Quantified Tree Risk Assessment Practice Note

1. INTRODUCTION

For a tree-failure hazard to exist, two criteria must be fulfilled. There must be potential for failure of the tree, and potential for injury or damage to result. The tree owner or manager needs to consider the likelihood of a combination of tree failure, people and property resulting in harm, and the likely severity of the harm.

The system enables tree assessors to allocate numerical estimates of risk, which can be compared with a generally accepted level of risk.

2. DEFINITION OF TERMS

Risk of Significant Harm

The risk of significant harm from tree failure is an estimate of the likelihood that within the coming year something of significant value will be lost or substantially harmed by tree failure.

Acceptable Risk

We are constantly exposed to and accept risks of varying degrees. For example, if we desire the convenience of electric lighting, we must accept that, having implemented control measures such as insulation, there remains a low risk of electrocution; this is an everyday risk taken and accepted by millions of people.

Having considered The British Medical Association Guide "Living With Risk" (1987) and with particular reference to the conclusion "*few people would commit their own resources to reduce an annual risk of death that was already as low as 1/10,000*", Helliwell (1990) suggests that 1/10,000 might be a suitable figure to start with as the limit of acceptable risk from tree failure. Furthermore, "*For members of the public who have a risk imposed on them 'in the wider interest' HSE (Health and Safety Executive) would set this limit at 1/10,000 per annum*" (Health and Safety Executive 1996). A tree owner or manager may adopt the 1/10,000 limit of acceptable risk or choose to operate to a higher or lower level.

Cost and Benefit

Trees confer many benefits, being essential to our well being and generally enhancing our built and natural environments. It can therefore be assumed that removal of all tree hazards would lead to certain impoverishment in the quality of human life. It is essential to maintain a balance between the benefits and costs of risk reduction, not only financial cost but also loss of amenity and other tree related benefits.

Value of Statistical Life

'Value of statistical life' is a term used in risk assessment to express the monetary value of an individual life, which is used to apportion resources to risk reduction. In the UK, this value is currently in the region of £750,000 - £1,000,000, (Health and Safety Executive 1995) and is used in Quantified Tree Risk Assessment to correlate the value of damage to property with the value of human life e.g. risk of death 1/2 is equivalent to a loss of property with a value of £500,000.

3. OWNERSHIP OF RISK

Where a risk is being considered in relation to the public at large, the risk of significant harm is a measure of how likely it is that a death or significant harm will result from failure of the tree. This risk usually affects many, largely anonymous, individuals. In these situations the tree owner/manager must make an informed decision and some level of risk will be imposed upon the wider public in the wider interest, unless the tree is removed.

Where the risk of harm relates to a specific individual or a select group of people, those at risk can be identified. Where the individuals otherwise have no control over their exposure to the risk (as with a tree leaning towards a dwelling on neighbouring land) it might, in some situations, be reasonable to allow the exposed person/s to input their views to the risk management process.

4. QUANTIFIED TREE RISK ASSESSMENT

The system quantifies three components of the tree failure risk - 1) target; 2) impact potential and 3) probability of failure. The product of these component probabilities is referred to as the 'Risk of Significant Harm'.

A risk of death 1/10,000 is considered by some authorities to be the limit of acceptable risk to the public at large where it is imposed in the wider interest (Health and Safety Executive 1996). Using the 1/10,000 limit, a risk of death exceeding 1/10,000 requires remedial action to reduce the risk unless the risk is limited to a selective individual or group - such as a tree owner, who may choose to accept a greater or lesser risk. Additionally, the tree might confer benefits that could be set against the risk of harm. The 1/10,000 threshold is not intended to be applied absolutely rigidly but necessarily includes a degree of flexibility.

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 1. 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, it is necessary to consider the approximate cost of repairs or replacement that might be required if the tree or branch under consideration should fail. The 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 the 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.

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 increased by weather such as in case of the phenomenon known as 'Summer 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.

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) 32,359 vehicles @ 80kph (50mph) 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) 1,617 vehicles @ 80kph (50mph) 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) 449 vehicles @ 80kph (50mph) 649 vehicles @ 50kph (32mph)	1/72
4	Moderate value >£57.87 - £1,388	>1 per day - 1 per hour	36 vehicles @ 110kph (68mph) 45 vehicles @ 80kph (50mph) 65 vehicles @ 50kph (32mph)	1/720
5	Low value >£8.60 - £57.87	> 1 per week - 1 per day	1.5 vehicles @ 110kph (68mph) 1.87 vehicles @ 80kph (50mph) 2.7 vehicles @ 50kph (32mph)	1/17,280
6	Very low value ≤ £8.60	≤ 1 per week	None	1/120,960

Table 1. '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.

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 (Table 2) 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). '

Dbh (mm)	Dry weight (kg) $y=ax^b$	Fraction of dry weight as a ratio
10	0.11263	1/23,505.722
25	1.0713	1/2,471.6699
50	5.8876	1/449.74
100	32.357	1/81.834
150	87.67	1/30.203
200	177.82	1/14.891
250	307.77	1/8.604
300	481.81	1/5.496
350	703.8	1/3.762
400	977.26	1/2.71
450	1305.5	1/2.03
500	1691.4	1/1.566
550	2138	1/1.24
600	2647	1/1

Table 2. Biomass weight estimates.
Source. Tritton & Hornbeck (1982)
x=dbh (mm); y=dry weight estimate; a=allometric coefficient 0.1126294414; b= allometric coefficient 2.458309949
Dbh (US - diameter measured at breast height – 1.37 metres)

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.

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.

Example

A 25.0 metre high, mature oak tree (*Quercus robur*), stem diameter 900mm (36"), in a low use area of woodland with no regular access within 30.0 metres but members of the public occasionally enter the target area. There is extensive heartwood decay and axial splitting in the main stem and the tree is highly unstable. 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 Potentia l		Probability of Failure		Risk of Harm
Range	6		1		1		
Probabili ty	1/120,9 60	x	1/1	x	1/1	=	1/120,960

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.

Intellectual Property

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References

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