QTRA Quantified Tree Risk Assessment

Simply Balancing Risks With Benefits

Quantified Tree Risk Assessment

PRACTICE NOTE

VERSION 5

CONTENTS

1. LIMITATIONS

Quantified Tree Risk Assessment (QTRA) is an expansion of concepts proposed by Paine (1971), Helliwell (1990, 1991) and Matheny and Clark (1994). It is a methodology for quantifying the risks from falling trees and branches.

The method does not provide predictions of what will or will not happen but an estimate of the risk from any particular tree hazard. The outputs of QTRA are dependent on the user's inputs, requiring the QTRA User to apply their knowledge and experience to the assessment of trees and the Targets[1] upon which trees could fail.

QTRA Registered User training introduces the user to the application of QTRA and to some general principles of risk assessment and management. The training provides an introduction to the assessment of tree structure and how to apply your observations to estimating the probability of tree and branch failure. It is for the user to identify and acknowledge their limitations in any part of the risk assessment process and to seek further information or skills where they consider it necessary. Arborists and foresters will usually be appropriately qualified to consider the stability and structural integrity of trees. When considering the structural condition of trees, it may be necessary to defer to someone more highly skilled. Where more information on land-use is required to inform an assessment, the QTRA User should seek guidance from the tree owner/manager in the first instance.

Quantified Tree Risk Assessment Limited proposes the use of advisory thresholds to assist risk decision making. It is for the tree manager to adopt these or other thresholds, having taken account of their own management priorities, objectives and resources. The QTRA Practice Note[2] is provided to inform tree owners and managers about the QTRA process and how it can assist their management decisions.

Ongoing research and development has and will continue to change the structure of the method and the data upon which it relies. As we have improved the QTRA method to better reflect the very low-risk relationship between people and trees, these changes have resulted in risks previously considered intolerable, being recognised as tolerable. Quantified Tree Risk Assessment Limited reserves the right to apply the changes and refinements that it considers necessary to develop the method.

QTRA Registered Users are made aware of the limitations of the method and by accepting the Know How Licence Agreement (copy available at www.qtra.co.uk), these limitations are accepted.

2. INTRODUCTION

Risk Assessment

When managing risks in all walks of life we strive to balance the costs of our actions and choices with the benefits that they provide. If, for example, you want to travel by car you must accept that even with all the extensive risk control measures, such as seat-belts, speed limits, airbags, and crash barriers, there is still a significant risk of death. This is an everyday risk that is taken for granted and accepted by millions of people in return for the benefits of convenient travel. Managing risks and benefits from trees should be no different.

Risk assessment is the overall process of risk identification, risk analysis and risk evaluation (ISO 2018). The job of the risk assessor is to identify and analyse the risk in terms of likelihood of tree failure and potential consequences. The outcome of this process should then inform the tree manager's evaluation of the risks and decisions on how to best to manage them.

Using a comprehensive range of values[3], QTRA enables the tree assessor to identify and analyse the risk from tree failure in three key stages:

1) to consider land-use in terms of vulnerability to impact and likelihood of occupation,
2) to consider the consequences of an impact, taking account of the size of the tree or branch, and
3) to estimate the probability that the tree or branch will fail onto the land-use in question.

These values are combined to calculate an annualised[4] Risk of Harm from a tree.

To inform management decisions, the risks from different hazards can then be considered against broadly acceptable or tolerable thresholds of risk.

[1] 'Target' refers to that which could be harmed by failure of a tree.
[2] Available for download from www.qtra.co.uk
[3] See Tables 1, 2 & 3.
[4] The components of the risk are considered in terms of likelihood of occurrence in a year and the Risk of Harm is therefore annualised.

A Proportionate Approach to Risks from Trees

The risks from tree failure are generally very low and high risks will usually be encountered only in areas with either high levels of human occupation or where valuable property can be affected by the structural failure of trees. Where human occupation and the value of property are sufficiently low, we may be able to identify that the risk is 'broadly acceptable' and that the assessment of trees for structural weakness may not be necessary. Even when land-use indicates that the assessment of trees is appropriate, it is seldom proportionate to analyse the risk for each individual tree in a population. Often, all that is required is to take a general view of the trees to identify gross signs of structural weakness or declining health.

The assessment of trees should be carried out at appropriate intervals, the frequency of which should be informed by the nature of the trees, the type of land-use (targets), and by the overall level of risk. Doing all that is reasonably practicable does not mean that all trees have to be individually examined on a regular basis (HSE 2013).

The QTRA method enables a range of approaches from the broad assessment of large collections of trees to, where necessary, the detailed assessment of an individual tree. Using QTRA, the level of assessment should be informed by the nature of the land-use and the size and general characteristics of the trees.

Balancing Costs and Benefits of Risk Reduction

Risk minimisation is often cited as an objective when managing risks from trees. This is not a reasonable aim because it does not take account of the cost of risk reduction. If reasonable management decisions are to be made, the benefits of controlling a risk must be balanced with its costs, and those costs are not just financial. The tree-related benefits that are lost to risk control are often a substantial cost of managing risks from falling trees.

As trees age, they develop features such as cavities and decaying wood that might compromise their structural integrity, while at the same time providing valuable wildlife habitats. A large proportion of these trees occur in rural areas, but many are to be found on our streets, in gardens, churchyards, and city parks. The benefits that trees provide must be considered when making risk management decisions, and this includes conservation value, aesthetic qualities, environmental and health benefits.

Where risk reduction comes at a disproportionately high cost, the risk control measure can be said to be unreasonable or disproportionate. Where safety from trees is concerned, the law in the UK, both common and in statute requires only that the occupier of land (the risk owner or manager) does what is reasonable (Mynors 2011).

By quantifying the Risk of Harm from falling trees, QTRA enables some comparison of the costs and benefits of risk reduction. Although the majority of tree-risk management decisions are not evaluated in terms of the detailed costs and benefits, this general balance should underpin tree risk management decisions.

General Legal Duty

The legal position in relation to tree ownership and safety varies from country to country and this User Manual is for general guidance only. It is not intended to be a guide to trees and the law.

No matter how low the risk, there is a 'duty of care' to consider risks from trees under your control. Property owners and managers have a duty (under English law at least) to ensure, insofar as 'reasonably practicable', that people and property are not exposed to unreasonable levels of risk from the failure of trees in their control.

Mynors (2011) provides a comprehensive account of the situation in English law and the following quotations are particularly pertinent to the risk assessment approach to tree safety management. In respect of the existence of a general duty of care upon occupiers in relation to hazards occurring on their land, Mynors (ibid) refers to, amongst others, the Court of Appeal in Leakey v National Trust, which defined the scope of the duty as ***"…a duty to do that which is reasonable in all the circumstances, and no more than what, if anything, is reasonable, to prevent or minimise the known risk of damage or injury to one's neighbour or his property***".

Reasonably Practicable

The concept of 'reasonably practicable' is a central tenet of English law, which is evident throughout the English Health and Safety legislation and guidance (e.g. Health and Safety at Work Act 1974), and in judgements of the higher courts in relation to tree failure.

In consideration of Leakey (above) and other cases, Mynors (ibid.) advises that "***You are thus only under a duty to protect those who are 'reasonably' likely to be affected by any omission on your part, and only if you can***

***'reasonably' foresee that they are likely to be injured as a result; and even then you are only required to take reasonable care to avoid such omissions. And Megaw L.J. in Leakey only envisaged a duty to do that which is 'reasonable in all the circumstances"*.**

The Structure of Trees

There is increasing knowledge and understanding of the ways that tree structure is affected by environmental factors and wood decay organisms in particular, but there are also severe limitations to how we can apply this knowledge to our assessments of the tree's ability to resist failure. Tree structure and its assessment are documented elsewhere and are not considered in any detail here. It is important to reiterate that the risk assessor should acknowledge the limitations in their assessment of the tree and when necessary, defer to someone with more knowledge or experience.

Land-use

Land-use is by far the most important component of QTRA. With many recreational sites, the use of land is very low during the kind of weather conditions that increase the likelihood of tree failure. By first assessing levels of land-use, it can easily be established whether the assessment of trees is necessary. By evaluating, and perhaps mapping the general nature of the tree population, it is possible to identify where there is a significant interface between trees and Targets, which in turn allows prioritisation of risk assessments.

A post-mature tree population adjacent to a busy urban road might require annual assessment, whereas a similar population in a remote wilderness might never be assessed in detail beyond establishing that the Target value is low. Between these extremes there is a range of assessment frequency, which should be applied as appropriate to the situation and according to the tree priorities and resources of the tree manager.

3. DEFINITION OF TERMS

It is necessary to define some of the terms and the basic principles that we apply in order to use them consistently. Below are some definitions of particular importance in tree risk management.

Hazard

A tree-failure hazard is the tree or branch that has potential to cause harm.

Risk

Risk is the combination of the probability of an event and its consequence (ISO 2009).

Risk of Harm

The QTRA output is termed the Risk of Harm and is a measure of the likelihood x consequence of tree failure. The baseline consequence in QTRA is the loss of a life, but this is not the only consequence that is considered, e.g. a Risk of Harm 1/100 000 can represent a 1/100 000 likelihood of a death, or a 1/1 likelihood of a consequence equivalent to a hundred-thousandth of a life, or any combination in-between.

As Low As Reasonably Practicable (ALARP)

Determining that risks have been reduced to As Low as Reasonably Practicable involves an evaluation of both the risk to be reduced and the sacrifice or cost involved in reducing that risk. If it can be shown that there is gross disproportion between them, the risk being insignificant in relation to the sacrifice or cost, it can be demonstrated that to reduce the risk further is not reasonably practicable.

Target

In tree-failure risk assessment, a Target is anything of value that could be harmed in the event of tree failure.

4. COSTS AND BENEFITS OF RISK CONTROL

Trees confer many benefits to people and the wider environment. When managing any risk, it is essential to maintain a balance between the costs and benefits of risk reduction, which should be considered in the determination of ALARP. It is not only the financial cost of controlling the risk that should be considered, but the loss of tree-related benefits, and the transfer of risk to workers and the public from the risk control measure itself.

When considering risks from falling trees, the cost of risk control will usually be too high when it is clearly 'disproportionate' to the reduction in risk. The issue of 'gross disproportion'[5], where decisions are heavily biased in favour of safety, is likely to be considered only where there are annualised risks greater than 1/10 000.

Acceptable and Tolerable Risks

The Tolerability of Risk framework (ToR) (HSE 2001) is a widely accepted approach to reaching decisions on whether risks are broadly acceptable, unacceptable, or tolerable if ALARP. Graphically represented in figure

[5] Discussed further on page 16.

1, ToR can be summarised as having 1) a Broadly Acceptable Region where the upper limit is an annual risk of death 1 / 1 000 000, 2) an Unacceptable Region of which the lower limit is 1 / 1 000, and between these 3) a Tolerable Region within which the tolerability of a risk will be dependent upon the costs and benefits of risk reduction. In the Tolerable Region, we must ask whether the benefits of risk control are sufficient to justify their cost.

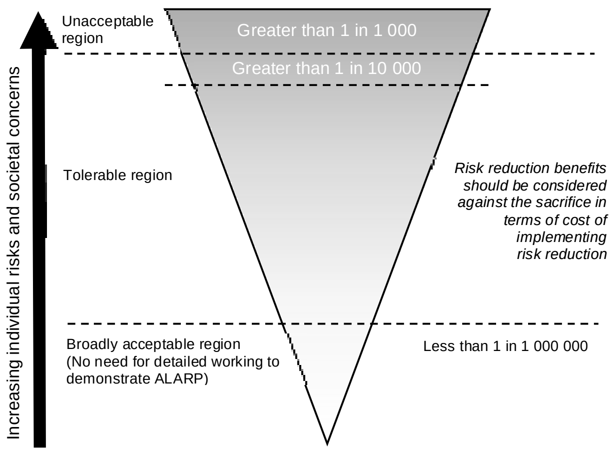


Fig. 1. Adapted from the Tolerability of Risk framework (HSE 2001).

In relation to risk management in the workplace and industry, the UK Health and Safety Executive (HSE 2001) suggests that "an individual risk of death of one in a thousand per annum should on its own represent the dividing line between what could be just tolerable for any substantial category of workers for any large part of a working life, and what is unacceptable for any but fairly exceptional groups. For members of the public who have a risk imposed on them 'in the wider interest of society' this limit is judged to be an order of magnitude lower – at 1 in 10 000 per annum." Furthermore, "HSE believes that an individual risk of death of one in a million per annum for both workers and the public corresponds to a very low level of risk and should be used as a guideline for the boundary between the broadly acceptable and tolerable regions." (ibid).

In respect of trees, some risks cross the Broadly Acceptable 1 / 1 000 000 boundary, but remain tolerable because any further reduction would involve a disproportionate cost in terms of the lost environmental, visual and other benefits in addition to the financial cost of controlling the risk.

Value of Statistical Life

The Value of Statistical Life (VOSL) is a widely applied risk management tool, which uses the value of a hypothetical life to guide the proportionate allocation of resources to risk reduction. In the UK, this value is currently in the region of £1 500 000 - £2 000 000. The VOSL used in the QTRA method at the time of publication is £2 000 000 (€2 200 000).

In QTRA, placing a statistical value on a human life has two particular benefits. Firstly, QTRA uses VOSL to enable damage to property to be compared with the loss of life, e.g. where VOSL is £2 000 000, a building with a replacement cost of £20 000 is valued at 0.01 (1 / 100) of a life, allowing the comparison of risks to people and property. Secondly, the proportionate allocation of financial resources to risk reduction can be informed by VOSL. "***A value of statistical life of £1 000 000 is just another way of saying that a reduction in risk of death of 1/100 000 per year has a value of £10 per year***" (HSE 1996).

Internationally, there is variation in VOSL and its computation. To provide consistency in QTRA outputs, it is suggested that VOSL of £2 000 000 should be applied internationally, but this is ultimately a decision for the tree manager.

5. THE QTRA METHOD

The QTRA method provides a framework for the assessment of the three primary components of tree-failure risk. The input values for these components are set out in broad ranges[6] of Target, Size, and Probability of Failure. The QTRA User estimates values for the three components and inputs them to either the QTRA manual calculator or software application to calculate the Risk of Harm.

ISO 31000 - Risk Management:
Principles and Guidelines

The international Standard for Risk Management sets out a five-stage process, which is outlined below in the flow diagram at figure 2. The five-stage process has been expanded to six stages to separate out the initial risk analysis at stage 3 from the detailed analysis at stage 4. This assists determination of whether a detailed analysis would be proportionate.

[6] See Tables 3, 5 & 6.

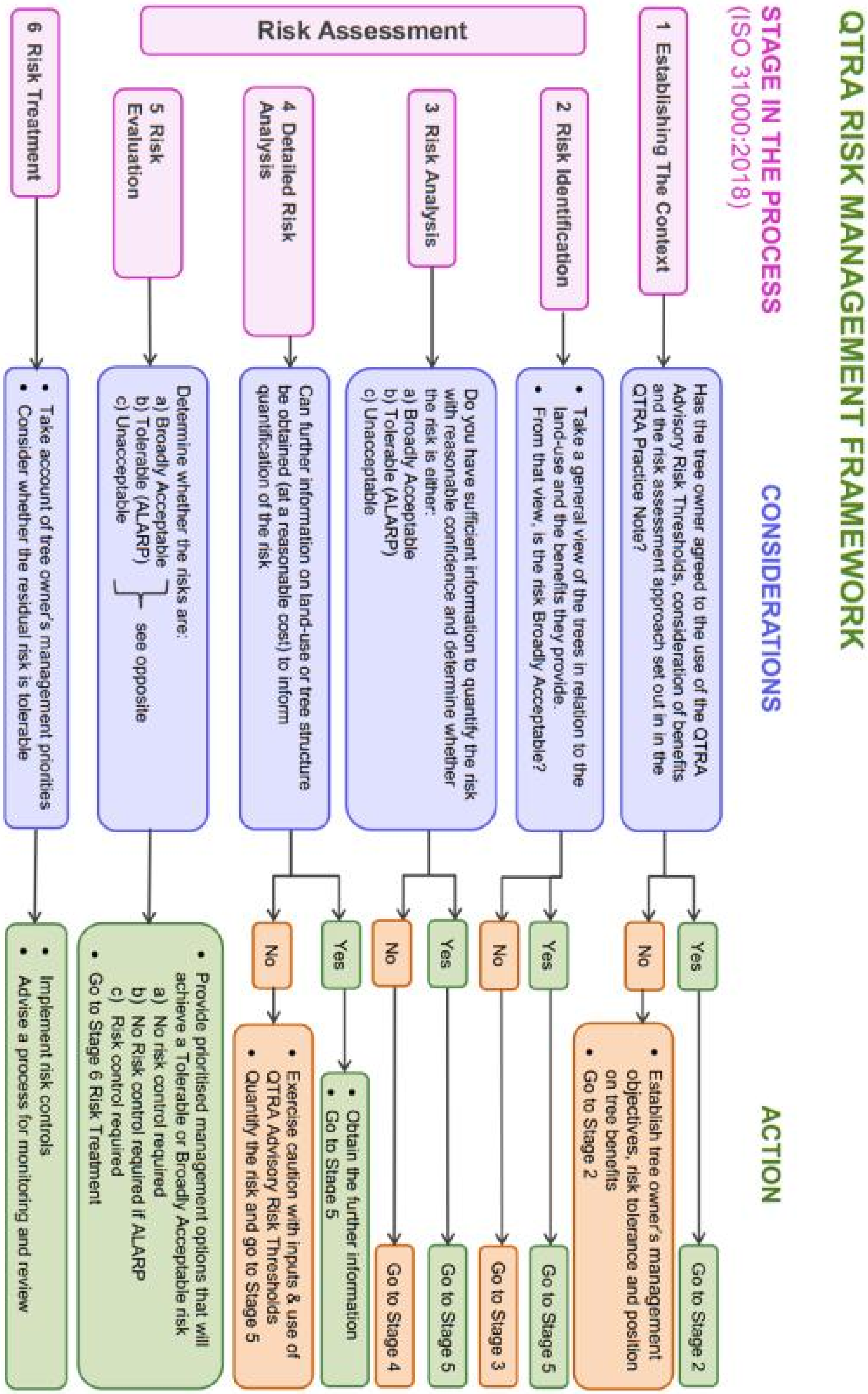

QTRA RISK MANAGEMENT FRAMEWORK
STAGE IN THE PROCESS
(ISO 31000:2018)
CONSIDERATIONS
ACTION
Risk Assessment
1 Establishing The Context
Has the tree owner agreed to the use of the QTRA Advisory Risk Thresholds, consideration of benefits and the risk assessment approach set out in the QTRA Practice Note?
Yes
Go to Stage 2
No
• Establish tree owner's management objectives, risk tolerance and position on tree benefits
• Go to Stage 2
2 Risk Identification
• Take a general view of the trees in relation to the land-use and the benefits they provide.
• From that view, is the risk Broadly Acceptable?
Yes
Go to Stage 5
No
Go to Stage 3
3 Risk Analysis
Do you have sufficient information to quantify the risk with reasonable confidence and determine whether the risk is either:
a) Broadly Acceptable
b) Tolerable (ALARP)
c) Unacceptable
Yes
Go to Stage 5
No
Go to Stage 4
4 Detailed Risk Analysis
Can further information on land-use or tree structure be obtained (at a reasonable cost) to inform quantification of the risk
Yes
• Obtain the further information
• Go to Stage 5
No
• Exercise caution with inputs & use of QTRA Advisory Risk Thresholds
• Quantify the risk and go to Stage 5
5 Risk Evaluation
Determine whether the risks are:
a) Broadly Acceptable
b) Tolerable (ALARP)
c) Unacceptable
see opposite
• Provide prioritised management options that will achieve a Tolerable or Broadly Acceptable risk
a) No risk control required
b) No Risk control required if ALARP
c) Risk control required
• Go to Stage 6 Risk Treatment
6 Risk Treatment
• Take account of tree owner's management priorities
• Consider whether the residual risk is tolerable
• Implement risk controls
• Advise a process for monitoring and review

Fig. 2

Establish Your Brief

Stage 1 of the ISO process (outlined at figure 2) is to 'establish the context' of the risk management exercise. This is where the tree manager's priorities should be established and the application of the QTRA decision-making thresholds should be agreed. Perhaps they are managing the pristine landscape setting of a high-end business park where the removal of dead branches would both reduce risks and, in their eyes, be aesthetically pleasing. The polar opposite to this might be a country park where a priority is to optimise the deadwood habitats for rare and endangered species, where the removal of dead branches would be a risk control measure of last resort.

An important component of your contract with the tree manager is establishing what you will and will not do and how the results of your assessment will be communicated. If you are to use QTRA, it is essential that the tree manager accepts both the general principle of quantifying risks and the decision-making thresholds of risk that will be used.

Targets

In the assessment of Targets, six ranges of value are available. Table 4 sets out these ranges for vehicle traffic, human occupation and the repair or replacement cost of damage to property.

The QTRA User should consider what the most significant relationship between the tree and Targets is, and recognise that when assessing different trees and even different parts of the same tree, the Targets may vary. An example of this is where a tree overhangs a footpath and is within striking distance of a major highway, but because the probability of whole tree failure onto the highway is very low, we might consider instead a large dead branch over the footpath. The footpath becomes the Target in our risk assessment. If you are uncertain of the most significant combination of Target and tree, a calculation can be made for each risk and the significant risks recorded.

When the QTRA User assesses the value or occupancy of Targets, it is necessary to consider the repair or replacement value of property that might be damaged and the average occupation by people over the coming year. This assessment will consider how many vehicles per day, or how many pedestrians per hour, day, week, month or year. In the assessment of Target occupancy we should consider the patterns of use that contribute to the overall occupation. The city street might be viewed during a busy part of the day, but we must consider average occupation to take account of use over the 24-hour day including those periods of low use. It is also important to account for a range of seasonal effects such as holiday periods, the average working week that might see no occupation at weekends, perhaps occasional events such as an annual concert in a park, and importantly, windy weather.

> Having assessed both Targets and trees the QTRA User should either:
>
> a) record that no significant risk (1/1,000 000 or greater) has been identified,
> b) calculate the risk, from a specified tree or
> c) calculate the risk, from a general attribute of the group, on the basis of the worst tree, without necessarily identifying an individual tree.
>
> If a risk is to be calculated, a Target Range (Table 4) should be selected for one of the following: Property, Human, or Vehicle Traffic.
>
> So that the risk assessment can be reviewed in the future, the QTRA User should also record a description of the risk that is being assessed, e.g. 'Tree failure onto footpath'.

Human Occupation

The probability of pedestrian occupation is calculated on the basis that the average pedestrian, walking at 1.4 metres per second, will spend five seconds walking beneath the average tree. For example, an average occupation of ten pedestrians per day, each occupying the Target for five seconds is a daily occupation of fifty seconds, giving a likelihood of occupation 1/1 728. Where a longer occupation is likely, as with a habitable structure, outdoor café or park bench, the period of occupation should be measured or estimated as a proportion of a given unit of time, e.g. six hours per day (1/4). The Target is recorded as one of the six Target Ranges (Table 4).

Child Targets

Objective assessment of Targets involving children is often difficult. For the purpose of the risk assessment, every human life has the same value. However, a child's perception of danger may be quite different to that expected of a mature adult and we should be mindful of this when assessing areas where children play. It should be remembered that in most outdoor situations, the presence of children substantially decreases during stormy weather. However, children congregate in some areas almost irrespective of the weather albeit at reduced levels; such Targets include entrance and exit points to schools and school bus stops. How children and some other categories of site user are considered in risk management decisions is a matter for the tree manager, for whom the risk to their reputation may be an important consideration.

Cyclists

Cyclists usually travel faster than the average pedestrian, which means that they spend less time beneath the tree but will have a longer reaction time in the event of a tree or branch failure occurring in front of them. In QTRA the cyclist is valued in the same way as the pedestrian, on the basis of a 5 second occupation beneath an average tree.

Weather Affected Targets

Often the nature of a structural weakness in a tree is such that the probability of failure is greatest during windy weather, while the probability of the site being occupied by people during those weather conditions is often low. This reduction in occupation during windy weather may be less in warmer climates but will have some effect in most situations.

Fig. 3. Thousands of people visit this stately home on a few weekends each year, but even modest winds will see visitor numbers reduce.

When estimating human Targets, the risk assessor must answer the question, 'In the weather conditions that I expect the likelihood of failure of the tree to significantly increase, what is my estimate of human occupation?' Taking this approach, rather than valuing the average usage, ensures that the assessor considers the relationship between weather, people and trees, and the nature of the average person with their ability to recognise and avoid unnecessary risks.

When selecting a Human Target, the QTRA User should consider the weather conditions that are most likely to initiate failure of the tree or branch and will estimate or measure either:

a) the number of pedestrians that would be expected to pass within striking distance of the hazard, during those weather conditions, in terms of pedestrians per hour, per day etc., or

b) the likely duration of occupation within striking distance of the hazard, during those weather conditions - minutes per hour, hours per day etc.

The estimate need only be sufficient to put the usage into one of the QTRA Target Ranges for Human occupation.

Vehicle Traffic

The occupation of vehicle Targets is quantified on the basis of average vehicle speed for the road (Table 1), which in the absence of traffic survey data would usually be recorded as the legal speed limit, and the flow rate (measured or estimated as the average number of vehicles per day). The probability of a vehicle occupying any particular point in the road is the ratio of the time a point in the road is occupied by a vehicle - including a safe stopping (deceleration) distance - to the total time in a day.

Large trees standing adjacent to highways often have potential to impact vehicles on both carriageways (traffic in both directions). In many situations, however, the tree or branch would affect only one side of the highway. Vehicle flow rates should therefore be considered in relation to the particular situation. If failure of a whole large tree is being considered and the entire width of the highway might be affected then the combined flow rate for both directions will be considered. If traffic in only one direction is affected then only half of the total flow for the highway will be considered.

In the case of vehicles, the likelihood of occupation may relate to either the falling tree or branch striking the vehicle from above or, more commonly, the vehicle striking the fallen tree. 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.

Table 1. Vehicular Occupation

S		D	T
Average Road Speed		Stopping distance + 6m vehicle length (metres)	Time that each vehicle occupies length of road 'I (seconds)
kph	mph		
150	93.21	183.15	4.40
140	87	160.32	4.12
130	80.78	139.06	3.85
120	74.57	119.38	3.58
110	68.35	101.27	3.31
100	62.14	84.74	3.05
90	55.93	69.78	2.79
80	49.71	59.39	2.67
70	43.50	46.58	2.39
60	37.28	34.34	2.06
50	31.07	25.68	1.85

$$T = \frac{D \times 3{,}600}{S \times 1{,}000}$$

$$D = \frac{(\text{initial velocity})^2}{2 \times \text{coefficient of friction (0.5)} \times \text{standard gravity (9.8)}}$$

(csgnetwork.com 2007)

The average vehicle on a UK road is occupied by 1.6 people (DfT 2010). To account for the substantial protection that the average vehicle provides against most tree impacts and in particular, frontal collisions, QTRA considers the substantially protected average occupation in addition to the average vehicle value as being equivalent to one unprotected human life.

When considering Vehicle Traffic Targets, the QTRA User should estimate or measure the daily flow rate for the highway and select a Target Range on the basis of this estimate and the average road speed (in most situations this is likely to be close to the legal speed limit).

The estimate need only be sufficient to put the usage into one of the QTRA Target Ranges for Vehicle Traffic.

Property

In QTRA, property is anything that could be damaged by a falling tree, from a dwelling or a parked car, to a simple fence. When evaluating the exposure of property to tree failure, the QTRA assessment considers the cost of repair or replacement that might result from failure of the tree.

In Table 4, The ranges of property value are based on a VOSL of £2 000 000, e.g. Target Range 2 represents a range of 1/10 to >1/100, giving a range of value £200 000 to >£20 000.

When assessing risks in relation to buildings, the Target might be the building or the occupants or both. The QTRA User should consider whether occupants are either protected from harm by the structure or substantially exposed to the impact from the falling tree or branch.

For Property Targets, all of the consequence of tree failure is considered in the estimated cost of repair or replacement. Therefore, the Size component is not used in the calculation because the Size of the tree or branch has already been fully accounted for when estimating the amount of damage it would cause if it failed. An example might be a tree that leans across a car park and because it is only a small tree the damage to a car is valued as being low. Had it been a larger tree, more damage would have been anticipated and perhaps a different Target Range selected.

When using the QTRA manual calculator, the QTRA User must select 'Property' on the Size vane and as a result, size will have no effect on the Risk of Harm. The software application does not allow Size to be selected for a risk calculation in relation to a Property Target.

Unoccupied vehicles are considered as property and on the basis of an average vehicle value of £8 500 (in the UK). Where a parking space is occupied by a known vehicle, the repair or replacement value could be appraised more accurately if necessary.

When considering Property Targets, the QTRA User should ask 'if this tree or branch falls onto that Target what is the likely range of cost for the repair or replacement of the property and which QTRA Target Range does it fall within?

If the value is greater than £2 000 000, a Multiple Target must be used.

The estimate need only be sufficient to put the cost into one of the QTRA Target Ranges for Property.

International VOSL Conversion

In January each year, Quantified Tree Risk Assessment Limited will publish currency conversions of Target Ranges for Property in the currencies of all Registered Users. VOSL values for 2018 are listed at Table 2.

Table 2. International VOSL Conversion

Country	Currency	VOSL*
United Kingdom	Pound sterling (GBP)	£2 000 000
Australia	Australian dollar (AUD)	$3 800 000
Canada	Canadian dollar (CAD)	$3 400 000
Czech Republic	Czech Republic koruna (CZK)	60 000 000Kč
Denmark	Danish Krona (DKK)	Kr18 000 000
European Union	Euro (EUR)	€2 200 000
Hong Kong	Hong Kong dollar (HKD)	$22 00 000
New Zealand	New Zealand dollar (NZD)	$4 000 000
Poland	Polish Zloty (PLN)	Zł10 000 000
Singapore	Singapore dollar (SGD)	$3 600 000
South Africa	South African rand (ZAR)	R44 000 000
Sweden	Swedish Krona (SEK)	24 000 000kr
United States	US dollar (USD)	$2 800 000

* Based on the interbank exchange rate supplied by www.oanda.com (1/1/2022)

Multiple Target Occupancy

A Target might, on average over a year, be constantly occupied by more than one person and QTRA allows for this to be accounted for. For example, if it is projected that the average occupation will be constant by 10 people, the Risk of Harm is calculated in relation to one person constantly occupying the Target before going on to identify that the average occupation is 10 people. This is expressed as Target 1(10T)/1, where 10T represents the multiple Target. In respect of property, 1(10T)/1 would be equivalent to a loss of £20 000 000 as opposed to £2 000 000.

Tree or Branch Size

In the quantification of risk from falling trees, stem or branch mass is probably the most realistic available measure of the likely force upon impact. The relationship between the diameter and the mass of the stem or branch provides a readily measurable estimate of this.

A small dead branch of less than 25mm (millimetres) diameter is unlikely to cause significant harm even in the case of direct contact with a Target and is not considered in QTRA. A falling branch with a diameter greater than 450mm is likely to cause harm in the event of contact with all but the most robust Targets. The increased potential for damage or 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 significant. Similarly, most property likely to be affected by tree failure can sustain only a limited amount of damage before further damage is likely to be inconsequential, i.e. when it is beyond economic repair.

The mass of a falling tree or branch contributes to the force that will be generated upon impact with a Target but is not the sole determinant. The distance and orientation of fall will influence the force upon impact. Other trees or branches might impede the path of a falling tree or branch and it might be predicted that the failure of a branch will result in it being hung-up without presenting an immediate danger or alternatively, that it might fall unimpeded.

It is unrealistic to attempt to calculate the effect of branch orientation, or the height from which a branch could fall. It is, however, necessary to be aware of factors other than mass that can contribute to the force upon impact but these factors should be recorded only where they are considered particularly significant in a given situation.

The method categorises the Size component of the risk from the diameter of tree stems and branches. An equation derived from weight measurements of trees of different stem diameters (Tritton & Hornbeck 1982) has been used to produce a data set (Table 3) of comparative weight estimates of trees and branches ranging from 25 to 600 mm basal diameter.

Table 3. Weight Estimates

Diameter (mm)	Dry weight (kg) $y=ax^b$	Fraction of dry weight as a ratio
25	1.0713	1/2 471.67
50	5.8876	1/449.74
100	32.357	1/81.83
150	87.67	1/30.2
200	177.82	1/14.89
250	307.77	1/8.6
300	481.81	1/5.5
350	703.8	1/3.76
400	977.26	1/2.71
450	1 305.5	1/2.03
500	1 691.4	1/1.57
550	2 138	1/1.24
600	2 647	1/1

Source. Tritton & Hornbeck (1982)
x=dbh (cm); y=dry weight estimate; a=allometric coefficient 0.1126294414; b= allometric coefficient 2.458309949
Dbh (US - diameter measured at breast height – 1.37 metres)

Table 4. QTRA Target Ranges

Target Range	Property (repair or replacement cost)	Human (not in vehicles)		Vehicle Traffic (number per day)	Ranges of Value (probability of occupation or fraction of £2 000 000)
1	£2 000 000 – >£200 000	Occupation: Pedestrians & cyclists:	Constant – 2.5 hours/day 720/hour – 73/hour	26 000 – 2 700 @ 110kph (68mph) 28 000 – 2 900 @ 100kph (62mph) 31 000 – 3 200 @ 90kph (56mph) 32 000 – 3 300 @ 80kph (50mph) 36 000 – 3 700 @ 70kph (43mph) 42 000 – 4 300 @ 60kph (37mph) 47 000 – 4 800 @ 50kph (32mph)	1/1 – >1/10
2	£200 000 – >£20 000	Occupation: Pedestrians & cyclists:	2.4 hours/day – 15 min/day 72/hour – 8/hour	2 600 – 270 @ 110kph (68mph) 2 800 – 290 @ 100kph (62mph) 3 100 – 320 @ 90kph (56mph) 3 200 – 330 @ 80kph (50mph) 3 600 – 370 @ 70kph (43mph) 4 200 – 430 @ 60kph (37mph) 4 700 – 480 @ 50kph (32mph)	1/10 – >1/100
3	£20 000 – >£2 000	Occupation: Pedestrians & cyclists:	14 min/day – 2 min/day 7/hour – 2/hour	260 – 27 @ 110kph (68mph) 280 – 29 @ 100kph (62mph) 310 – 32 @ 90kph (56mph) 320 – 33 @ 80kph (50mph) 360 – 37 @ 70kph (43mph) 420 – 43 @ 43kph (37mph) 470 – 48 @ 50kph (32mph)	1/100 – >1/1 000
4	£2 000 – >£200	Occupation: Pedestrians & cyclists:	1 min/day – 2 min/week 1/hour – 3/day	26 – 4 @ 110kph (68mph) 28 – 4 @ 100kph (62mph) 31 – 4 @ 90kph (56mph) 32 – 4 @ 80kph (50mph) 36 – 5 @ 70kph (43mph) 42 – 5 @ 60kph (37mph) 47 – 6 @ 50kph (32mph)	1/1 000 – >1/10 000
5	£200 – >£20	Occupation: Pedestrians & cyclists:	1 min/week – 1 min/month 2/day – 2/week	3 – 1 @ 110kph (68mph) 3 – 1 @ 100kph (62mph) 3 – 1 @ 90kph (56mph) 3 – 1 @ 80kph (50mph) 4 – 1 @ 70kph (43mph) 4 – 1 @ 60kph (37mph) 5 – 1 @ 50kph (32mph)	1/10 000 – >1/100 000
6	£20 – £2	Occupation: Pedestrians & cyclists:	<1 min/month – 0.5 min/year 1/week – 6/year	None	1/100 000 – 1/1 000 000

Vehicle, pedestrian and property Targets are categorised by their frequency of use or their monetary value. The probability of a vehicle or pedestrian occupying a Target area in Target Range 4 is between the upper and lower limits of >1/1 000 and 1/10 000 (column 5). Using the VOSL £2 000 000, the property repair or replacement value for Target Range 4 is £2 000 - >£200.

An upper limit of 600mm has been selected to represent a 1/1 value for the Size component of the QTRA calculation on the presumption that an 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 value reduces to 1/2 500 for a 25mm branch.

Often the degradation of dead branches substantially reduces their mass. Where considered appropriate by the QTRA User, the reduced mass of branches can be calculated into the risk assessment by multiplying Risk of Harm by the fraction of mass that remains. If a branch is thought to be degraded to less than half of its original mass, multiply the Risk of Harm by 1/2. Only two multipliers are recommended; 1/2 and 1/4. To carry out this additional calculation, the Risk of Harm is multiplied by the Reduced Mass vale. E.g. Risk of Harm 1/20 000 x Reduced Mass 1/4 = 1/80 000.

Table 5. QTRA Size Ranges

Size Range	Size of tree or branch	Impact Potential
1	> 450mm (>18") dia.	1/1 - >1/2
2	450mm (18") dia.- 260mm (10$^1/_2$") dia.	1/2 - >1/8.6
3	250mm (10") dia. - 110mm (4$^1/_2$") dia.	1/8.6 - >1/82
4	100mm (4") dia. - 25mm (1") dia.	1/82 - 1/2 500

* Range 1 is based on a diameter of 600mm.

When considering the size of a tree or branch, the QTRA User should estimate the diameter (away from any basal taper or growth anomaly). The estimate need only be sufficient to put the tree or branch into one of the QTRA Size Ranges.

If a tree or branch is particularly small for its diameter and at the bottom of a Size Range, the QTRA User might consider using the next lowest Size Range.

In the case of dead branches, the QTRA User might consider that the branch is degraded to such an extent that its size should be discounted to either a half or a quarter of the value for an average branch of the same diameter. In this situation, a Reduced Mass multiplier is applied as described above.

Probability of Failure

The Probability of Failure within the coming year for the tree or branch is assessed against two benchmarks and recorded in the QTRA assessment as a Range of value (Table 6).

Selecting a Probability of Failure Range requires the assessor to consider the structural state of the tree or branch and the environmental conditions that it is exposed to. It should then be considered against a benchmark of either the structurally acclimatised tree at Probability of Failure Range 7, or a tree or branch that is between certain to fail (1/1) and a greater than a 1/10 chance of failing within the year, which is represented by Probability of Failure Range 1.

The lower benchmark Range 7 (1/1 000 000 to 1/10 000 000) represents the structurally acclimatised tree or branch that presents no signs of being structurally compromised, has been selected on the basis that the UK Health and Safety Executive as a regulator acting on behalf of wider society have stated in their publication 'Reducing Risk Protecting People' (HSE 2001) "HSE believes that an individual risk of death of one in a million per annum for both workers and the public corresponds to a very low level of risk and should be used as the boundary between the broadly acceptable and tolerable regions" (see fig. 1, page 4). On this basis, it is reasonable to assume that because society accepts the presence of many large trees in high occupation areas of our towns and cities as a broadly acceptable the risk of death from these trees must be as low as, or lower than, 1/1 000 000.

The QTRA User will estimate and record as a QTRA Range, the Probability of Failure for the tree or branch over the coming year under prevailing weather conditions.

If the tree or branch is structurally compromised then we must follow the three-stage process outlined in figure 4 and first ask the question, 'Which of the benchmarks is the tree or branch closest to, Range 7 or Range 1?

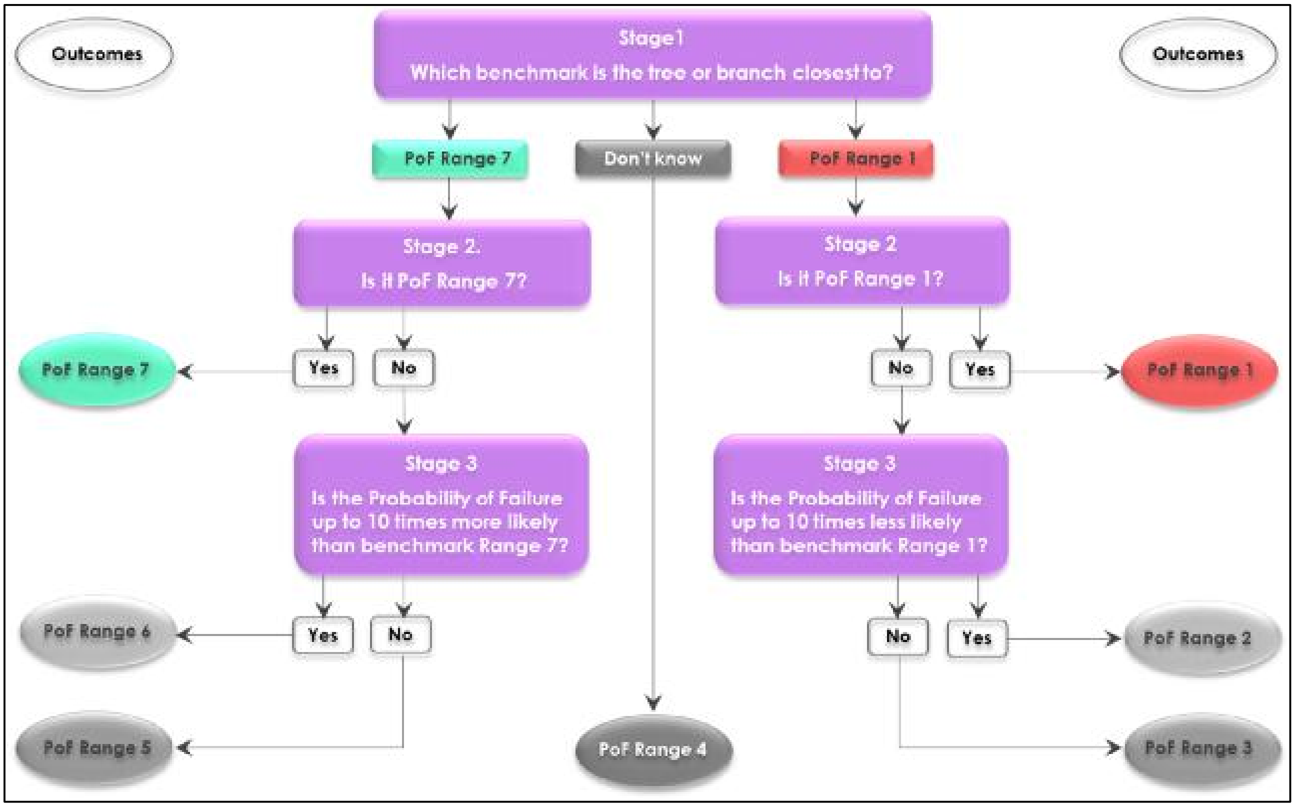
Using the benchmarking process and a range of examples during QTRA training, QTRA Registered Users are able to calibrate their estimates of Probability of Failure and compare them with other trainees under the guidance of the instructor.

Table 6. QTRA Probability of Failure Ranges

Probability of Failure Range	Probability of Failure
1	1/1 - >1/10
2	1/10 - >1/100
3	1/100 - >1/1 000
4	1/1 000 - >1/10 000
5	1/10 000 – >1/100 000
6	1/100 000 – >1/1 000 000
7	1/1 000 000 – 1/10 000 000

The probability that the tree or branch will fail within the coming year.

Fig. 4 QTRA Estimating Probability of Failure - the process



Assessment of the structural condition of trees is well documented elsewhere (Lonsdale 1999; Matheny & Clark 1994; Mattheck and Breloer 1994) and is not discussed here.

Risk of Harm Calculation

Having identified and recorded QTRA Ranges for Target, Size and Probability of Failure, the QTRA User should select the corresponding Ranges on either the QTRA manual calculator or the software application.

The input Ranges and Risk of Harm and should be recorded against the tree or group of trees along with Multiple Targets and Reduced Mass if they have been applied.

The assessor selects a Range of values for each of the three input components, Target, Size, and Probability of Failure. The Ranges are entered on either the QTRA manual calculator or software application where they are combined to produce a Risk of Harm.

It should be noted that, due to limited space on the manual calculator, Probability of Failure Range 1 does not calculate, but all possible outcomes for this Range are printed on the rear of the calculator.

The QTRA manual calculator and software application display a colour coded Risk of Harm. The colours represent the bands of risk in Table 7, page 15.

Risk of Harm - Monte Carlo Simulations

The Risk of Harm for all possible combinations of Target, Size and Probability of Failure has been calculated using Monte Carlo simulations[7]. A calculation has been run 10 000 times for each possible combination of input Ranges. The outcomes are the mean values from each set of results.

The Risk of Harm SHOULD NOT be calculated without the manual calculator or software application.

[7] For further information on the Monte Carlo simulation method, refer to http://en.wikipedia.org/wiki/Monte_Carlo_method

Assessing Groups and Populations of Trees

When assessing populations or groups of trees, the highest risk in the group is quantified and if that risk is tolerable, it follows that risks from the remaining trees will also be tolerable, and further calculations are unnecessary. Where the risk is unacceptable, the next highest risk will be quantified, and so on until a tolerable risk is established. The Risk of Harm recorded for a group of trees should be the residual risk after the Risk of Harm for any individually assessed trees has been recorded.

6. INFORMING MANAGEMENT DECISIONS

Applying the ToR Framework to QTRA

In applying ToR to QTRA, there are three threshold values. A Risk of Harm less than 1/1 000 000 is Broadly Acceptable (green) and already ALARP. A Risk of Harm 1/1 000 or greater (red) is unacceptable and will not ordinarily be tolerated. Between these two thresholds, the Risk of Harm is in the Tolerable region of ToR and will be tolerable if it is ALARP; but a Risk of Harm 1/10 000 or greater (amber) will not ordinarily be Tolerable where it is imposed on others, such as the public. Here, management decisions are informed by consideration of the costs and benefits of risk control, including benefits provided by trees that would be lost to risk control measures. Where a risk is between 1/100 000 and <1/10 000 it is in the Tolerable region, but it has no resilience and if The Probability of Failure increases by one range before the next review, the risk will move from yellow to amber. In these circumstances it is particularly important to consider whether the risk is likely to get worse, remain the same or reduce before the next review, and if it is an imposed risk and the is expected to increase it is unlikely to be ALARP.

Balancing Costs and Benefits of Risk Control

When controlling risks from falling trees, the benefit of reduced risk is obvious, but the costs of risk control are often less apparent. For every risk reduced there will be costs, and the most obvious of these is the financial cost of implementing the control measure. Frequently overlooked is the transfer of risks to workers and the public who might be directly affected by the removal or pruning of trees. Perhaps more importantly, most trees confer benefits, the loss of which should be considered as a cost when balancing the costs and benefits of risk control.

When balancing risk management decisions using QTRA, consideration of the benefits from trees will usually be of a very general nature and not require detailed consideration. The tree manager can consider, in simple terms, whether the overall cost of risk control is proportionate. Where risks are approaching 1/10 000, this may be a straightforward balancing of cost and benefits. Where risks are 1/10 000 or greater, it will usually be appropriate to implement risk controls unless the costs are grossly disproportionate to the benefits rather than simply disproportionate. In other words, the balance being weighted more on the side of risk control with higher associated costs.

There will be occasions when a tree is of such minimal value and the monetary cost of risk reduction so low that it might be reasonable to further reduce an already relatively low risk. Conversely, a tree might be of such considerable value that an annual risk of death greater than 1/10 000 would be deemed tolerable.

Occasionally, decisions will be made to retain elevated risks because the benefits from the tree are particularly high or important to stakeholders, and in these situations, it might be appropriate to assess and document the benefits in some detail. If detailed assessment of benefits is required, there are several methodologies and sources of information (Forest Research 2010).

Considering the Benefits from Trees

It is necessary to consider the benefits provided by trees, but they cannot easily be monetised and it is often difficult to place a value on those attributes such as habitat, shading and visual amenity that might be lost to risk control.

Fig. 5

A simple approach to considering the value of a tree is proposed here, using the concept of 'average benefits'. When considered against other similar trees, a tree providing 'average benefits' will usually present a range of benefits that are typical for the species, age and situation. Viewed in this way, a tree providing 'average benefits' might appear to be low when compared with particularly important trees – such as those in Figure 5, but should nonetheless be sufficient to offset a Risk of Harm of less than 1 / 10 000. Without having to consider the benefits of risk controls in any detail, we might reasonably assume that below 1 / 10 000, the risk from a tree that provides 'average benefits' is ALARP.

In contrast, if it can be said that the tree provides lower than average benefits because, for example, it is declining and in poor physiological condition, it may be necessary to consider two further elements. Firstly, is the Risk of Harm in the upper part of the Tolerable Region, and secondly, is the Risk of Harm likely to increase before the next review because of an increased Probability of Failure? If both these conditions apply then it might be appropriate to consider the balance of costs and benefits of risk reduction in order to determine whether the risk is ALARP. This balance requires the tree manager to take a view of both the reduction in risk and the costs of that reduction. Here, VOSL can be used to inform a decision on whether the cost of risk control is proportionate. Example 3 (page 16) puts this evaluation into a tree management context.

Lower Than Average Benefits from Trees

Usually, the benefits provided by a tree will only be significantly reduced below the 'average benefits' that are typical for the species, age and situation, if the life of the benefits is likely to be shortened, perhaps because the tree is declining or dead. That is not to say that a disbenefit, such as undesirable shading, lifting of a footpath, or restricting the growth of other trees, should not also be considered in the balance of costs and benefits.

The horse chestnut tree in figure 6 has recently died, and may provide valuable habitats over the next few years. However, for this tree species and the relatively fast rate at which its wood decays, the lifetime of these benefits is likely to be limited to only a few years. This tree has an already reduced value that will continue to reduce rapidly over the coming five to ten years at the same time as the Risk of Harm is expected to increase. There will be changes in the benefits provided by the tree as it degrades. Visual qualities are likely to reduce while the decaying wood provides habitats for a range of species, for a short while at least. There are no hard and fast measures of these benefits and it is for the tree manager to decide what is locally important and how it might be balanced with the risks.

Delegating Risk Management Decisions

Understanding of the costs with which risk reduction is balanced can be informed by the risk assessor's knowledge, experience and on-site observations, but the risk management decisions should be made by the tree manager. That is not to say that the tree manager should review and agree every risk control measure, but when delegating decisions to surveyors and other staff or advisors, tree managers should set out in a policy, statement or contract, the principles and perhaps thresholds to which trees and their associated risks will ordinarily be managed.

QTRA Advisory Risk Thresholds

The QTRA advisory thresholds in Table 7 are proposed as a reasonable approach to balancing safety from falling trees with the costs of risk reduction. This approach takes account of the widely applied principles of ALARP and ToR, but does not dictate how these principles should be applied. While the thresholds can be the foundation of a robust policy for tree risk management, tree managers should make decisions based on their own situation, values, resources and priorities. Importantly, to enable tree assessors to provide appropriate management guidance, it is helpful for them to have some understanding of the tree owner's management objectives and priorities before assessing the trees.

A Risk of Harm that is less than 1 / 1 000 000 is Broadly Acceptable and is already ALARP. A Risk of Harm 1 / 1 000 or greater is unacceptable and will not ordinarily be tolerated. Between these two values, the Risk of Harm is in the Tolerable Region of ToR and will be tolerable if it is ALARP. In the Tolerable Region, management decisions are informed by consideration of the costs and benefits of risk control, including the nature and extent of those benefits provided by trees, which would be lost to risk control measures.

Table 7. QTRA Advisory Risk Thresholds

Thresholds	Description	Action
	Unacceptable Risks will not ordinarily be tolerated	• Control the risk
1/1 000	Unacceptable (where imposed on others) Risks will not ordinarily be tolerated	• Control the risk • Review the risk
	Tolerable (by agreement) Risks may be tolerated if those exposed to the risk accept it, or the tree has exceptional value	• Control the risk unless there is broad stakeholder agreement to tolerate it, or the tree has exceptional value • Review the risk
1/10 000	Tolerable (where imposed on others) Risks are tolerable if ALARP	• Assess costs and benefits of risk control • Control the risk only where a significant benefit might be achieved at reasonable cost • Review the risk
1/1 000 000	Broadly Acceptable Risk is already ALARP	• No action currently required • Review the risk

For the purpose of managing risks from falling trees, the Tolerable Region can be further broken down into two sections. From 1/1 000 000 to less than 1/10 000, the Risk of Harm will usually be tolerable providing that the tree confers 'average benefits' as discussed above. As the Risk of Harm approaches 1/10 000 it will be necessary for the tree manager to consider in more detail the benefits provided by the tree, the direction in which the risk might move, and the overall cost of mitigating the risk.

A Risk of Harm in the Tolerable Region, of 1/10 000 or greater, will not usually be tolerable where it is imposed on others, such as the public, and if retained, will require a more detailed consideration of ALARP. In some circumstances a tree owner might choose to retain a Risk of Harm that is 1/10 000 or greater. Such a decision might be based on the agreement of those who are exposed to the risk, or perhaps that the tree is of great importance. In these situations, the prudent tree manager will consult with the appropriate stakeholders whenever possible.

7. QTRA CALCULATION AND RISK MANAGEMENT DECISION EXAMPLES

Below are three examples of QTRA calculations and application of the QTRA Advisory Thresholds.

Example 1.

	Target		Size		Probability of Failure		Risk of Harm
Range	6	x	1	x	3	=	<1/1 000 000

Example 1 is the assessment of a large (Size 1), defective tree with a probability of failure of between 1/100 and >1/1 000 (PoF 3). The Target is a footpath with less than one pedestrian passing the tree each week (Target 6). The Risk of Harm is calculated as less than 1/1 000 000 (green). This is an example of where the Target is so low that calculation of the Risk of Harm, of even a large tree, would not usually be necessary. It is already clear that the Risk of Harm is less than 1/1 000 000.

Example 2.

	Target		Size		Probability of Failure		Risk of Harm
Range	1	x	4	x	3	=	1(2T)/50 000

In Example 2, a recently dead branch (Size 4) overhangs a busy urban high street that is on average occupied constantly by two people, and here Multiple Target occupation is considered.

Having an average occupancy of two people, the Risk of Harm 1(2T)/50 000 (yellow) represents a twofold increase in the magnitude of the consequence and is therefore equivalent to a Risk of Harm 1/20 000 (yellow). This risk does not exceed 1/10 000, but being a dead branch at the upper end of the Tolerable Region it is appropriate to consider the balance of costs and benefits of risk control. Dead branches can be expected to degrade relatively quickly, with the Probability of Failure increasing as a result. Because it is dead, some of the usual benefits from the branch have been lost and it will be appropriate to consider whether the financial cost of risk control would be proportionate.

Example 3.

	Target		Size		Probability of Failure		Risk of Harm
Range	3	x	3	x	3	=	1 / 500 000

In Example 3, a 200mm diameter defective branch overhangs a country road along which travel between 470 and 48 vehicles each day at an average speed of 50kph (32mph) (Target Range 3). The branch is split and is assessed as having a probability of failure for the coming year of between 1 / 100 and 1 / 1 000 (PoF Range 3). The Risk of Harm is calculated as 1 / 500 000 (yellow) and it needs to be considered whether the risk is ALARP. The cost of removing the branch and reducing the risk to Broadly Acceptable (1 / 1 000 000) is estimated at £350. A simple calculation of VOSL x Risk of Harm can give a broad indication of whether the cost of control is likely to be proportionate to the reduction in risk but should be used only to assist consideration of this balance and not as a standalone decision-making tool. £2 000 000 (VOSL) x 1 / 500 000 = £4 indicating that the projected cost of £350 would be disproportionate to the benefit. Taking account of the financial cost, risk transfer to arborists and passers-by, the cost could be described as being grossly disproportionate, even if accrued benefits over say ten years were taken into account.

8. WALKOVER RISK ASSESSMENT

The walkover tree risk assessment should be the default starting point for the risk assessment of any tree population. The purpose of a walkover tree risk assessment is to identify the general nature of the tree population and its relationship with significant Targets. The level of detail with which the trees are assessed will be informed by their relationship with Targets. Large trees adjacent to higher value Targets would ordinarily require closer assessment than smaller trees adjacent to a lower value Target.

The survey should record individually significant trees in a way that they can be readily related to the group, compartment or area within which they are located. The walkover tree risk assessment should follow the methodology described at section 9.

9. ASSESSMENT OF SITE AND TREES

Stepwise Procedure for a Walkover Risk Assessment

1. Assess the site for Targets. The detail of this assessment will be led by the general nature of both site and trees.

2. Map and assess the tree population in broad or areas groups in relation to the Targets. Grouping to be informed by the character of the tree population and relationship with Targets.

3. A walkover tree risk assessment might describe collections of trees as:
   a. ‘Groups’ for trees in relatively discreet collections
   b. ‘Areas’ for trees in loose collections, perhaps comprising scattered individuals and small groups
   c. ‘Compartments’ if there is need to subdivide large groups or woodlands

4. A group, area or compartment comprising several or many trees that can be grouped by their common attributes can first be assessed as a whole.

5. Make a sufficient record of any significant observations and findings to inform any future assessment and any management that is being proposed.

6. Assess the trees at an appropriate level of detail in relation to the Targets.

7. Calculate and record those risks likely to exceed a chosen threshold, e.g. Risk of Harm 1 in 100 000 or 1 / 1 000 000.

8. Having identified, calculated any significantly elevated risks and made individual records of them, record the residual risk for the group. If there are no significantly elevated risks, record that no significant risks were identified, or that the risk is less than 1 / 1 000 000.

9. If risk control is required, provide management options.

During the group assessment, trees may be identified as requiring detailed assessment or investigation. How and when these trees are assessed will usually be dependent upon the brief the inspector is working to. Where the tree manager’s instruction or the organisation’s policy permits, it is usually most cost effective to assess individual trees during the walkover tree risk assessment. If resources limit the walkover tree risk assessment to a broad assessment, the presence of significant individual trees should be recorded and their assessment carried out when resources permit or when an instruction or contract has been issued.

Stepwise Procedure for the Assessment of Individual Trees

1. Assess the tree in relation to the Targets.
2. Is additional information required, such as specialist investigation or testing, or further information on the site and how it is used? Can this information be obtained at a reasonable cost, or should the risk be controlled based on the available information?
3. Identify, calculate and record any significant risks. If there are none, record that no significant risks were identified, or that the risk is less than 1/1 000 000.
4. If risk control is required, provide management options.

10. RISK REDUCTION

The Role of the Tree Assessor

The role of the tree assessor is to assess the tree at whatever level is instructed or agreed by the instructing party and to report findings and options for management. Informed by risk assessment, and inspections the manager must then make the management decisions. In some circumstances more than one management option may be appropriate. The tree assessor should provide options for risk management based on the need to reduce the risk to the level agreed with the client. Where management is under consideration for reasons other than safety, the tree assessor should distinguish clearly between management options provided for safety reasons and options for other purposes.

Notification of High Risks

High risks identified during the risk assessment should be notified to the client at the earliest opportunity.

Modifying Targets

Where arboricultural intervention could have a significant effect on the value of trees, modification of Targets should be considered. Moving a park bench or obstructing a desire-line footpath are simple examples of modifying Targets to eliminate or reduce the need for arboricultural intervention.

11. MANAGEMENT GUIDANCE

Consultation

It is important to engage with stakeholders to identify and reconcile different management objectives, especially on sites where old and perhaps structurally unstable trees are present.

Policy

To manage tree safety effectively and at reasonable cost, tree managers should develop a tree safety policy with aims and a plan for achieving them. For municipalities and other large organisations, a tree safety policy will be influenced by the organisation's strategic approach to managing trees, landscape and ecology, and will usually require consultation with a range of stakeholders.

Whilst it might not be documented, the approach taken by an individual with responsibility for a small number of trees in a private garden should consider the same components and the same general issues as the policy of a large organisation.

A documented policy should set out the aims of the tree manager and how they will be achieved. In most situations, the aims will centre on achieving maximum value, whatever that might be in any given situation, and the maintenance of risks at levels that are reasonable and either acceptable or tolerable to society or to those more specifically affected by them. These primary objectives should be achieved at a reasonable cost. It is inappropriate to either spend disproportionate resources on risk reduction or to disproportionately diminish the value of the tree resource. Consideration of what is proportionate is a matter for the tree manager, and a robust policy will balance all of the issues affected by it to achieve the most desirable outcomes possible.

Forward Planning

Forward planning can design out some potentially high-risk situations. For example, if a glass-roofed cafeteria is constructed in an open area rather than adjacent to trees, a potentially high-risk situation may be avoided. The positioning of car parking, bus stops, outdoor seating and play areas are elements of design that, amongst others, can affect tree safety management.

Arboricultural Works

When recommending remedial action, the tree assessor should consider the effects of arboricultural works in the short, medium and long term. What is in the best long-term interest of the client and the trees? Provide a range of management options, where appropriate and in your advice, guide the client by providing interpretation. All arboricultural operations should be specified and implemented in accordance with current best practice in the form of National Standards and Industry Guidance.

Interpretation

Always provide sufficient information to enable the client to accurately interpret your findings and advice. You probably have a far greater understanding of tree risk assessment than your client so whenever possible set out a clear proposal and have the client instruct you on the basis of your own specification.

Accuracy of Outputs

The purpose of QTRA is not necessarily to provide high degrees of accuracy, but to provide for the quantification of risks from falling trees in a way that a risk can be assessed within broad ranges where this is sufficient and with greater rigour when required.

Where the input values are broadly estimated, the proposed risk thresholds should be applied cautiously. Where the manager is reasonably confident in the input values, the thresholds can be more rigorously applied. An example of this would be where, based on an initial brief assessment, a recreational woodland Target is estimated to be within range 5 (up to one person passing each day). As a result, no tree in the woodland can achieve a 'Risk of Harm' exceeding 1/40 000. Even with a large unstable tree the 'general limit of tolerability' (Target Range 5, Size Range 1, Probability of Failure Range 1 = Risk of Harm 1/40 000). If the estimate of occupancy is based on accurate historical data and providing that the trees cannot be demonstrated to be of particularly low value, their detailed assessment should not be required for safety purposes. However, in order to make a decision not to assess the trees, it would be necessary to be reasonably confident that the Target valuation is either based on accurate data or an over estimate. If the landowner had estimated an occupation of one pedestrian per week, one could be reasonably confident that there would have been no need to assess the trees because range 5 values the Target between 2 pedestrians per day and 2 pedestrians per week. Conversely, where the occupancy could be as high as two or three people a day, it might be appropriate to monitor and measure occupation more accurately.

REFERENCES

DfT. 2006. Department for Transport. Transport Statistics Bulletin - National Travel Survey 2005. Transport Statistics, London. 60 pp.

Forest Research. 2010. Benefits of green infrastructure - Report by Forest Research. Forest Research, Farnham, Surrey. 42 pp.

Health and Safety at Work Act. 1974. Elizabeth II. Her Majesty's Stationery Office, London.

HSE. 1995. Health and Safety Executive. Generic Terms and Concepts in the Assessment and Regulation of Industrial Risks. Discussion Document. HSE. Books, Sudbury, Suffolk. 43 pp.

HSE. 1996. Health and Safety Executive. Use of Risk Assessment Within Government Departments. Report prepared by the Interdepartmental Liaison Group on Risk Assessment. HSE Books, Sudbury, Suffolk. 48 pp.

HSE. 2001. Health and Safety Executive. Reducing Risks: Protecting People. HSE Books, Sudbury, Suffolk. 80pp. Available for download at http://www.hse.gov.uk/risk/theory/r2p2.pdf

HSE. 2013. Health & Safety Executive. ***Sector Information Minute - Management of the risk from falling trees or branches***. Health & Safety Executive, Bootle, [online]. Available for download at http://www.hse.gov.uk/foi/internalops/sims/ag_food/010705.htm (accessed 05/11/2013).

Helliwell, D. R. 1990. Acceptable Level of Risk Associated with Trees. Arboric. Jour. Vol. 14 No. 2:159-162.

Helliwell, D. R. 1991. Letters to the Editor, Arboric. Jour. Vol. 15 No. 2:179.

ISO 2018. ISO Guide 73. Risk Management Vocabulary. International Organization for Standardization. Geneva. 15 pp.

Lonsdale, D. 1999. Principles of Tree Hazard Assessment. Her Majesty's Stationery Office, London. 388 pp.

Mattheck, C. and Breloer, H. 1994. The Body Language of Trees. Her Majesty's Stationery Office, London. 241 pp.

Matheny, N. P. and J. R. Clark. 1994 (2nd ed.) A Photographic Guide to the Evaluation of Hazard Trees in Urban Areas. International Society of Arboriculture, Savoy, Illinois. 85 pp.

Mynors, C. 2011. The Law of Trees, Forests and Hedgerows. Sweet & Maxwell, London. 961 pp.

Paine, L. A. 1971. Accident Hazard: Evaluation and control decisions on forested recreation sites. Research paper 68/1971 of the USDA Forest Service. 10 pp.

Transport Statistics Great Britain. 1997. Her Majesty's Stationery Office, London.

Tritton, L. M. and Hornbeck, J. W. 1982. Biomass Equations for Major Tree Species. General Technical Report NE69. United States Department of Agriculture.

Acknowledgments

I would like to thank everyone who has contributed comments over more than twenty years since the first murmurings of Quantified Tree Risk Assessment. Users of the method have made regular contributions to discussion and debate that has moved the management of tree safety forward to a place where it is now possible to justify reasonable management decisions rather than simply pass the buck.

Mike Ellison.

APPENDIX 1

SAMPLE SURVEY SCHEDULES

WALKOVER TREE RISK SURVEY

SITE:	**SURVEYOR:**
CLIENT:	**ASSESSMENT DATE:**
BRIEF:	**VIEWING CONDITIONS:**
	JOB REFERENCE:

PAGE:

REF.	SPECIES	AGE RANGE	HEIGHT (M)	DIA. (MM)	VITALITY	TARGET RANGE	SIZE RANGE	POF RANGE	REDUCED MASS %	RISK OF HARM	PRIORITY
						RISK ASSESSMENT DESCRIPTION (TREE/BRANCH & TARGET)					

COMMENTS	MANAGEMENT

VERSION 5.10-16

HEADINGS & ABBREVIATIONS

REF: REFERENCE FOR THE GROUP OR COMPARTMENT,
SPECIES: THREE TO FIVE CHARACTER ABBREVIATION OF COMMON NAMES OF THE SPECIES BEING RECORDED
AGE RANGE: Y = YOUNG, SM = SEMI-MATURE, EM = EARLY-MATURE, M = MATURE, PM = POST-MATURE
HEIGHT: MEASURED OR ESTIMATED HEIGHT (IDENTIFY WHERE HEIGHTS ARE ESTIMATED)
DIA: LARGEST STEM DIAMETER FOR THE GROUP - MEASURED AT A HEIGHT OF APPROXIMATELY 1.5 METRES
VITALITY: A MEASURE OF PHYSIOLOGICAL CONDITION. D = DEAD, MD = MORIBUND, P = POOR, R = REDUCED FOR THE SPECIES AND AGE, N = WITHIN THE NORMAL RANGE FOR THE SPECIES AND AGE
SIZE RANGE: QTRA SIZE RANGE OF THE TREE OR BRANCH THAT HAS BEEN ASSESSED.
POF RANGE: QTRA RANGE OF PROBABILITY OF FAILURE WITHIN 12 MONTHS.
TARGET RANGE: QTRA TARGET RANGE. WHERE THERE IS CONSTANT OCCUPATION OF THE TARGET BY MORE THAN ONE PERSON, OR A PROERTY TARGET HAS A REPAIR OR REPLACEMENT VALUE THAT IS GREATER THAN VOSL, THIS IS EXPRESSED AS A 'MULTIPLE TARGET E.G. CONSTANT OCCUPATION BY 10 PEOPLE WOULD BE EXPRESSED AS TARGET RANGE 1(10T). THE 'MULTIPLE TARGET IS THEN CARRIED THROUGH TO THE RISK OF HARM TO IDENTIFY THE INCREASED CONSEQUENCE
REDUCED MASS % WHERE THE MASS OF A BRANCH IS REDUCED BY DEGRADATION THE RISK OF HARM IS MULTIPLED BY A FRACTION OF EITHER 1/4 OR 1/2 TO REFLECT THE REMAINING PROPORTION OF THE ORIGINAL BRANCH
RISK OF HARM: THE RISK OF HARM FOR THE COMING YEAR
PRIORITY: MANAGEMENT PRIORITIES (AS COMMUNICATED TO THE CLIENT. THIS MIGHT BE A SIMPLE SCALE OF HIGH TO LOW, A NUMERIC SCALE, OR OTHER FORM OF PRIORITISATION)
RISK ASS. DESCRIP: DESCRIPTION OF THE TREE/BRANCH AND TARGET THAT HAS BEEN ASSESSED

INDIVIDUAL TREE RISK SURVEY (A)

SITE:	
CLIENT:	
BRIEF:	

SURVEYOR:	
ASSESSMENT DATE:	
VIEWING CONDITIONS:	
JOB REFERENCE:	

PAGE:

REF.	SPECIES	AGE RANGE	HEIGHT (M)	CROWN SPREAD	STEM DIA. (MM)	VITALITY	RISK ASSESSMENT DESCRIPTION (TREE/BRANCH & TARGET)	TARGET RANGE	SIZE RANGE	POF RANGE	REDUCED MASS %	RISK OF HARM	PRIORITY

COMMENTS	**MANAGEMENT**

COMMENTS	**MANAGEMENT**

VERSION 5.10-16

HEADINGS & ABBREVIATIONS

REF:	REFERENCE FOR THE TREE,
SPECIES:	THREE TO FIVE CHARACTER ABBREVIATION OF COMMON NAMES OF THE SPECIES BEING RECORDED
AGE RANGE:	Y = YOUNG, SM = SEMI-MATURE, EM = EARLY-MATURE, M = MATURE, PM = POST-MATURE
HEIGHT:	MEASURED OR ESTIMATED HEIGHT (IDENTIFY WHERE HEIGHTS ARE ESTIMATED)
DIA:	STEM DIAMETER - MEASURED AT A HEIGHT OF APPROXIMATELY 1.5 METRES
VITALITY:	A MEASURE OF PHYSIOLOGICAL CONDITION. D = DEAD, MD = MORIBUND, P = POOR, R = REDUCED FOR THE SPECIES AND AGE, N = WITHIN THE NORMAL RANGE FOR THE SPECIES AND AGE
SIZE RANGE:	QTRA SIZE RANGE OF THE TREE OR BRANCH THAT HAS BEEN ASSESSED.
POF RANGE:	QTRA RANGE OF PROBABILITY OF FAILURE WITHIN 12 MONTHS.
TARGET RANGE:	QTRA TARGET RANGE. WHERE THERE IS CONSTANT OCCUPATION OF THE TARGET BY MORE THAN ONE PERSON, OR A PROERTY TARGET HAS A REPAIR OR REPLACEMENT VALUE THAT IS GREATER THAN VOSL, THIS IS EXPRESSED AS A 'MULTIPLE TARGET E.G. CONSTANT OCCUPATION BY 10 PEOPLE WOULD BE EXPRESSED AS TARGET RANGE 1(10T). THE 'MULTIPLE TARGET IS THEN CARRIED THROUGH TO THE RISK OF HARM TO IDENTIFY THE INCREASED CONSEQUENCE
REDUCED MASS %	WHERE THE MASS OF A BRANCH IS REDUCED BY DEGRADATION THE RISK OF HARM IS MULTIPLED BY A FRACTION OF EITHER 1/4 OR 1/2 TO REFLECT THE REMAINING PROPORTION OF THE ORIGINAL BRANCH
RISK OF HARM:	THE RISK OF HARM FOR THE COMING YEAR
PRIORITY:	MANAGEMENT PRIORITIES (AS COMMUNICATED TO THE CLIENT. THIS MIGHT BE A SIMPLE SCALE OF HIGH TO LOW, A NUMERIC SCALE, OR OTHER FORM OF PRIORITISATION)
RISK ASS. DESCRIP:	DESCRIPTION OF THE TREE/BRANCH AND TARGET THAT HAS BEEN ASSESSED

INDIVIDUAL TREE RISK SURVEY (B)

SITE:	**SURVEYOR:**	**PAGE:**
CLIENT:	**ASSESSMENT DATE:**	
BRIEF:	**VIEWING CONDITIONS:**	
	JOB REFERENCE:	

TREE NO.	SPECIES	AGE RANGE	HEIGHT (M)	CROWN SPREAD	STEM DIA. (MM)	VITALITY	COMMENTS	MANAGEMENT	TARGET RANGE	SIZE RANGE	POF RANGE	REDUCED MASS %	RISK OF HARM	PRIORITY
									RISK ASSESSMENT DESCRIPTION (TREE/BRANCH & TARGET)					

VERSION 5.10-16

HEADINGS & ABBREVIATIONS

REF: REFERENCE FOR THE TREE,
SPECIES: THREE TO FIVE CHARACTER ABBREVIATION OF COMMON NAMES OF THE SPECIES BEING RECORDED
AGE RANGE: Y = YOUNG, SM = SEMI-MATURE, EM = EARLY-MATURE, M = MATURE, PM = POST-MATURE
HEIGHT: MEASURED OR ESTIMATED HEIGHT (IDENTIFY WHERE HEIGHTS ARE ESTIMATED)
DIA: STEM DIAMETER - MEASURED AT A HEIGHT OF APPROXIMATELY 1.5 METRES
VITALITY: A MEASURE OF PHYSIOLOGICAL CONDITION. D = DEAD, MD = MORIBUND, P = POOR, R = REDUCED FOR THE SPECIES AND AGE, N = WITHIN THE NORMAL RANGE FOR THE SPECIES AND AGE
SIZE RANGE: QTRA SIZE RANGE OF THE TREE OR BRANCH THAT HAS BEEN ASSESSED.
POF RANGE: QTRA RANGE OF PROBABILITY OF FAILURE WITHIN 12 MONTHS.
TARGET RANGE: QTRA TARGET RANGE. WHERE THERE IS CONSTANT OCCUPATION OF THE TARGET BY MORE THAN ONE PERSON, OR A PROERTY TARGET HAS A REPAIR OR REPLACEMENT VALUE THAT IS GREATER THAN VOSL, THIS IS EXPRESSED AS A ‘MULTIPLE TARGET E.G. CONSTANT OCCUPATION BY 10 PEOPLE WOULD BE EXPRESSED AS TARGET RANGE 1(10T). THE ‘MULTIPLE TARGET IS THEN CARRIED THROUGH TO THE RISK OF HARM TO IDENTIFY THE INCREASED CONSEQUENCE
REDUCED MASS % WHERE THE MASS OF A BRANCH IS REDUCED BY DEGRADATION THE RISK OF HARM IS MULTIPLED BY A FRACTION OF EITHER 1/4 OR 1/2 TO REFLECT THE REMAINING PROPORTION OF THE ORIGINAL BRANCH
RISK OF HARM: THE RISK OF HARM FOR THE COMING YEAR
PRIORITY: MANAGEMENT PRIORITIES (AS COMMUNICATED TO THE CLIENT. THIS MIGHT BE A SIMPLE SCALE OF HIGH TO LOW, A NUMERIC SCALE, OR OTHER FORM OF PRIORITISATION)
RISK ASS. DESCRIP: DESCRIPTION OF THE TREE/BRANCH AND TARGET THAT HAS BEEN ASSESSED

DETAILED INDIVIDUAL TREE RISK INSPECTION

SITE:						
CLIENT:						
BRIEF:	SPECIFIC (DETAIL BELOW)		GENERAL		DETAILED	

SURVEYOR:	
ASSESSMENT DATE:	
VIEWING CONDITIONS:	
JOB REFERENCE:	

PAGE:

NO.	SPECIES	AGE RANGE	HEIGHT (M)	CROWN SPREAD (M)	DIA (MM)	BASAL DIA (MM)	VITALITY	ASPECT	SOIL TYPE AND MOISTURE	LEAN DEGREE & DIRECTION	RISK ASSESSMENT DESCRIPTION (TREE/BRANCH & TARGET)	TARGET RANGE	SIZE RANGE	POF RANGE	REDUCED MASS %	RISK OF HARM	PRIORITY

COMMENTS:

MANAGEMENT:

VERSION 5.10-16

HEADINGS & ABBREVIATIONS

REF: REFERENCE FOR THE TREE,
SPECIES: THREE TO FIVE CHARACTER ABBREVIATION OF COMMON NAMES OF THE SPECIES BEING RECORDED
AGE RANGE: Y = YOUNG, SM = SEMI-MATURE, EM = EARLY-MATURE, M = MATURE, PM = POST-MATURE
HEIGHT: MEASURED OR ESTIMATED HEIGHT (IDENTIFY WHERE HEIGHTS ARE ESTIMATED)
DIA: STEM DIAMETER - MEASURED AT A HEIGHT OF APPROXIMATELY 1.5 METRES
VITALITY: A MEASURE OF PHYSIOLOGICAL CONDITION. D = DEAD, MD = MORIBUND, P = POOR, R = REDUCED FOR THE SPECIES AND AGE, N = WITHIN THE NORMAL RANGE FOR THE SPECIES AND AGE
SIZE RANGE: QTRA SIZE RANGE OF THE TREE OR BRANCH THAT HAS BEEN ASSESSED.
POF RANGE: QTRA RANGE OF PROBABILITY OF FAILURE WITHIN 12 MONTHS.
TARGET RANGE: QTRA TARGET RANGE. WHERE THERE IS CONSTANT OCCUPATION OF THE TARGET BY MORE THAN ONE PERSON, OR A PROERTY TARGET HAS A REPAIR OR REPLACEMENT VALUE THAT IS GREATER THAN VOSL, THIS IS EXPRESSED AS A 'MULTIPLE TARGET E.G. CONSTANT OCCUPATION BY 10 PEOPLE WOULD BE EXPRESSED AS TARGET RANGE 1(10T). THE 'MULTIPLE TARGET IS THEN CARRIED THROUGH TO THE RISK OF HARM TO IDENTIFY THE INCREASED CONSEQUENCE
REDUCED MASS % WHERE THE MASS OF A BRANCH IS REDUCED BY DEGRADATION THE RISK OF HARM IS MULTIPLED BY A FRACTION OF EITHER 1/4 OR 1/2 TO REFLECT THE REMAINING PROPORTION OF THE ORIGINAL BRANCH
RISK OF HARM: THE RISK OF HARM FOR THE COMING YEAR
PRIORITY: MANAGEMENT PRIORITIES (AS COMMUNICATED TO THE CLIENT. THIS MIGHT BE A SIMPLE SCALE OF HIGH TO LOW, A NUMERIC SCALE, OR OTHER FORM OF PRIORITISATION)
RISK ASS. DESCRIP: DESCRIPTION OF THE TREE/BRANCH AND TARGET THAT HAS BEEN ASSESSED

APPENDIX 2

WHAT IS QUANTIFIED TREE RISK ASSESSMENT? – A NON TECHNICAL SUMMARY

What is Quantified Tree Risk Assessment?
A Non-technical Summary

Tree safety management is a matter of balancing the Risk of Harm from falling trees with the benefits from 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 the land on which the trees stand, which in turn will inform the process of assessing the trees.

Quantified Tree Risk Assessment (QTRA) applies established and accepted risk management principles to tree safety management in accordance with ISO 31000:2009, ***Risk management – Principles and guidelines***, which is published by national standards agencies. By quantifying the Risk of Harm as a probability, QTRA enables the tree manager to manage the risk from tree failure to widely accepted risk thresholds.

Using the QTRA approach, the land-use (people and property) upon which trees could fail is assessed and quantified first. This enables tree managers to determine whether or not and to what degree of rigour a survey or inspection of the trees is required. Where necessary, the tree or branch is then considered in terms of both size (potential impact) and probability of failure. Values derived from the assessment of these three components are combined to calculate the risk of harm as a probability, which can then be compared to advisory levels of risk acceptability.

The method moves the management of tree safety away from labelling trees as either ‘safe’ or ‘unsafe’, thereby requiring definitive statements of tree safety from either tree surveyors or tree managers. Instead, QTRA quantifies the risk of significant harm from tree failure in a way that enables tree managers to balance safety with tree value and operate to predetermined risk thresholds.

By taking a QTRA approach to tree risk, tree managers commonly find they spend less resources on assessing and managing tree risk, whilst maximising the benefits their tree populations provide. Furthermore, in the event of a 'tolerable' or 'acceptable' tree risk being realised, they are in a robust position to demonstrate that they have acted reasonably and proportionately.

QTRA Quantified Tree Risk Assessment

T. +44(0)1625 618999
E. admin@qtra.co.uk
W. www.qtra.co.uk

9 Lowe Street
Macclesfield
Cheshire
England
SK11 7NJ