The Right TRAQ?

Quantified Tree Risk Assessment (QTRA)
&
Tree Risk Assessment Qualification (TRAQ)
Compatibility and Common Ground

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Contents

1 Summary

1.1 This document is a summary of a thread that ran on the Arbtalk discussion forum in 2014 (p.3). I started the thread to debate and analyse the International Society of Arboriculture's Tree Risk Assessment Qualification (TRAQ – p.7) in an effort to find common ground and compatibility with the Quantified Tree Risk Assessment (QTRA –p.6) approach to tree 'risk assessment' and guidance on tree 'risk management'.

1.2 Analysis of TRAQ Likelihood and Risk Matrices category inputs and *risk rating* outputs indicate they seem to suffer from extremes of what Cox (2008) labels 'poor resolution', 'range compression', risk rating 'errors', and 'ambiguity' (pp.8-26).

1.3 The range of values in the TRAQ categories, Likelihood of Impacting the Target and Likelihood of Failure, can be remarkably narrow and precise. Thereby, implying a very high level of confidence, or very low uncertainty, which is difficult to justify. Conversely, they can be remarkably broad and imprecise to the extent their worth in generating a reasonable estimate of risk to inform the owner/manager is questionable (pp.8-21).

1.4 Three of the four TRAQ Likelihood of Impacting the Target categories fall within the highest QTRA Target range, and three of the four Likelihood of Failure categories fall within the highest QTRA Probability of Failure range (pp.8-12). Consequently, there is little common ground in QTRA risks and TRAQ *risk ratings*.

1.5 It is reasonable to conclude there are significant and substantial 'errors' with the TRAQ *risk ratings* of **Extreme**, **High**, **Moderate**, and **Low** and the risk values attached to them. For example, playing Russian Roulette would have a **Low** *risk rating*, and is not a dangerous enough game to qualify as an **Extreme**, **High**, or **Moderate** risk (p.15).

1.6 The Likelihood Matrix suffers from *betweenness* (Cox 2008) to the extent that the highest values of **Unlikely**, **Somewhat likely**, and **Likely**, are the same.

1.7 The Risk Matrix also suffers from *betweenness* to the extent that the highest values of the **Low** and **Moderate** *risk ratings* are the same.

1.8 The combined impact of *betweenness* on the Likelihood and Risk Matrices is such that a **Low** *risk rating* has the same highest value as an **Extreme** *risk rating*.

1.9 There is little significant common ground or compatibility between how QTRA and TRAQ provide advice and guidance on tree 'risk management' to owners/managers (pp.27-35). QTRA's advisory guidance proposes the tree owner/manager defers to the Tolerability of Risk Framework risk tolerance thresholds, regarding the level of tree risk they are prepared to impose (p.6). TRAQ advices the owner/manager selects one of its risk ratings, of **Extreme**, **High**, **Moderate**, or **Low** depending on their *risk tolerance* (p.7).

1.10 TRAQ *risk ratings* of **Extreme**, **High**, **Moderate**, or **Low** cannot be compared to other published levels of risk, and *tolerable* or *acceptable* risk, nor can they be compared to levels of risk the owner/manager might understand.

1.11 The evidence in the Risk Management section analysis suggests there is a strong argument that TRAQ 'risk assessments', which are made by the risk assessor, can stray beyond their remit and effectively become 'risk management' decisions.

1.12 With TRAQ *risk ratings* it is not possible for the owner/manager to identify where the most cost-effective allocation of resources should be directed when risk mitigation is proposed.

2   Introduction

2.1   This is a summary of the 'Tree Risk Assessment Qualification (TRAQ) – ISA Best Management Practices' thread on the Arbtalk discussion forum in 2014. I have put it together in a referenceable and formatted document following a number of requests to have the information on the thread in an easy to access form, without the inevitable distractions that are part and parcel of a discussion forum. It has been updated based on feedback (which I am grateful for), having met more TRAQ accredited arborists, discussions on a number of forums, and the perspective that comes from a review of previous work.

2.2   My plan is to have this as a working document that can be updated as and when improved analysis comes to the fore, or if any errors that I might have made in it are identified. I am very mindful that in some of the technical parts of this exercise I am operating at the boundaries of my knowledge.

2.3   I've decided to keep the same informal conversational style of writing as the Arbtalk thread. I'm doing this because I hope a 'newsletter', rather than 'academic journal', style will be more inclusive, and help get across what can sometimes be quite complicated points.

2.4   From the feedback I've had putting this together, I've been told it can be very hard work in places; particularly if some of the concepts are new to you. Unfortunately, complexity is necessary at times because trying to understand the underlying mechanisms of a risk assessment system can be hard work. To help with understanding, I've broken the discussion and analysis down into a buffet of what I hope readers will find to be easily digestible bite size pieces.

2.5   At the time of writing, in May 2015, there have been no new posts on the Arbtalk thread since June 2014, when the view count was at around 2 600. Nevertheless, there still appears to be considerable interest in the thread because it has been viewed more than 6 000 times since the last posting. I'm going to post this document on a new thread because I think the content has evolved enough to warrant a clean sheet, and maintain an email alert for any new posts on the old one. I would very much welcome any comments on the forum or privately about the contents. I greatly appreciate these messages and am more than happy to honour the confidentiality of anyone who requests it.

Cheers

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3   Background

3.1   In February 2014, 8 year old Bridget Wright tragically died when she was hit by a branch that failed from a tree at her school in Pitt Town, north-west of Sydney, Australia. On the back of that incident the Department of Education in New South Wales produced a directive to inspect trees in all state public schools for safety. In order to meet the criteria of the directive arborists had to be qualified to Level 5, be a Quantified Tree Risk Assessment (QTRA) Registered User, or have the International Society of Arboriculture (ISA) Tree Risk Assessment Qualification (TRAQ). TRAQ is founded on the ISA's 'Best Management Practices - Tree Risk Assessment' (Risk BMP), and TRAQ has become the general term coined for the risk assessment method outlined in the Risk BMP.

3.2   I was in Australia delivering QTRA & Visual Tree Assessment workshops shortly after the directive, and was asked by a number of TRAQ arborists who were at the training whether there was scope for QTRA and TRAQ to work in tandem. This point was also raised by QTRA Registered Users, who were ISA members, and looking to become TRAQ accredited.

3.3   During that Australian trip, and by email and phone after it, I discussed TRAQ with arborists who had attended both courses, and went through the Risk BMP publication and TRAQ Tree Risk Assessment Manual in the search for common ground and compatibility. My starting point for the analysis of the Likelihood and Risk matrices in TRAQ was a number of publications, some of which are cited in Section 12.

3.4   Perhaps, the most important of these publications is Tony Cox's seminal paper 'What's Wrong with Risk Matrices' (2008 - Risk Analysis), where he outlines the underlying mathematical reasons why risk matrices have an *"inherent inability to order risks logically"* (Ball & Watt, 2013).

3.5   Some of the typical limitations with risk matrices identified by Cox are;

- **Poor resolution** – it is not possible to rank risks that have the same qualitative risk rating to identify the highest risks

- **Range compression** – identical risk ratings can have very different risk values

- **Errors** – lower risk values can be assigned higher qualitative risk ratings

- **Resource allocation** – The risk assessor or owner/manager cannot identify where risk mitigation resources should be allocated most cost-effectively. Or whether resources should be allocated or not for risk mitigation where risks are *tolerable*, and could be As Low As Reasonably Practicable (ALARP).

- **Ambiguous** inputs and outputs

4   Objectives

4.1   Risk Assessment

4.1.1   What do TRAQ *risk ratings* of **Extreme**, **High**, **Moderate**, and **Low** mean in terms of actual risk values, and where do they sit in the Tolerability of Risk Framework, in a one year time frame or review period?

4.1.2   What is the common ground between QTRA and TRAQ as 'risk assessment' methods, and where are there significant differences?

4.1.3   The 'risk assessment' analysis and discussion is covered in Sections 7 – 10 (pp.8-26).

4.2   Risk Management

4.2.1   How do QTRA and TRAQ differ when giving advice and guidance to risk owners/managers to help them inform 'risk management' decisions?

4.2.2   The 'risk management' analysis and discussion is covered in Section 11 (pp.27-34).

5   Quantified Tree Risk Assessment (QTRA)

5.1   QTRA quantifies tree risk using range values for Target, Size, and Probability of Failure which are entered into a calculator. Monte Carlo simulations determine the most likely outcome from a combination of the three input range values, and the calculator produces a Risk of Harm as a traffic light colour-coded risk, with a numerical probability, which is the 'risk assessment'. The level of risk can then be compared to *risk tolerance* thresholds in the widely accepted and internationally recognised Tolerability of Risk (ToR) Framework by the risk owner/manager, who makes the 'risk management' decision about the level of risk they are going to impose.
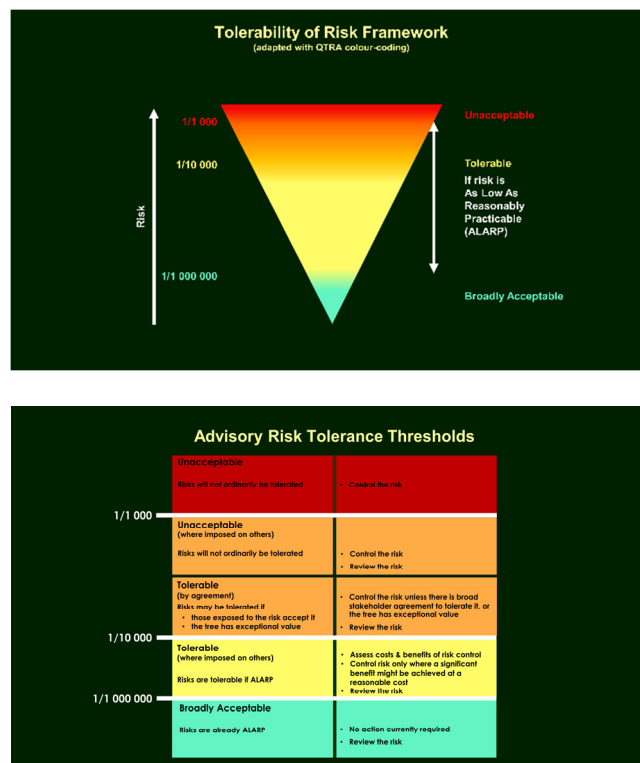
5.2   QTRA further provides a framework which considers the balance between the benefits provided by trees, levels of risk they pose, and costs of 'risk management'. This helps the risk owner/manager determine whether a *tolerable* risk is As Low As Reasonably Practicable (ALARP).

5.3   The QTRA approach to tree risk assessment, including an advisory on 'risk management', is outlined in the QTRA Practice Note.

6 Tree Risk Assessment Qualification (TRAQ)

6.1 TRAQ uses two matrices. Firstly, a 'Likelihood Matrix' for the likelihood of a failure impacting a specified target, which produces a 'Likelihood' category. The Likelihood categories are then fed into a 'Risk Matrix', where 'Consequences' are also categorised, to produce a qualitative *risk rating* of **Extreme**, **High**, **Moderate**, or **Low**, which is the 'risk assessment'. The risk owner/manager then manages their level of tree risk at **Extreme**, **High**, **Moderate**, or **Low** depending on their *risk tolerance*, and this constitutes the 'risk management' decision.

6.2 I've reproduced the two TRAQ matrices below, which are abbreviated to the Likelihood Matrix and Risk Matrix, and the cells are coloured to make it easier to identify similar categories or ratings.

TRAQ Likelihood Matrix

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

TRAQ Risk Matrix

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

6.3 If you're unfamiliar with TRAQ, there's an introduction to it in <u>Arborist News</u>.

7   Risk Assessment - Likelihood Matrix

7.1   Introduction

7.1.1   I'm going to start off with the Likelihood Matrix and look at what the Likelihood of Impacting the Target and Likelihood of Failure input categories and their values are. Then compare them to QTRA Target and Probability of Failure ranges.

7.1.2   Once the Likelihood input categories have been established it will be possible to work out what the values for **Very likely**, **Likely**, and **Somewhat likely** are.

7.1.3   The horizontal axis of the Likelihood Matrix has four categories of Likelihood of Impacting the Target, descending in order of magnitude, **High**, **Medium**, **Low**, and **Very low**.

7.1.4   The vertical axis of the Likelihood Matrix has four categories of Likelihood of Failure, descending in order of magnitude, **Imminent**, **Probable**, **Possible**, and **Improbable**.

7.1.5   Four categories of Likelihood of Failure and Impact form the cells of the matrix, descending in order of magnitude, **Very likely**, **Likely**, **Somewhat likely**, **Unlikely**.
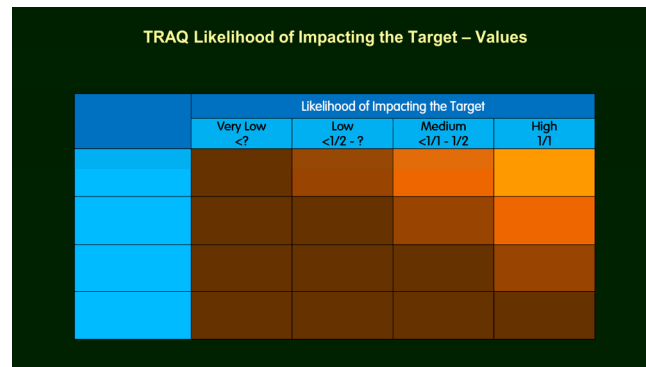
7.2 Likelihood of Impacting the Target – Values

7.2.1   A detailed analysis of the Likelihood of Impacting the Target values can be found in Appendix A. The values are;

High   = 1/1
Medium = Less than <1/1 - 1/2
Low   = Less than <1/2 –?
Very Low = Less than <?

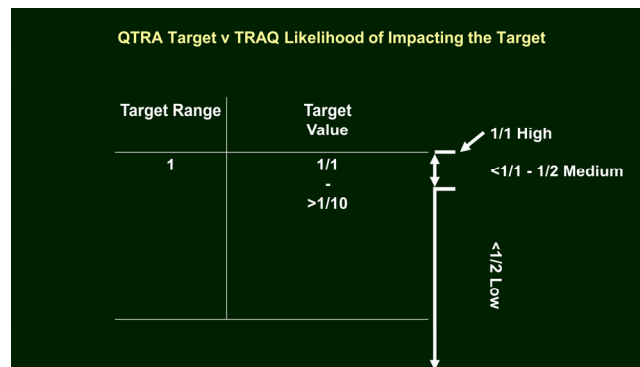### 7.3 QTRA Target Ranges - TRAQ Likelihood of Impacting the Target

7.3.1   I have removed the *Property* target range values column from the QTRA Target Table because in TRAQ, *monetary damage value* is considered in the Consequences columns of the Risk Matrix. *Monetary damage* to Property in TRAQ is discussed in Section 8.8 (pp.20-21).

7.3.2   The boundary between the **Low** and **Very Low** Likelihood of Impacting Target is not clearly defined in TRAQ, and where it sits here is my best estimate based on the clues given.

7.3.3   The upper and lower values of the **High** and **Medium** categories of Likelihood of Impacting the Target, and the highest value of the **Low** category, cannot be separated out at this level.

7.3.4   Zooming into QTRA Target range 1, it is possible to distinguish between the upper and lower values of the **High** and **Medium** Likelihood of Impacting the Target categories, and the highest values of **Low**.

7.3.5   It is noteworthy that three of four TRAQ Likelihood of Impacting the Target categories, **High**, **Medium**, and the upper values of **Low** all fall into the highest QTRA Target range 1. Constant Targets, such as structures, can clearly have a 1/1 Likelihood of Impact with a high level of certainty. However, there is little room for uncertainty, or margin for error, in Likelihood of Impact categories of **High** or **Medium** where the Targets are pedestrians or moving vehicles because their values are so precise and narrow in range.

7.3.6   The **Low** Likelihood of Impacting the Target is such a wide ranging category it is difficult to see how it assists the risk assessment. Its range is so broad at around x10 000, depending on the other inputs, a risk could be *unacceptable*, *tolerable*, or *broadly acceptable* with a **Low** Likelihood of Impacting the Target.

7.4 Likelihood of Failure Values

7.4.1 A detailed analysis of the Likelihood of Failure values can be found in Appendix B. The values are;

Imminent   = 1/1
Probable   = 1/1 – Greater than >1/2
Possible   = 1/2 - ?
Improbable = <?

7.5 QTRA Probability of Failure – TRAQ Likelihood of Failure

7.5.1 QTRA Probability of Failure (PoF) ranges have two benchmarks, 1 and 7. The 'risk assessor' chooses which benchmark to anchor their opinion from when estimating the PoF. The two benchmarks are where there is the highest level of confidence and the lowest level of uncertainty in the estimate the tree is not expected to fail (PoF range 7), or the tree is expected to fail in the next year (PoF range 1). From these benchmarks the 'risk assessor' estimates, within broad ranges of x10, how much more or less likely the tree is to fail than the respective benchmark. PoF range 4 is the furthest range that can be reached from either of the benchmarks, and it is the range where there is the lowest level of confidence and highest level of uncertainty.

7.5.2   The boundary between **Possible** and **Unlikely** of Likelihood of Failure Target is not clearly defined in TRAQ. Where it sits here is my best estimate for a tree without 'defects'.

7.5.3   The upper and lower values of the **Imminent** and **Probable** categories of Likelihood of Failure and the highest value of the **Possible** category, cannot be separated out at this scale.
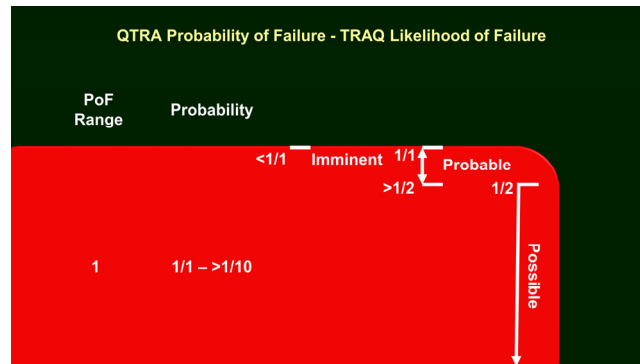
7.5.4   Zooming into QTRA Probability of Failure Range 1, it is possible to distinguish between the upper and lower values of the **Imminent** and **Probable** Likelihood of Failure categories, and the highest value of **Possible**.

7.5.5   There is always some uncertainty in any risk assessment. Often, the greatest level of uncertainty lies in the Likelihood or Probability of Failure component. One of the ways QTRA addresses uncertainty with PoF is to use benchmarks, where there is the highest level of confidence and the lowest level of uncertainty, and broad ranges when estimating PoF. It is noteworthy that three of four TRAQ Likelihood of Failure categories, **Imminent**, **Probable**, and the upper values of **Possible** fall into the highest QTRA PoF range. This implies that Likelihood of Failure categories have a precision, confidence, and degree of certainty that is difficult to justify with current knowledge.

7.5.6   Conversely, the **Possible** Likelihood of Failure straddles the whole spectrum of risk in ToR. This means with the highest Likelihood of Impacting the Target and Consequences, and a **Possible** Likelihood of Failure, a risk could be *unacceptable*, *tolerable*, or *broadly acceptable*, and there is no way to distinguish between these three levels of risk.

7.5.7   **Possible** Likelihood of Failure, "*Failure could occur, but is unlikely*", is such a wide ranging uncertain category it's difficult to see how it assists with a risk assessment.

7.6   Likelihood Matrix – Likelihood Outputs

A detailed analysis of the Likelihood Matrix output values can be found in Appendix C. The values are;

Very likely   = 1/1 – 1/1
Likely   = 1/1 – 1/2
Somewhat likely = less than <1/1 – greater than >1/4
Unlikely   = less than <1/2

TRAQ Likelihood Matrix - Upper & Lower Values Equalised

Likelihood of Failure	Likelihood of Impacting the Target			
	Very Low	Low	Medium	High
Imminent	Unlikely <1/2	Somewhat likely <1/1 - >1/4	Likely 1/1 - 1/2	Very likely 1/1
Probable	Unlikely <1/2	Unlikely <1/2	Somewhat likely <1/1 - >1/4	Likely 1/1 – 1/2
Possible	Unlikely <1/2	Unlikely <1/2	Unlikely <1/2	Somewhat likely <1/1 - >1/4
Improbable	Unlikely <1/2	Unlikely <1/2	Unlikely <1/2	Unlikely <1/2

8   Risk Assessment - Risk Matrix

8.1   Introduction

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

8.1.1   There are four Likelihood categories produced by the Likelihood Matrix, which form the vertical axis of the Risk Matrix. They descend in order of magnitude, **Very Likely**, **Likely**, **Somewhat likely**, and **Unlikely**.

8.1.2   The horizontal axis in the Risk Matrix is populated by four categories of Consequences, descending in order of magnitude, **Severe**, **Significant**, **Minor**, and **Negligible**.

8.1.3   The four Likelihood of Failure and Impact and four Consequences categories generate four *risk ratings*, descending in order of magnitude, **Extreme**, **High**, **Moderate** and **Low** in the matrix.

8.2   TRAQ Risk Rating - Consequences for a Death

8.2.1   With the Likelihood Matric outputs established it is possible to work out the *risk ratings* for a *Severe* Consequence, where the Consequence is a death.

8.2.2   The Likelihood of Failure & Impact values in vertical axis of the Risk Matrix below are derived from the analysis summarised in Section 7 (pp.8-12) and detailed in Appendices A, B, and C.

8.2.3   The description of **Severe** Consequences to a person range from "*serious personal injury to a death*" in TRAQ.   A death is the highest possible Consequence and therefore mathematically it is 1/1.   There is no clear guidance in TRAQ where Consequences may be greater than one death; eg two deaths would clearly have twice the Consequences of one.

8.2.4   The values for a **Severe** Consequence of a death, are the same as the Likelihood of Failure & Impact categories because being multiplied by 1/1, means the risk value is the same value as the Likelihood category.

**8.3   What Does a Low Risk Rating for a Death Mean?**

8.3.1   The risk of death when playing Russian Roulette is 1/6.   The *risk rating* from playing Russian Roulette is not high enough to qualify as a **Moderate**, **High**, or **Extreme** *risk rating* in TRAQ.   A game of Russian Roulette would have a **Low** *risk rating*.

8.3.2   The risk of a healthy person dying whilst tucked up in bed, with the doors and windows locked, would also qualify as a **Low** *risk rating*.

8.3.3   It is possible for a person to play a quick game of Russian Roulette, and if they didn't lose, then go to bed for a peaceful night's sleep, and not step outside of a **Low** *risk rating*.

8.4 Risk Ratings for a Death & Tolerability of Risk Framework

8.4.1 As outlined in Section 4, QTRA calculates tree risk as a traffic light colour-coded numerical probability, which the risk owner/manager can compare to the Tolerability of Risk Framework (ToR), and they make a 'risk management' decision about the level of risk from their trees they are prepared to impose. Having worked out the TRAQ *risk rating* outcomes of **Extreme**, **High**, **Moderate**, and **Low** where the Consequences are for a death, it is now possible to see where these *risk ratings* sit in ToR. The scaling in the following slides is for illustrative purposes.
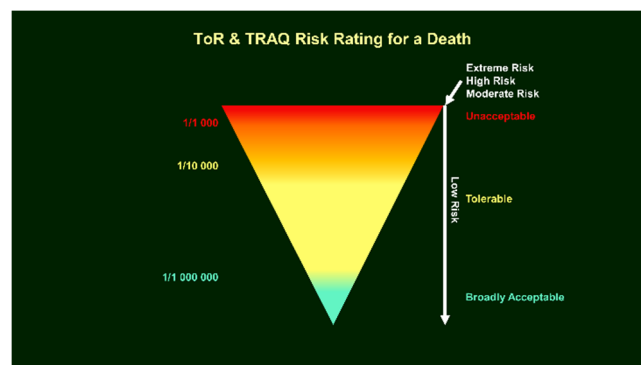
8.4.2 At this level it can be seen where some TRAQ **Low** *risk rating* for a death lies in ToR, but it is not possible to make out where **Extreme**, **High**, and **Moderate** *risk ratings*, or the upper value of **Low** sits.
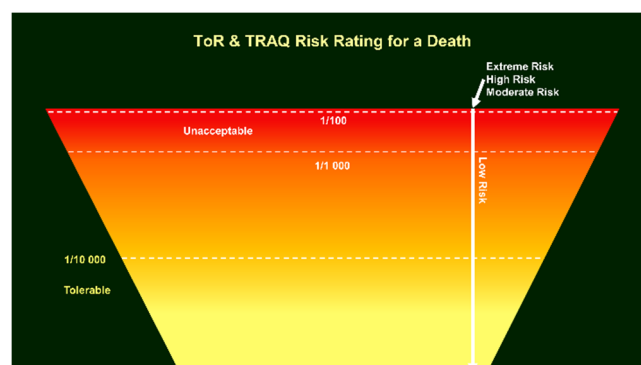
8.4.3 Zooming into ToR to highlight the 1/10 000 threshold of *risk tolerance*, where risks can be reasonably imposed if there are benefits attached to the risk, and the *unacceptable* 1/1 000 threshold of *risk tolerance*. Part of the TRAQ **Low** *risk rating* for a death can be seen, but it is still not possible to focus on where **Extreme**, **High**, and **Moderate** sit, or where the upper value of **Low** is.
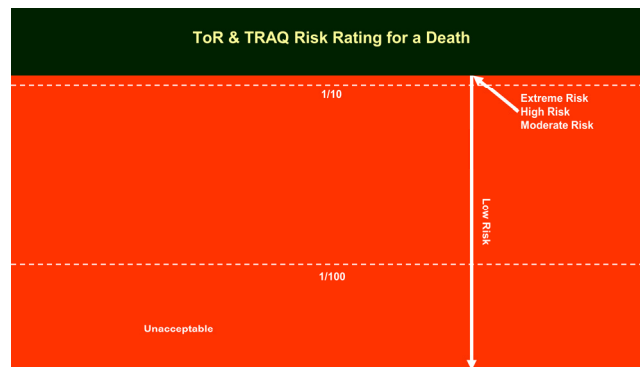
8.4.4   Zooming in further to levels of risk at 1/100 and 1/10. It is still not possible to focus on where the *risk ratings* of **Extreme**, **High**, and **Moderate** lie, or where the highest value of **Low** sits.
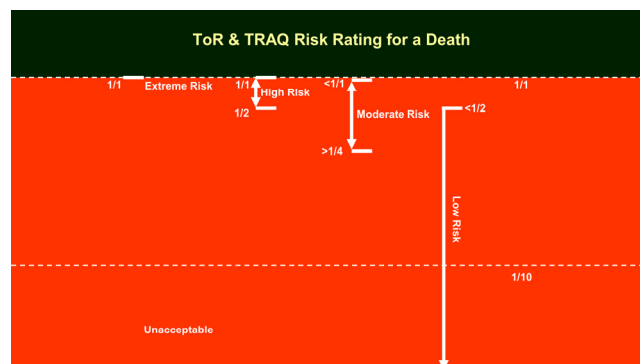

8.4.5   It is only when ToR is zoomed into at a level where a **1/10** risk can be identified do the values attached to the *risk ratings*, **Extreme**, **High**, **Moderate**, and the upper value of **Low** where the Consequences are a death come into focus.

8.5 Risk Ratings – Overlap & Percentages

8.5.1 The TRAQ *risk ratings* where Consequences are for a death overlap and they are not exclusive.

- A **Low** risk of death can be a higher risk than a **Moderate** risk of death
- A **Moderate** risk of death can be a higher risk than a **High** risk of death
- A **High** risk of death can be the same as an **Extreme** risk of death
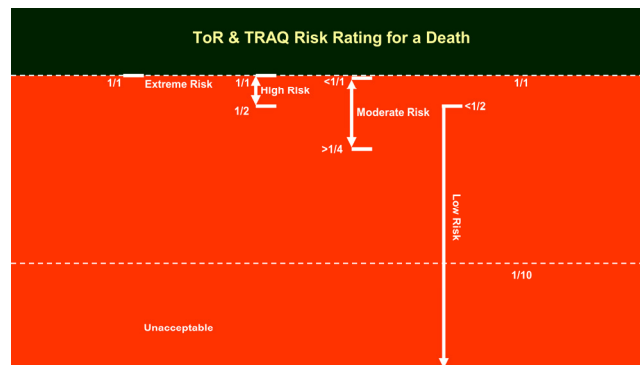
8.5.2 Some find percentages easier to comprehend than fraction probabilities

- **Extreme** Risk of death   = 1/1   = 100%
- **High** Risk of death   = 1/1 – 1/2   = 100% – 50%
- **Moderate** of death Risk   = <1/1 - >1/4   = 99 - 26%
- **Low** Risk of death   = <1/2 - 1/10M   = 49% - 0.00001%

8.5.3 It is useful to compare the percentages with ToR *risk tolerance* thresholds.

- **Unacceptable**   = 0.1% (1/1 000)
- **Tolerable**   = 0.01% - 0.0001% (1/10 000 – 1/1 000 000)
- **Broadly Acceptable**   = 0.0001% (1/1 000 000)

8.5.4 **Extreme**, **High**, and **Moderate** *risk ratings* for a death all fall into the *Unacceptable* region of risk in ToR. A **Low** risk rating could be an *Unacceptable*, *Tolerable*, or *Broadly Acceptable* risk, and there is no mechanism to work out which of these regions a **Low** risk rating would fall into.

8.5.5 By way of context, and to frame the above figures with some level of proportionality, an annual risk of death from tree failure in the UK is around 0.00001% - 1/10 000 000 (Ball & Watt, 2013 The Risk to the Public of Tree Fall).

8.5.7   When I arrived at these conclusions about what TRAQ *risk rating* values were if the Consequences were a death, to say I was surprised is something of an understatement. I have checked it many times, asked colleagues to pick holes in the analysis and reasoning, and posted links to the Arbtalk thread, on the UK Tree Discussion Forum (UKTC), the QTRA discussion list, and the LinkedIn American Society of Consulting Arborists (ASCA) and ISA forums, inviting contributions and criticism. To date, no one has come forward to put an alternative take on these *risk ratings*. As I said in the introduction, if anyone can explain flaws in the reasoning here, or an alternative take on it, then I would very much welcome hearing from them. Either reply on any of the forums where the threads have been run, or privately should you wish to do so or be confidential. I'll update this document as and when better information, or analysis comes to the fore.

8.6   Cognitive Dissonance – The Risk is Low Yet Extreme

Over the last year or so it has been interesting discussing what a **Low** *risk rating* for a death from trees means with some TRAQ qualified arborists who experience what could be called 'cognitive dissonance' when they encounter the TRAQ *risk rating* for a death. Cognitive dissonance happens when someone is confronted by new information that conflicts with existing beliefs, ideas, or values. I think it occurs here because no one actually believes a **Low** risk of death from tree failure is just under 1/2, or up to 49%. When the underlying maths is revealed someone suffering from cognitive dissonance will try to override the facts by saying something like, "But the tree has a **Low** risk". This reaction occurs because they are trying to reconcile the reality of a risk that can be higher than playing Russian Roulette being rated as **Low,** with what they consider a **Low** risk for a tree should actually be.

8.7   A Low Risk Rating is a Good Thing

A number of TRAQ arborists have pointed out to me that one of the major benefits of TRAQ is it's very difficult, or uncommon, for a *risk assessor* to generate anything but a **Low** *risk rating*. This may well be the case, but given a Low risk rating can have as high a risk value as less than <1/2, or 49%, risk for a death, then I struggle to see how a **Low** *risk rating* can help inform the owner/manager to reasonably manage tree risk.

8.8   Cox's Risk Matrix Limitations

The TRAQ Likelihood and Risk Matrices appear to suffer from extreme 'poor resolution', 'range compression', 'ambiguity', and 'errors' (3.5, p.4).

8.9 Property - QTRA Risk & TRAQ Risk Rating Comparisons

Risk Matrix – QTRA Property Risk

Likelihood of Failure & Impact	Consequences			
	Negligible T5	Minor T4	Significant T3 & T2	Severe T1
Very likely 1/1	Low 1/30K	Moderate 1/3 000	High 1/300 & 1/30	Extreme 1/3
Likely 1/1 – 1/2	Low 1/30K	Moderate 1/3 000	High 1/300 & 1/30	High 1/3
Somewhat likely <1/1 - >1/4	Low 1/30K	Low 1/3 000	Moderate 1/300 & 1/30	Moderate 1/3
Unlikely <1/2	Low <1/30K	Low <1/3 000	Low <1/300 & <1/30	Low <1/3

8.9.1 This matrix is a comparison of the TRAQ *risk ratings* and QTRA colour-coded risk outcomes for damage to a property Target (T). The property values are my best effort at interpreting the text in the Risk BMP and TRAQ Manual in relation to the QTRA Target ranges for property listed below. A more detailed analysis of Consequences to property can be found in Appendix D.

> T1 = £1 500 000 - >£150 000
> T2 = £150 000 - >£15 000
> T3 = £15 000 - >£1 500
> T4 = £1 500 - >£150
> T5 = £150 - >£15
> T6 = £15 - £1

8.9.2 With QTRA, the colour-coding and numerical probabilities are there for the risk owner/manager to compare to ToR, and I've repeated the advisory table from the introduction below.

Advisory Risk Tolerance Thresholds

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 • 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 & benefits of risk control • Control risk only where a significant benefit might be achieved at a reasonable cost • Review the risk
1/1 000 000		
Broadly Acceptable Risks are already ALARP		• No action currently required • Review the risk

Risk Matrix – QTRA Property Risk

Likelihood of Failure & Impact	Consequences			
	Negligible T5	Minor T4	Significant T3 & T2	Severe T1
Very likely 1/1	Low 1/30K	Moderate 1/3 000	High 1/300 & 1/30	Extreme 1/3
Likely 1/1 – 1/2	Low 1/30K	Moderate 1/3 000	High 1/300 & 1/30	High 1/3
Somewhat likely <1/1 - >1/4	Low 1/30K	Low 1/3 000	Moderate 1/300 & 1/30	Moderate 1/3
Unlikely <1/2	Low <1/30K	Low <1/3 000	Low <1/300 & <1/30	Low <1/3

8.9.3   As can be seen from this matrix, QTRA risks are the same for all the Likelihood of Failure & Impact categories of **Very Likely**, **Likely**, **Somewhat likely**, and **Unlikely** (part of the **Unlikely**) within each Consequences column. All four Likelihood of Failure & Impact categories fall into one QTRA Probability of Failure Range 1 (1/1 – >1/10) and property is a constant target, so the only other consideration in the value of the damage.

8.9.4   The **Severe** Consequences *risk ratings* column of **Extreme**, **High**, **Moderate**, and **Low** are all red *unacceptable* risks at 1/3 with **Low** being less than <1/3.

8.9.5   The **Significant** Consequences *risk ratings* appear to straddle both T2 and T3 QTRA Target ranges (an alteration from the Arbtalk thread). The Significant column of **High**, **Moderate**, and **Low** are all red *unacceptable* risks at 1/300 or 1/30, with **Low** being less than <1/300 or <1/30.

8.9.6   The *Minor* Consequences *risk ratings* column of **Moderate** and **Low** are all amber **unacceptable** risks to impose (unless there is great value or the stakeholders agree) at 1/3 000 with **Low** being less than <1/ 3 000.

8.9.7   The *Negligible* Consequences *risk ratings* column are all **Low**, and are yellow *tolerable if* ALARP risks at 1/30 000, except the *Unlikely* cell which is less than <1/30 000. These are *tolerable* risks that can be imposed if the risk is ALARP.

9   Risk Assessment - Betweenness

I'm going go through another common flaw found in many risk matrices called *betweenness* and how it affects the TRAQ matrices. I shall briefly highlight the concept with an example. A detailed analysis of *betweenness* can be found in Appendix E.

9.1   How Hot is it? - A Betweenness Example

9.1.1   *Betweenness* seems to have been a particularly difficult concept for some people to get their heads around, and I've added this slide and text because it may help you grasp the concept right from the beginning. It's based on common dishes found on menus in a UK 'curry house', but the gist should be clear enough for those of you who might be unfamiliar with Indian food to grasp.

9.1.2   The heat gradient on this curry menu matrix runs from bottom left to top right. The mildest heat rating for each curry category is at the bottom left corner, and the hottest heat rating at the top right corner. The heat rating of how hot a curry is increases in magnitude from mildest to hottest, bottom left to top right, Korma, Madras, Vindaloo, Phal.

9.1.3   What *betweenness* shows here, with the red arrows, is if you were to order a curry that was a just a bit hotter than a Korma you could get a Vindaloo, whereas a Madras is the actually the next hottest curry. Similarly, if you order a curry that was just a bit hotter than a Madras you could get a Phal, whereas a Vindaloo is actually the next hottest curry.

9.1.4   In effect, the hottest Korma is rated as having the same heat as the hottest Madras, and the hottest Madras is rated as having the same heat as the hottest Vindaloo. Eating in this restaurant means when you order a curry there is no difference between how hot a Korma, Madras, or Vindaloo could be.

9.2   Betweenness

9.2.1   Combining the effect of *betweenness* in the Likelihood and Risk Matrices so that each Consequences column has consistent risk ratings.

Here's the above Risk Matrix, expressed in probability ranges.

9.2.2   When *betweenness* is accounted for, a **Low** *risk rating* shares part of the same value as an **Extreme** *risk rating*.

10 Risk Assessment - Risk Contour Conflicts

10.1   A more detailed analysis of the conflicts between risk matrices and **risk contours** can be found in Appendix F.

10.2   The **risk contours** represent a lines of equal risk. In the same way that contours on an Ordinance Survey are points of equal elevation. The top right contour is the highest level of risk and left contour is the lowest. The contours are 'illustrative' only to demonstrate a problem that risk matrices often suffer from.

10.3   The geometry of the **risk contours** and the horizontal and vertical cell structure of matrices has implications for the actual risk values in relation to the *risk ratings*.

- Risk A = **High** *risk rating*
- Risk B = **Low** *risk rating*

Overlay with illustrative **risk contours**.

Remove all but one **risk contour**, which is a line of equal risk.

- Risk A, the **High** risk rating, lies to the left of the risk contour
- Risk B, the **Low** risk rating, lies to the right of the risk contour

10.4 However, the actual value of the risk is lower at any point to the **left** of the **risk contour**, and higher at any point to the **right** of the **risk contour**.

10.5 Risk B, the **Low** *risk rating* in the Risk Matrix, is actually a higher level of risk than Risk A, with the **High** *risk rating*. The reason for this being the case is because Risk B is on the right hand side of the risk contour, and Risk A is on the left hand side of the risk contour.

10.6 The portion of the **Low** Risk B cell that lies to the right of the risk contour, is a higher risk than the portion of the **High** Risk A cell that lies to left of the contour. What this means is;

- Low risk ratings can be higher levels of risk than High risk ratings
- High risk ratings can be lower levels of risk than Low risk ratings

10.7 The problem that all risk matrices face is **risk contours** are negatively sloped, running top left to bottom right, whereas the cells are infinitely sloped being constructed of vertical and horizontal lines. Consequently, matrix cells of different qualitative *risk ratings* will be bisected by *risk contours* of the same risk value. Hence, anything to the left of the **risk contour** in a matrix cell is a lower level of risk than anything to the right of the **risk contour**, which will be higher level of risk.

10.8 With the TRAQ Risk Matrix, there is such intense 'range compression', 'poor resolution', 'errors', 'ambiguity', overlap and lack of identity with the ranges in the Likelihood of Failure & Impact categories that it's not possible to plot the **risk contours**. My best Scientific Wild Ass Guess would be that they are extremely negatively sloped, running almost vertical like the stripes on a zebra because of the probabilities for the risk of a death.

11 Risk Management - Risk Tolerance & the Tolerability of Risk Framework

The relationship and distinction between risk assessment and risk management is of fundamental importance.

11.1 Overview

11.1.1 With QTRA the Risk of Harm from trees can be compared to levels of *tolerable* and *acceptable* risk in the Tolerability of Risk (ToR) Framework by the risk owner/manager who makes the 'risk management' decision.

11.1.2 With TRAQ the owner/manager manages their acceptable level of tree risk at **Extreme**, **High**, **Moderate**, or **Low** depending on their *risk tolerance*, and this constitutes the 'risk management' decision.

11.1.3 I have great difficulty squaring the QTRA approach of deferring to ToR thresholds of risk as an advisory to owners/managers, with the *risk tolerance* choices in TRAQ. I'm going to explore what these difficulties with *risk tolerance* are.

11.1.4 I'll start off by looking at what *risk tolerance* is, as outlined in the BMP and TRAQ Tree Risk Assessment Manual.

> *"Risk evaluation is the process of comparing the assessed risk against given risk criteria to determine the significance of the risk. This is usually done by the tree owner or risk manager, sometimes in consultation with the risk assessor. You, as the risk assessor, present the level of risk that you determined, your recommended mitigation actions or options, and their associated residual risks. The tree owner or risk manager must then decide on what actions, if any, to take.*
>
> *How people perceive risk and their need for personal safety is inherently subjective; therefore, risk tolerance and action thresholds vary among tree owners/managers. What is within the tolerance of one person may be unacceptable to another.*
>
> *Acceptable risk is the degree of risk that is within the owner/manager's or controlling authority's tolerance, or that which is below a defined threshold."*

11.1.5 The *risk tolerance* issues will be broken down into eight main areas, with some degree of overlap. I have summed up the point of concern in bold at the beginning of each of section.

11.2 Hobson's Choice – The Only Way is Low

The only level of *risk tolerance* that can be reasonably chosen by the owner/manager as acceptable is Low.

11.2.1 A simple way of re-framing the *risk tolerance* choice of the tree owner/manager with TRAQ.

> *What's your risk tolerance for a child getting killed? Is it **Extreme**, **High**, **Moderate**, or **Low**?*

11.2.2 It's not reasonably conceivable that anyone is going to have a r*isk tolerance* to tree risk where they manage and impose it at an **Extreme** or **High** level. TRAQ effectively excludes **Extreme** as an option, and the exclusion would also apply to **High** for obvious reasons. Realistically, a tree owner/manager's choice of r*isk tolerance* is limited to either a **Moderate** or **Low** *risk rating* from the outset.

11.2.3 However, when faced with a choice between a **Moderate** or **Low** *risk rating* there's then little option but to go for a **Low** level of *acceptable* risk tolerance. The reason for this is partially because when faced with such a choice it's only natural to prefer a lower level of risk, so it is 'safer', if there is no clarity about what is *tolerable* or *acceptable*. However, another driver to the only choice being a **Hobson's Low** *risk tolerance* is because mitigation options showing how to lower the risk from **Moderate** to **Low** are part of TRAQ, and included in its Basic Tree Risk Assessment Form.

11.2.4 To play out a scenario as why the only choice is **Low**. After a discussion with the 'risk assessor' it is established the tree owner/manager's *risk tolerance* is **Moderate**, which becomes their threshold of *acceptable* risk, and the tree 'risk management' policy. However, all tree reports identifying **Moderate** *risk ratings* will have mitigation options to show how the risk could have been reduced from **Moderate** to **Low**. If a **Moderate** risk is realised, resulting in injury or death, I struggle to see how it would be a very robust defence that the owner/manager had discharged their 'duty of care' because their *risk tolerance* to tree risk was **Moderate** rather than **Low**, if there was the budget available to reduce the risk. Consequently, they didn't undertake the tree work to lower the risk from **Moderate** to **Low**, and someone got badly hurt or died.

11.3 Lower Than Low

With a Low *risk rating* there's still scope for the 'risk assessor' to sell more tree work to the 'risk owner/manager', in order to lower the risk, despite there being no lower *risk rating* than Low.

11.3.1 Risk mitigation options, irrespective of the *risk rating*, are part of TRAQ. Even where the *risk rating* is **Low**, TRAQ assessors are expected to provide mitigation options. A case study on p.148 of the TRAQ Manual describes a **Low** risk from a dead limb over a path in an urban park. The mitigation recommendation is to "*remove the dead limb to reduce the risk*", which does not lower the *risk rating* because it was **Low** before the mitigation, and remains **Low** after the mitigation. Curiously, it is explained if the *risk tolerance* of the client is **Low** there could be even more mitigation costs for them to bear by restricting access to the path until the dead limb is removed. The owner/manager is now in a position where they're obligated to reduce a risk, even though the risk is **Low** before and after mitigation, if they have the budget.

11.3.2 I'll being revisiting this case study when discussing ALARP in Section 8.8.

11.4 Lost in Translation

Risk ratings cannot be compared to any other risks by the risk owner/manager, or the 'risk assessor'.

11.4.1 **Extreme**, **High**, **Moderate**, or **Low** *risk ratings* are defined by the inputs and outputs of the TRAQ matrices, and they only have meaning within TRAQ. A tree owner/manager cannot compare TRAQ tree *risk ratings* to any other risks they have to manage, published levels of *tolerable* or *acceptable* levels of risk, or levels of risk they might understand. The *risk ratings* are effectively another language which cannot be translated so they can be measured against established *acceptable* level of risk thresholds in a risk management policy, or what the tree owner/manager might consider to be an **Extreme**, **High**, **Moderate**, or **Low** risk. The 'risk assessment' is effectively a 'risk management' decision made by the 'risk assessor'.

11.5 Is it Safe?

Many tree owners/ managers will not have enough knowledge about risk for the risk assessor to determine what their risk tolerance is.

11.5.1 Generally, people are notoriously bad at working out what levels of risk they are exposed to. They tend to grossly overestimate the risks of high consequence very low likelihood events such a shark attacks, plane crashes, and terrorist atrocities. And grossly underestimate much higher daily risks such as driving, diet, and household tasks. There's a wealth of psychosocial literature from behavioural economists to psychologists, which demonstrates that people are simply bad at working out risks. Ball and Watt's (2013) in 'Further Thoughts on the Utility of Risk Matrices' outline a number of reasons why risk assessors can be similarly afflicted when using risk matrices.

11.5.2 From a discussion between both parties, I think it extremely unlikely a 'risk assessor' is sufficiently well trained in risk perception, or the owner/manager has sufficient knowledge of how they 'perceive' risk, that either can determine what a credible *risk tolerance* is to tree risk, unless they choose **Low**.

11.6 An Imposition

Where tree risk is imposed, the *risk tolerance* of those who have the risk imposed on them is not considered.

11.6.1 Where a tree, or part of a tree, has the capacity to fail outside of the owner/manager's property, the risk is imposed on others and the risk is not solely 'owned' by the tree owner/manager. Tree risk being imposed in this manner is overwhelmingly the case for many trees; particularly where there are the highest value Targets, and consequently where there are the highest potential risks. The *risk tolerance* of those who are exposed to having the risk imposed on them is not considered.

11.7 Tree Risk Assessment v Tree Risk Management

Tree 'risk assessment' decisions made by the risk assessor effectively become tree 'risk management' decisions on the part of the risk owner/manager.

11.7.1 TRAQ, in line with ISO 31000:2009 Risk Management – Principle and Guidelines, makes an important point about distinguishing between 'risk assessment' and 'risk management'. However, the *risk ratings* of **Extreme**, **High**, **Moderate**, and **Low** are not only 'risk assessments' but are also crossing the boundary into 'risk management' decisions, for some of the reasons I've outlined previously.

11.7.2 To paraphrase this warning about 'risk assessments' straying into 'risk management' by David Ball, (Professor of Risk Management Decision Analysis and Risk Management), in his book, 'Public Safety and Risk Assessment' (which is a great and enlightening read for those of you who are interested in the subject – see Section 13).

> *"It is sometimes not appreciated by technical persons who do risk assessments, or their recruiters, that they may not be qualified, authorized, or in an intellectual position to make risk management decisions."*

11.7.3 Those of you who are interested enough to want to explore this area, have a look at Section 5.3 'Establishing the Context' of ISO 31000, and ask yourself whether the 'risk assessor' is sufficiently trained or in a position to establish the *risk tolerance* and 'risk management' policy of the tree owner/manager.

11.8 As Low As Reasonably Practicable (ALARP)

There's no mechanism to work out whether a risk is ALARP

11.8.1   The QTRA approach to Tree Risk Assessment is to calculate a Risk of Harm as a probability so it can be compared to thresholds of risk in the Tolerability of Risk Framework (ToR). Owners/managers are then able to make tree 'risk management' decisions based on the *risk tolerance* thresholds and principles in ToR. One of the key elements of ToR is a region where the risk is Tolerable if it is ALARP.
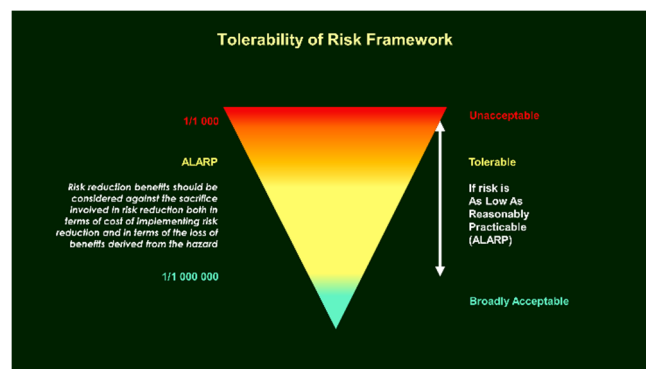
11.8.2   There is a substantial difference in approach between QTRA and TRAQ here because TRAQ has is no mechanism to determine whether the risk from a tree is ALARP. The consequences of not assessing whether the risk from a tree is ALARP are that the costs to the owner/manager of managing the risk from their trees, and the benefits that could be lost, are not considered.   Consequently, the risk assessment can not only be unbalanced, biased, and *risk averse*, but also stray into becoming a tree 'risk management' decision on the part of the 'risk assessor', which could result in unnecessary and disproportionate expenditure on tree work and a loss of tree-related benefits.

11.8.3 ALARP is born out of the *reasonably practicable* element in the universal common law *duty of care*, and international variations of the 'Occupiers' Liability'. The purpose of ALARP here is to recognise that when the risk from trees fall below a certain level, making trees safer involves costs in reducing the risk to an even lower level. These costs are the financial costs of the tree work, the loss in tree-related benefits, as well as the transfer of risks from the tree work to the workers and public. Such costs should be considered and balanced against the benefits in the reduction of risk to determine whether a risk is *tolerable*. Otherwise, tree risk management can become a disproportionate tail-chasing exercise where there is often a lower level of risk that could be achieved, with no regard to how much it might cost. To not consider ALARP is to be *risk averse* and worship at the unattainable altar of complete safety with zero risk, no matter the costs to the client or loss of benefits. Assessing whether a risk is *tolerable* and ALARP is about being *risk aware*, rather than *risk averse*, by not only recognising that there's an the elephant in the room but by making an effort to weighing it.

11.8.4 I highlighted an example of the problems faced by the tree owner/manager when ALARP is not considered, in Section 8.3 'Lower Than Low'. To recap. The case study on p.148 of the TRAQ Manual describes a **Low** risk from a large dead limb over a path in an urban park. The mitigation recommendation is to "*remove the dead limb to reduce the risk*". It is explained that if the *risk tolerance* of the client is **Low** there could be even more mitigation costs for them to bear by restricting access to the path until the dead limb is removed. The reasoning behind the recommendations is explained as "*mitigation is easy and inexpensive*".

11.8.5 Notwithstanding, the confusing issue of why recommend risk mitigation tree work that will cost money and does not change the risk rating - a **Low** risk will still be a **Low** risk after mitigation. Or that if the *risk tolerance* of the owner/manager is **Low** why is even more money being spent restricting access despite the risk being **Low**, until the tree work is undertaken and the **Low** risk remains a **Low** risk. The work and restriction of access are likely to cost hundreds of dollars to manage what was already a **Low** risk.

11.8.6 Without consideration of ALARP there's no mechanism to work out whether the financial costs of the restriction in access to the path and the tree work exceed the benefits of the reduced risk. Moreover, such tree risk assessment decisions have tree 'risk management' implications that any **Low** risk should be mitigated to a lower risk if the arborist can suggest a way of spending the owners/managers money and the funds are available.

11.9 Resource Allocation

"Effective allocation of resources to risk-reducing countermeasures cannot be based on the categories provided by risk matrices."

11.9.1 Tony Cox (2008) warns "*Effective allocation of resources to risk-reducing countermeasures cannot be based on the categories provided by risk matrices*". In other words, the most cost-effective use of limited resources to reduce risk cannot be worked out with risk matrices because there is no mechanism to do this. Nor is there any way to distinguish between levels of risk within each TRAQ risk rating.

12 Conclusions

12.1   The TRAQ Likelihood and Risk Matrices appear to suffer significantly from the critical limitations of risk matrices identified in Cox's 'What's Wrong with Risk Matrices' (2008). Namely, 'poor resolution', 'range compression', 'errors' between *risk ratings* and their risk value, and 'ambiguity' of inputs and outputs.

12.2   There are a number of examples of *betweenness* (Cox 2008) that mean a **Low** *risk rating* shares the same highest value as an **Extreme** *risk rating*.

12.3   Playing Russian Roulette would have a **Low** TRAQ *risk rating*, and is not a dangerous enough game to qualify as an **Extreme**, **High**, or **Moderate** risk

12.4   All risk assessments have degrees of uncertainty attached to the inputs and outputs. Some of the TRAQ input and output categories, and *risk rating*, values can be so precise and narrow in range it is questionable whether such high confidence and accuracy could be achieved by a risk assessor. Alternatively, the values can be so broad-ranged and ill-defined it is doubtful how useful they are when informing a 'risk assessment', or providing worthwhile guidance to the owner/manager to assist them in making a reasoned and reasonable 'risk management' decision.

12.5   There is little, if any, common ground and compatibility between the QTRA and TRAQ methods of tree 'risk assessment'. The difference in the inputs and outputs is so divergent it is difficult to see how they could be run in tandem or support each other.

12.6   There is little significant common ground or compatibility between how QTRA and TRAQ provide advice and guidance on tree 'risk management' to owners/managers.

12.7   TRAQ *risk ratings* cannot be compared to other levels of risk, published levels of tolerable risk, or risks that the owner/manager might understand.

12.8   It is not possible for the owner/manager to identify where the most cost-effective allocation of limited resources should be spent where risk mitigation is proposed with TRAQ.

12.9   The weight of evidence in the Risk Management section indicates there is a very strong case to be made that TRAQ 'risk assessments', made by the 'risk assessor', can exceed their purpose and become 'risk management' decisions.

13 Risk Matrix Literature

For those of you who are interested in reading a bit more about risk matrices, and want to get a better understanding of their intrinsic flaws from people who have forgotten more about the subject than I know, here's some links.

What's Wrong with Risk Matrices – Tony Cox

What's Wrong with Risk Matrices? (2008 - Risk Analysis) is the ground-breaking and seminal paper by Tony Cox that first looked at risk matrices in detail. The paper is hard work and very mathematical in parts. It is the foundation for much of the analysis in this document.

Kailish Awati

Kailash Awati does a great job of distilling the essence of the Cox's work on his 'Eight to Late' blog entry, Cox's risk matrix theorem and its implications for project risk management, which is easier to grasp on first time reading than Cox's paper.

Douglas Hubbard

The Failure of Risk Management, Chapter 7 - Worse than Useless: The Most Popular Risk Assessment Method and Why it Doesn't Work. It's a great book overall, but chapter 7 is picked because it focuses on Risk Matrices. The link is for Amazon.com, which I gone for over the UK because there are a lot more reviews.

Risk Matrices: Implied Accuracy and False Assumptions

Alexander Pickering & Stephen P Cowley, 'Risk Matrices: Implied Accuracy and False Assumptions' (OHS SJ Internals 9-16), is a good paper and pretty easy to grasp.

David Ball and Laurence Ball

Public Safety and Risk Assessment: Improving Decision Making, is one of the few books that I took a highlighter pen to because its content was so important. It includes discussion of the BS 8615 Recommendations for Tree Safety Inspections 'gambit'.

David Ball and John Watt

Since the Arbtalk thread David Ball and John Watt have had two papers published. One is on the utility of risk matrices, on which David has an extended abstract on his blog. The other relates to the quantification of tree risk, and the data set they provided for the National Tree Safety Group in the UK.

Further Thoughts on the Utility of Risk Matrices

The Risk to the Public of Tree Fall

Appendix A

Likelihood of Impacting the Target Analysis

1   Likelihood of Impacting the Target - Analysis

Quoted text is from the BMP and/or TRAQ training manual. I'm going to use the symbols < for less than, and > for greater than, and will include the wording as well because the < > symbol's meaning can be difficult to immediately interpret for some.

1.1   High

"…most likely impact the target"

"Constant occupancy…24hours a day…7 days a week"

Highest Likelihood of Impacting the Target **High** category, has to be a value of 1/1. So the Likelihood of Impacting the Target categories are explicit and do not overlap, because of the upper value of the **Medium** category is less than <1/1.

When expressed in percentage terms High may not be a fixed point value at 100%, and there could be a boundary between where the **High** category begins and the **Medium** category ends somewhere between 100 – 50%. However, if that is the case, where that threshold lies is not clear (see below).

- Highest & lowest value of **High** = **1/1**.

1.2 Medium

"as likely to impact the target as not"

Lowest value of the **Medium** category is **1/2**.

Parked car occupancy at 14 hours is described as *"frequent – large proportion of a day - 'Medium'."*

It is not entirely clear whether a car has to be parked for 24 hours of occupancy before is goes from being a **Medium** to a **High** category.

Medium category is 1/2, and must be less than **High** (1/1), so the Likelihood of Impacting the Target categories are explicit and do not overlap.

- Highest value of **Medium = <1/1**
- Lowest value of **Medium = 1/2**

1.3 Low

"not likely…will impact the target."

Highest value of the **Low** category has to be less than the **Medium** 1/2 category, so the categories are explicit and do not overlap.

Lowest value of the **Low** category is not clearly defined.

- Highest value of **Low = <1/2**
- Lowest value of **Low = ?**

1.4 Very low

"likelihood…of impacting…is remote"

Highest and lowest value of the **Very low** category is not clearly defined.

- Highest value of **Very Low = ?**
- Lowest values of **Very Low = ?**

1.5   The Likelihood of Impacting Target Values

High   = 1/1
Medium   = Less than <1/1 - 1/2
Low   = Less than <1/2 –?
Very Low = Less than <?

Appendix B

Likelihood of Failure
Analysis

1   Likelihood of Failure - Analysis

Quoted text is from the BMP and/or TRAQ training manual. I'm going to use the symbols < for less than, and > for greater than, and will include the wording as well because the < > symbol's meaning can be difficult to immediately interpret for some.

1.1   Imminent

Likelihood of Failure category of **Imminent** must be 1/1, and in a much shorter time frame than a review period of one year.

- Highest & Lowest value of **Imminent** = **1/1**

1.2   Probable

"failure may be expected within the specified time frame."

Probable category has an upper value of 1/1. Potential conflict of **Imminent** and **Probable** categories not being explicit and overlapping, but **Imminent** is over a much shorter review period than one year.

- Highest value of **Probable** category = **1/1**
- Lowest value of **Probable** category = **greater than >1/2**

1.3   Possible

"Failure could occur, but is unlikely"

Highest value of **Possible** category must be 1/2 because the lowest value of **Probable** is greater than >1/2, so the categories are explicit and don't overlap.

Lowest value of **Possible** category is not clearly defined.

- Highest value of **Possible** category = **1/2**
- Lowest value of **Possible** category = **?**

1.4 Improbable

"..not likely to fail"

Highest and lowest value of **Improbable** category is not clearly defined.

- Highest value of **Improbable** category = ?
- Lowest value of **Improbable** category = ?

1.5 Likelihood of Failure Values

The Likelihood of Failure values are;

Imminent   = 1/1
Probable   = 1/1 – Greater than >1/2
Possible   = 1/2 - ?
Improbable = <?

Appendix C

Likelihood Matrix Output Category Analysis

1   Likelihood Matrix Output Categories - Analysis

With the values derived from the Likelihood of Impacting the Target and Likelihood of Failure categories, the values for the **Very likely**, **Likely**, **Somewhat likely**, and **Unlikely** categories can be worked out.

1.1   Likelihood Matrix – 'Very Likely' Values

Imminent Likelihood of Failure
& **High** Likelihood of Impacting the Target= **Very likely**
1/1 x 1/1 = 1/1

Highest and Lowest value for **Very likely** category = **1/1**

1.2   Likelihood Matrix – 'Likely' Values

Imminent Likelihood of Failure

Medium Likelihood of Impacting the Target = Likely

- 1/1 x <1/1 - 1/2

= <1/1 - 1/2

Probable Likelihood of Failure

High Likelihood of Impacting the Target = Likely

- 1/1 - >1/2 x 1/1

= 1/1 - >1/2

Highest value in **Likely** category = **1/1**

Lowest value in **Likely** category = **1/2**

1.3   Likelihood Matrix – 'Somewhat likely' Values

TRAQ Likelihood Matrix – 'Somewhat Likely' Values

Likelihood of Failure	Likelihood of Impacting the Target			
	Very Low <?	Low <1/2 - ?	Medium <1/1 - 1/2	High 1/1
Imminent 1/1		Somewhat likely <1/2 - ?		
Probable 1/1 - >1/2			Somewhat likely <1/1 - >1/4	
Possible 1/2 - ?				Somewhat likely 1/2 - ?
Improbable <?				

Imminent Likelihood of Failure

Low Likelihood of Impacting the Target = **Somewhat likely**

- 1/1 x <1/2 - ?

= <1/2 - ?

Probable Likelihood of Failure

Medium Likelihood of Impacting the Target = **Somewhat likely**

- 1/1 - >1/2 x <1/1 - >1/2

= <1/1 - >1/4

Possible Likelihood of Failure

High Likelihood of Impacting the Target = **Somewhat likely**

- 1/2 - ? x 1/1

= 1/2 - ?

Highest value in **Somewhat likely** category = Less than **<1/1**
Lowest value in **Somewhat likely** category = Greater than **>1/4**

1.4 Likely Matrix – 'Unlikely' Values

TRAQ Likelihood Matrix – 'Unlikely' Values

Likelihood of Failure	Likelihood of Impacting the Target			
	Very Low <?	Low <1/2 - ?	Medium <1/1 - 1/2	High 1/1
Imminent 1/1	?			
Probable 1/1 - >1/2	?	Unlikely <1/2 - ?		
Possible 1/2 - ?	?	Unlikely <1/4 - ?	Unlikely <1/2 - ?	
Improbable <?	?	?	?	?

Probable Likelihood of Failure

Low Likelihood of Impacting = **Unlikely**

- 1/1 - >1/2 x <1/2 - ?

= <1/2 - ?

Possible Likelihood of Failure

Medium Likelihood of Impacting = **Unlikely**

- 1/2 - ? x <1/1 - >1/2

= <1/2 - ?

Possible Likelihood of Failure

Low Likelihood of Impacting = **Unlikely**

- 1/2 - ? x <1/2 - ?

= <1/4 - ?

Highest value in **Unlikely** category = Less than **<1/2**
Lowest value in **Unlikely** category = **?**

1.5   Highest and Lowest Values of the Likelihood Matrix

Very likely $= 1/1 - 1/1$

Likely $= 1/1 - 1/2$

Somewhat likely = less than $<1/1$ – greater than $>1/4$

Unlikely   = less than $<1/2$

TRAQ Likelihood Matrix - Upper & Lower Values Equalised

Likelihood of Failure	Likelihood of Impacting the Target			
	Very Low	Low	Medium	High
Imminent	Unlikely <1/2	Somewhat likely <1/1 - >1/4	Likely 1/1 - 1/2	Very likely 1/1
Probable	Unlikely <1/2	Unlikely <1/2	Somewhat likely <1/1 - >1/4	Likely 1/1 – 1/2
Possible	Unlikely <1/2	Unlikely <1/2	Unlikely <1/2	Somewhat likely <1/1 - >1/4
Improbable	Unlikely <1/2	Unlikely <1/2	Unlikely <1/2	Unlikely <1/2

Appendix D

Property
QTRA Risk & TRAQ Risk Rating
Comparisons

1 Risk to Property - QTRA Risk & TRAQ Risk Rating Comparisons

Risk Matrix – QTRA Property Risk

Likelihood of Failure & Impact	Consequences			
	Negligible T5	Minor T4	Significant T3 & T2	Severe T1
Very likely 1/1	Low 1/30K	Moderate 1/3 000	High 1/300 & 1/30	Extreme 1/3
Likely 1/1 – 1/2	Low 1/30K	Moderate 1/3 000	High 1/300 & 1/30	High 1/3
Somewhat likely <1/1 - >1/4	Low 1/30K	Low 1/3 000	Moderate 1/300 & 1/30	Moderate 1/3
Unlikely <1/2	Low <1/30K	Low <1/3 000	Low <1/300 & <1/30	Low <1/3

This matrix is a comparison of the TRAQ *risk ratings* and QTRA colour-coded risk outcomes for damage to a property Target (T). The property values are my best effort at interpreting the text in the Risk BMP and TRAQ Manual in relation to the QTRA Target ranges for property listed below.

> T1 = £1 500 000 - >£150 000
> T2 = £150 000 - >£15 000
> T3 = £15 000 - >£1 500
> T4 = £1 500 - >£150
> T5 = £150 - >£15
> T6 = £15 - £1

1.1 TRAQ Property Consequences – Monetary Damage

1.1.1 Elements of this categorisation are tentative because the *monetary damage* Consequences categories in TRAQ are not clearly defined and can be ambiguous. They are described as;

- **Negligible** = Low monetary damage
- **Minor** = Moderate monetary damage
- **Significant** = Moderate to High monetary damage
- **Severe** = There is no monetary damage descriptor

There is no indication of what **Low**, **Moderate**, **High**, or **Severe** *monetary damage* Consequences mean in terms of actual monetary value in TRAQ.

There are some guidelines that give clues;

1.1.2 **Negligible**

"A small branch striking a fence."

"A medium-sized branch striking a shrub bed."

"A large part striking a structure and causing low monetary damage."

1.1.3 **Minor**

"A small branch striking a house roof from a high height."

"A medium-sized branch striking a deck from a moderate height."

"A large part striking a structure and causing moderate monetary damage."

1.1.4 **Significant**

"A medium-sized part striking an unoccupied new vehicle from a moderate or high height."

"A large part striking a structure and resulting in high monetary damage."

1.1.5 **Severe**

No *monetary damage* descriptor.

1.1.6   It is not clearly defined;

At what diameter and/or length a *small branch* becomes a *medium-sized branch*, or a *medium-sized* branch becomes a *large part*.

Where a *low* height becomes a *moderate* height, or a *moderate* height becomes a *high* height.

1.1.7   The problems that can occur where the boundaries of *monetary damage*, *size*, and *height* are ambiguous and not clearly defined are illustrated with the following example from the TRAQ Manual.

1.1.8   A *medium-sized part* striking an *unoccupied new vehicle* from a *moderate or high height* causes *moderate to high monetary damage* and is a **Significant** Consequence. It's implied, but not clear, the Consequences could be a category lower, from **Significant** down to **Minor** and *moderate monetary damage*, with a change in height from *moderate or high* to *low* with the same *medium-sized branch*. Rather confusingly, a **Significant** Consequence and a **Minor** Consequence could then both cause a *moderate* amount of *monetary damage* to an *unoccupied new vehicle*. Similarly, does a *small branch* striking an *unoccupied new vehicle* cause **Minor** consequences from a *medium* or *high height*?

Or, how much older a vehicle has to be than a new one, before the Consequences of being struck by a *medium-sized part* from a *moderate or high height* go from **Significant** *moderate* to *high monetary damage* down to **Minor** *moderate monetary damage*. And so forth.

Appendix E

Betweenness Analysis

1   Betweenness - Analysis
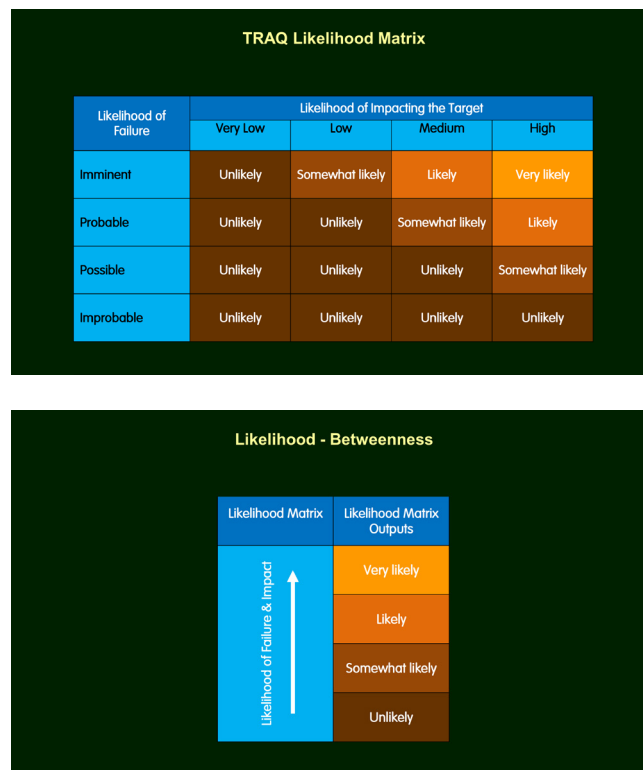
1.1   The Likelihood Matrix has for output categories increasing in magnitude from;

1) **Unlikely** > 2) **Somewhat likely** > 3) **Likely** > 4) **Very likely**

I've numbered the Likelihood categories to help with what's coming later because the numbers help identify what's going on with *betweenness* with greater clarity than the semantic confusion that can easily come from four kinds of Likelihood as words.
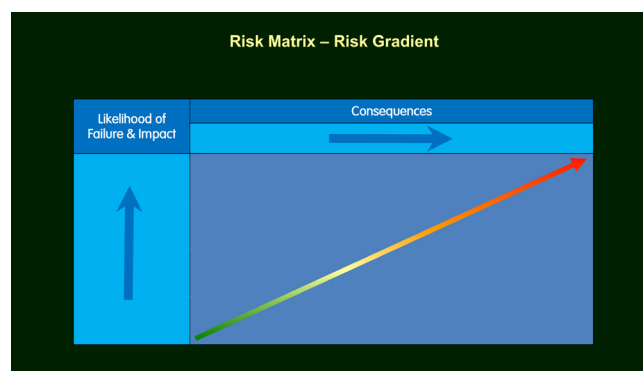
The *risk gradient* shows the increase in risk rating from bottom left to top right.

Risk Matrix – Risk Gradient

Likelihood of Failure & Impact	Consequences			
	Negligible	Minor	Significant	Severe
Very Likely				
Likely				
Somewhat Likely				
Unlikely				

1.2   Risk gradient overlaid onto the **Risk Matrix**.

- The lowest risk for each cell in the matrix is the bottom left corner
- The highest risk for each cell in the matrix is the top right corner

Likelihood - Betweenness

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

1.3   To illustrate the first example of *betweenness*, I'll start off with, **Possible** Likelihood of Failure and **Medium** Likelihood of Impacting the Target.

- **Possible + Medium** = 1) **Unlikely**

Likelihood - Betweenness

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

1.4   Likelihood of Failure increases by the smallest amount necessary to change the category from **Possible** to **Probable**.

1.5   Likelihood of Impacting the Target increases by the smallest amount necessary to change the category from **Medium** to **High**.

1.6   The output of the Likelihood Matrix has changed from

- **Possible** + **Medium** = 1) Unlikely

  to

- **Probable** + **High** = 3) Likely

The Likelihood of Failure and Impacting category has jumped from 1) **Unlikely** to 3) **Likely**.

1.7   The Likelihood of Failure and Impact category has gone from 1) **Unlikely** to 3) **Likely**, completely bypassing 2) **Somewhat likely**.

1.8 1) **Unlikely** goes directly to 3) **Likely**, without going through 2) **Somewhat likely**.

The top of 1) **Unlikely** is kissing the bottom of 3) **Likely**.

2) **Somewhat likely** has been jumped.
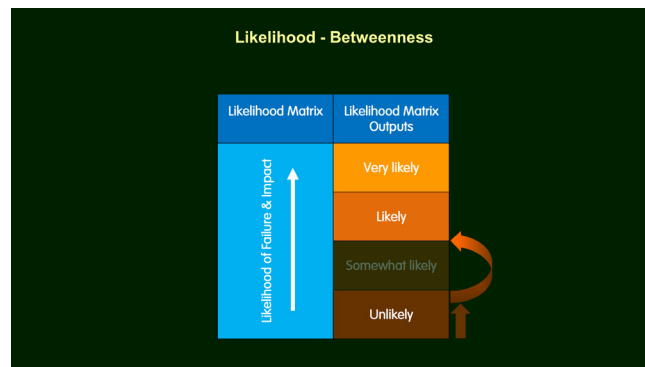
1.9 The highest value of 1) **Unlikely** has to be the same as the highest value of 2) **Somewhat likely** because the same increase in Likelihood of Failure and Impact changes the category from 1) **Unlikely** or 2) **Somewhat likely**, to 3) **Likely**.

The highest value of 1) **Unlikely**

=

The highest value of 2) **Somewhat likely**

Similarly, Likelihood of Failure and Impacting can jump over 2) **Somewhat Likely** here.

- **Probable** + **Low** = 1) **Unlikely**
  Jumps directly to
- **Imminent** + **Medium** = 3) **Likely**

Without bothering 2) **Somewhat likely**

1.10 With this configuration, the Likelihood of Failure and Impact category can jump from 2) **Somewhat likely** to 4) **Very likely**, completely bypassing 3) **Likely**.

- **Probable** + **Medium** = 2) **Somewhat likely**
  jumps directly to
- **Imminent** + **High** = 4) **Very likely**

2) **Somewhat likely** goes directly to 4) **Very likely**, without going through 3) L**ikely**.

The top of 2) **Somewhat likely** is kissing the bottom of 4) **Likely**

3) **Likely** has been jumped
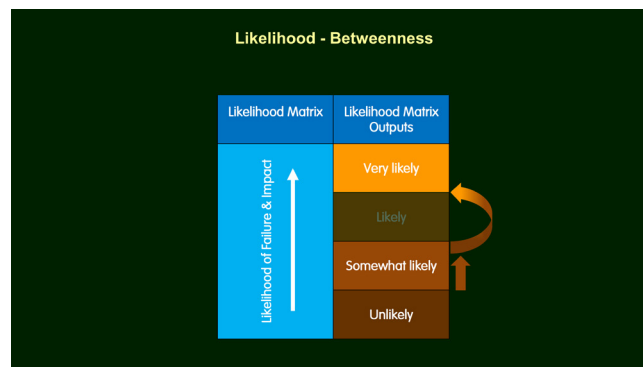
1.11 The highest value of 2) **Somewhat unlikely** has to be same as the highest value of 3) **Likely** because the same increase in Likelihood of Failure and Impact can change the category from 2) **Somewhat likely** or 3) **Likely**, to 4) **Very likely**.

The highest value of 2) **Somewhat likely**
=
The highest value of 4) **Very likely**

1.12 What *betweenness* means for the Likelihood Matrix is the highest value in 1) **Unlikely** has the same highest value as 2) **Somewhat likely**.

The highest value in 2) **Somewhat** likely has the same highest value as 3) **Likely**.

Therefore, the highest value of 1) **Likely** has to have the same highest value of 2) **Somewhat likely**, and the same highest value as 3) **Likely**.

To put it into words, **Unlikely**, **Somewhat likely**, and **Likely** can mean exactly the same thing as each other in the Risk Matrix.

2   Likelihood Betweenness – Effect on Risk Ratings

2.1   As the highest values of **Unlikely**, **Somewhat**, and **Likely** Likelihood of Failure and Impact are all the same. Then whatever the *risk rating* is for **Likely**, is also the highest *risk rating* for the **Somewhat likely** and **Unlikely** ranges in their Consequences columns. And whatever the highest *risk rating* is for **Somewhat likely** is the same for **Unlikely**.

3 Risk Matrix Betweenness

3.1 There is one example of *betweenness* in the Risk Matrix. The risk rating can jump from **Low** to **High**, completely bypassing **Moderate**.

- **Somewhat likely + Minor = Low**
  jumps directly to
- **Likely + Significant = High**

3.2 What *betweenness* means for the Risk Matrix is the highest value in the **Low** *risk rating* has to have same highest value as that in the **Moderate** *risk rating*, otherwise it would not be possible for the *risk rating* to change from **Low** to **High** without having to go through **Moderate**.

3.3 To put it into words, a **Low** *risk rating* and a **Moderate** *risk rating* can mean exactly the same thing.

3.4 As the highest values of **Low** and a **Moderate** *risk rating* are the same, then any cells in the Risk Matrix that have a *risk rating* of **Low** must also have a *risk rating* as **Moderate** for their highest values.

4   Likelihood & Risk Betweenness

4.1   Combining the effect of *betweenness* in the Likelihood and Risk Matrices so that each Consequences column has the same risk ratings.

Likelihood & Risk Betweenness – Risk Ratings Equalized

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

Here's the above Risk Matrix, expressed in probability ranges.

Betweenness – Risk Matrix Probabilities

Likelihood of Failure & Impact	Consequences			
	Negligible	Minor	Significant	Severe
Very likely	1/1 - <1/2	1/1 - >1/4	1/1 - 1/2	1/1
Likely	1/1 - <1/2	1/1 - >1/4	1/1 - 1/2	1/1 - 1/2
Somewhat likely	1/1 - <1/2	1/1 - <1/2	1/1 - >1/4	1/1 - >1/4
Unlikely	1/1 - <1/2	1/1 - <1/2	1/1 - <1/2	1/1 - <1/2

4.2   A **Low** *risk rating* shares the same value as an **Extreme** *risk rating*.
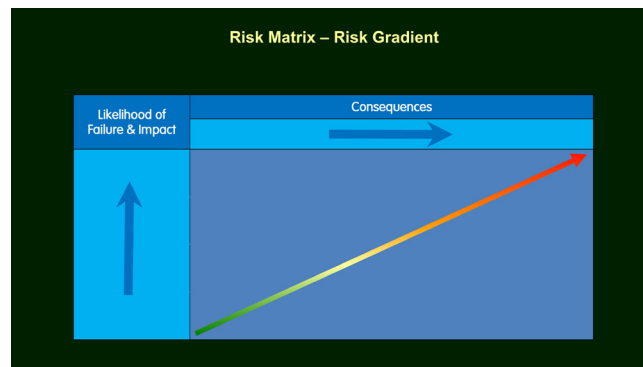
Appendix F

Risk Contours
Analysis

1   Risk Contours - Analysis

1.1   I'm going to repeat the *Betweenness* slide to discuss the intrinsic conflict that occurs in any risk matrix, which are constructed of cells with vertical and horizontal boundaries, and the actual levels of risk which in are negatively sloped **risk contours**.


The *risk gradient* shows the increase in *risk rating* from bottom left to top right.
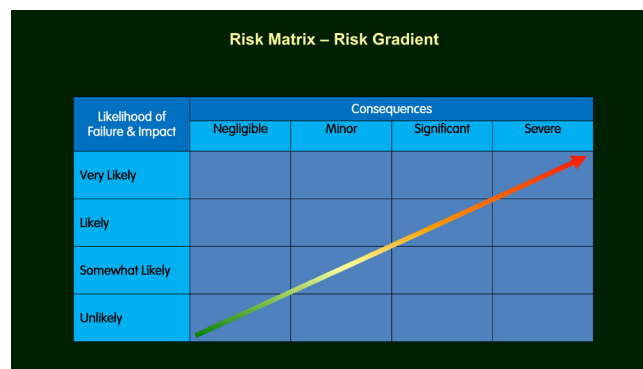
Risk gradient overlaid onto the **Risk Matrix**.

- The lowest risk for each cell in the matrix is the bottom left corner
- The highest risk for each cell in the matrix is the top right corner

1.2   Here's what the **risk contours** typically look like if the Likelihood and Consequences axis were of a similar scale.
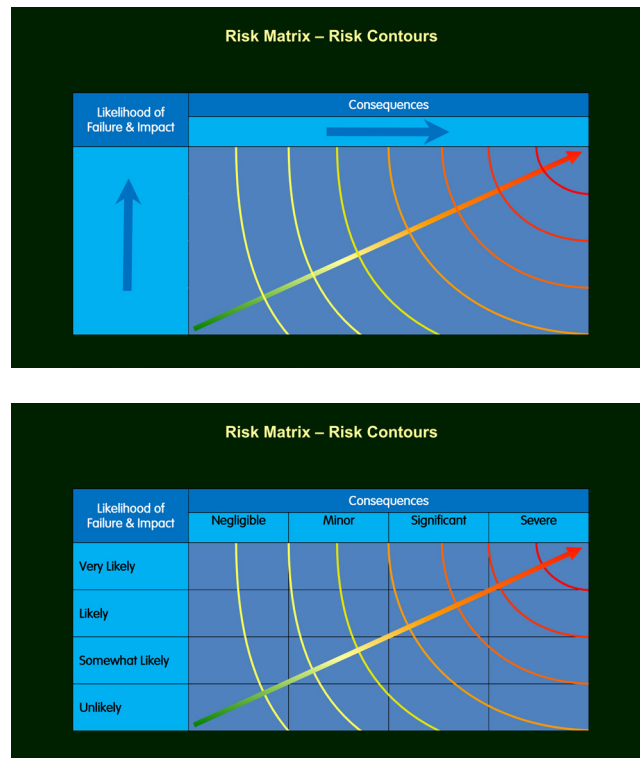

1.3   The **risk contours** represent a line of equal risk. In the same way that contours on an Ordinance Survey are points of equal elevation. The top right contour is the highest level of risk and left contour is the lowest. The contours are 'illustrative' only to demonstrate a problem that all risk matrices suffer from.

1.4   The geometry of the **risk contours** and the horizontal and vertical cell structure of matrices has implications for the actual risk values in relation to the *risk ratings*.
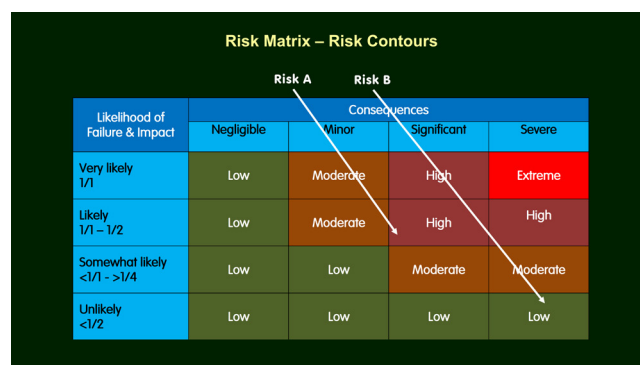
- Risk A = **High** *risk rating*
- Risk B = **Low** *risk rating*
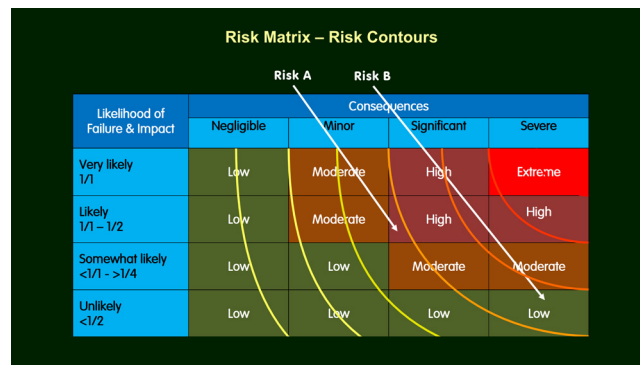
Overlay with illustrative **risk contours**.
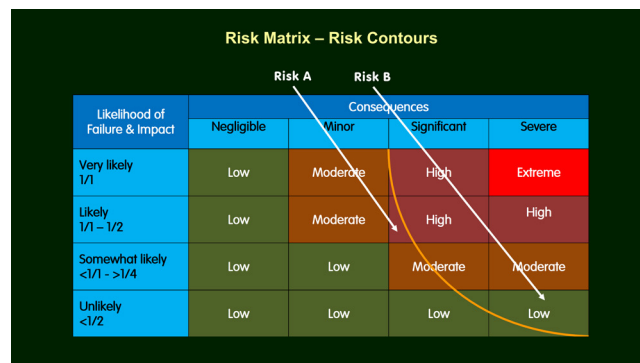
Remove all but one **risk contour**, which is a line of equal risk.

- Risk A, the High risk rating, lies to the left of the risk contour
- Risk B, the Low risk rating, lies to the right of the risk contour

1.5 However the actual value of the risk is lower at any point to the **left** of the **risk contour**, and higher at any point to the **right** of the **risk contour**.

1.6 Risk B, the **Low** *risk rating* in the Risk Matrix, is actually a higher level of risk than Risk A, with the **High** *risk rating*. The reason for this being the case is because Risk B is on the right hand side of the risk contour, and Risk A is on the left hand side of the risk contour.

1.7 The portion of the **Low** Risk B cell that lies to the right of the risk contour, is a higher risk than the portion of the **High** Risk A cell that lies to left of the contour. What this means is;

- Low risk ratings can be higher levels of risk than High risk ratings
- High risk ratings can be lower levels of risk than Low risk ratings

1.8 The problem that all risk matrices face is **risk contours** are negatively sloped, running top left to bottom right, whereas the cells are infinitely sloped being constructed of vertical and horizontal lines. Consequently, cells of different qualitative *risk ratings* will be bisected by *risk contours* of the same risk level, pitching anything to the left of the **risk contour** in a cell at a lower level of risk than anything to the right of the **risk contour**, which will be higher level of risk.

1.9 With the TRAQ Risk Matrix, there is such intense 'range compression', 'poor resolution', overlap, and lack of identity of the ranges in the Likelihood of Failure and Impact axis that it's not possible to plot the **risk contours**. My best Scientific Wild Ass Guess would be that they are extremely negatively sloped, running almost vertical like the stripes on a zebra because of the probabilities for the risk of a death.