01% | 1/10,000 |

**Table 4. Probability of Failure.**
The probability that the tree or selected tree-part will fail within a year.

### QTRA Example

A highly unstable 25.0 metre high tree with a stem diameter 900mm (36"), in a low use area of woodland with no regular access but members of the public occasionally enter the target area. The most significant part likely to strike the target area is the stem or part of the crown with the weight of the whole tree behind it.

| | Target | | Impact Potential | | Probability of Failure | | Risk of Harm |
|---|---|---|---|---|---|---|---|
| **Range** | 6 | | 1 | | 1 | | |
| **Probability** | 1/120,960 | x | 1/1 | x | 1/1 | = | 1/121,000 |

The absence of structures and the very low level of public access indicate that detailed assessment of the tree is not essential. If it could be established that a 'Weather Factor' of 1/4 was appropriate, the overall probability of harm would be reduced to 1/483,840.

**GOODE v CITY OF BURNSIDE [2007]**

In the case of Goode v City of Burnside [2007], the court considered an appeal against the Council's decision to refuse permission for the removal of two River Red Gum trees (*Eucalyptus camaldulensis* sub sp. *camaldulensis*). Two issues were considered. 1) The risk from failure of the trees, or part thereof, 2) damage to the tree owner's dwelling from root activity. The Judgment of Commissioner Hodgson makes various references to QTRA and its application by the Council's arboriculturist Mr. Lodge.

There are two important issues relating to QTRA that are raised in the judgement and there appears to be misunderstanding of both the inputs and outputs of the QTRA method by the Commissioner. Firstly, the Commissioner, at paragraph 18 of the judgment, states "*In response to questions from the Court, Mr Lodge acknowledged that there was a fair measure of subjectivity entailed in the assignment of scores to the three criteria under this method* (ISA method – Matheny and Clark 1994)*. That being the case, I have little confidence in the rating arrived at as an accurate reflection of the risk associated with the subject trees.*" At paragraph 25, the Commissioner says "*It seems to me that the Ellison methodology suffers from the same defect as the Hazard Rating system, namely, that it requires a fair measure of subjectivity in determining the probability of failure and the size of branch most likely to fail, these in turn having a significant effect on impact potential*". The commissioner proceeds at paragraph 27 to suggest, without any particular qualification, that he finds the evidence of Mr. Nicolle, expert for the Appellant, more persuasive.

It is apparent from the Commissioner's concerns over the subjective judgement required in the assessment of tree-failure risk, that he does not understand the underlying concepts. In the context of the commissioner's comments on this matter, the term 'subjective' is broadly synonymous with 'judgement' or 'a person's views' Concise Oxford English Dictionary (2007). It is not and has never been claimed that QTRA is wholly objective and it is clear that a risk assessment cannot be so. As with any method of assessing tree safety, the judgement of the assessor based upon his knowledge and experience is required whether the risk assessment is an overview of a large tree population or a detailed assessment of an individual tree and its situation. The evidence of Mr Nicolle on the matter of potential for branch failure was no less subjective than that of Mr Lodge who had in fact limited the subjective input to his assessment by applying the structure of the QTRA method.

Secondly, the commissioner states at paragraph 24 of the judgment *"Mr Nicolle's evidence was that the limbs most likely to fail in Tree 1 were 300mm or more in diameter. If that diameter were substituted for the 100mm diameter used in Mr Lodge's calculation of risk of harm, with no other change, the risk would, on my calculations, become 1/592, clearly unacceptable against the criteria underlying Mr Lodge's calculations. Were the probability of failure reduced to a level consistent with Mr Lodge's survey of failure in this species, the risk of harm, based on the Ellison methodology, would be, on my calculations, 1/5,920, again greater than the posited acceptable level of risk of 1/10,000".* What the Commissioner did not consider is that large branches are inherently more stable than small branches and the 300mm diameter branch exhibiting no signs of significant defect would have a far lower likelihood of failure than the 100mm diameter branch and that this reduction in the 'Probability of Failure' component of the QTRA would reduce the risk of harm in both cases to below the acceptable threshold.

Thirdly, At paragraph 21, the Commissioner cites the QTRA journal paper thus. "*Having read that paper and carefully considered Mr Lodge's evidence, I have significant reservations about the utility of the Quantified Tree Risk Assessment System in providing a reliable measure of the risk represented by a particular tree or trees. The precise nature of the way in which "Risk of Harm" is expressed suggests a level of accuracy and reliability not borne out by a close examination of the inputs to the calculation of that risk."* Here the Commissioner makes a reasoned observation and indeed is correct in that expressing the QTRA 'Risk of Harm' output to as many as four significant figures QTRA outputs infer a level of precision that does not exist. This is not a problem with the utility of the QTRA method, because inputs can involve precision, but with the way in which outputs are expressed. The QTRA system benefits from considerable input and feedback from licensed users through an internet discussion forum on which the topic of precision has been discussed. At the next revision the significant figures in QTRA outputs will be reduced.

Users of the Quantified Tree Risk Assessment system are trained in application of the system and should possess the skills to apply the method to the assessment of tree-failure risk. Providing evidence on the underlying principles of QTRA requires a greater level of understanding and few people have that in depth understanding of the subject. For the future, Quantified Tree Risk Assessment Limited will provide a review service and will compile a register of individuals who have attained sufficient understanding of the system to provide confidential review and guidance to other users.

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# SPEAKER PROFILE AND CONTACT DETAILS

## MIKE ELLISON

Quantified Tree Risk Assessment Ltd.
16 Pickwick Road
Poynton
Cheshire
SK12 1LD
United Kingdom

Tel: +441625 856804
Fax: +441625 850216
Email: mike@qtra.co.uk

Mike Ellison is principal arboricultural consultant and partner in the UK based Cheshire Woodlands Arboricultural Consultancy.

Having worked in the timber industry from 1976, Mike formed Cheshire Woodlands in 1980. The company's focus on arboricultural services developed through the eighties and it is now a respected arboricultural consultancy practice specialising in the field of trees and built development and tree safety management.

In 1996, Mike developed the Quantified Tree Risk Assessment (QTRA) system principally out of frustration with the pressure from clients to provide impossible assurances that trees were safe. In 2005, a peer reviewed paper on the subject was published in the Journal of Arboriculture.

Over the past two years, over 400 Licensed Users have been trained in the application of QTRA in Europe, Australia, New Zealand and the United States.