Tree Structure and Risk Management: Part 1

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Why Tree Risk Management is Important

- Biological Risk to Tree Growth
- Structural Risk of Tree Failure
- Professional Risk of Malpractice
- Infrastructure Risk to Trees
- Infrastructure Risk to Arborists

Many Risks in the Urban Forest

Tree Structure and Risk Management...

Part 1:
- Act I: How Trees Grow (A Biological Basis)
- Act II: How Trees Respond (Actions and Outcomes)

Intermission

Part 2:
- Act III: What is Risk Management (What to Consider)
- Act IV: Applying Risk Management (What to Do)

Terms and Definitions
Knowledge Changes
Keeping Literate is a Challenge

Sometimes the Message is Mixed

http://www.uwsp.edu/cnr/Forestry/faculty/Hauer/index.aspx
or Google Hauer UWSP
True or False
“...a tree gains a new ring every year.”

“never enter the stem deeper than you found it; for profound burying very frequently destroys a tree.”

Both True and Long Known

John Evelyn (1664): Sylva, or a discourse of forest trees

Meet the Geno and Pheno Type Family

They had a Child …

Tilia tilted “their fallen son”

Basic Tree Biology: Anatomy (Structure)

Trees Generate and Regulate

Basic Tree Biology: Physiology (Function)

Trees Manufacture

Trees are a System

- Know the system
- System: orderly collection of parts (structure) and processes (function)
- Consumers (Insects, Disease, Other)
- Associates (Ecology)

Trees are not a Random Assortment of Things
Survival Factors
1) Energy
2) Genetic programming
3) Space to grow
4) Water
5) Essential elements
6) Temperature
7) Time
8) Concentrations of factors

Tree Ingredients for Survival

Energy trees and the system
- Vigor (how big)
- Vitality (how full)
- Capacity (how much)

Storage and Stored

Energy Reserves: Storage

We can Measure Tree Health

Dynamic Mass and Energy
Decreases with age of tree
One reason why trees fail

Dynamic Mass Changes with Time

Stress, Strain, and Askenasy

Dynamic Mass:
Pruning and Dose

Treatment Approaches Change with Time
Act II: How Trees Respond (Actions and Outcomes)

Tree Defense Strategies

**Morphological**
- Trichomes
- Barrier Zone
- Callus Tissue
- Woundwood
- Tyloses
- Shedding Parts

**Chemical**
- Reaction Zone
- Barrier Zone
- Phenols & Terpenes
- Secondary Metabolites
- Systematic Acquired Responses
- Abscission Zone

Trees Use Many Defense Strategies

Tree Defense Mechanisms

- Bioattitude
- Photos by Jacob Ryg (City Forester, Rochester, MN)

There is a Limit to Tree Response

Pruning Trees and CODIT

- Genetics of Compartmentalization

Tree Response to Decay Varies (Weak to Strong)

CODIT Models Tree Response to Wounding

- A) Tree Defense Strategy for Wounding
- B) Resist, Slow, Stop? Wood Decay
- C) Morphological and Chemical Decay
- D) Compartment based
  - A) Cellular
  - B) Groups of cells within radial & marginal parenchyma
  - C) Growth increment

Alex Shigo, Modern Arboriculture
3 Orders of Radial Compartments

(A) Cellular
(B) Bounded by Radial/ Marginal
(C) Growth Rings

Fraxinus latifolia
(A. Shigo)

Alex Shigo, Tree Anatomy

3 Orders of Radial Compartments

(1) Annual growth increment (C)
(2) Sub-divided by sheets of radial parenchyma (R)
(3) Compartment within a compartment (C + R)

Beginnings of the 3D model

Alex Shigo, Modern Arboriculture

Compartmentalization of Decay in Trees

4 Major Episodes in CODIT

1. Wounding (live tissue)
2. Response (compartmentalize injured & infected wood)
3. Succession (organism invasion and survival strategies)
4. Development of discolored & decayed wood within the compartment(s)

An Action Results in a Reaction

Trees respond to wounds and subsequent infections by
1) resisting spread outside of the 3 orders of compartments (Stage 1)
2) separating wood present at the time of wounding and new wood that is formed later (Stage 2)

Wound/ infection response is an energy demanding process
Effectiveness response a function of energy + genetics

Two Stages of CODIT

Stage 1: Wall 1
Vertical Spread
Vessels & Trachids
Resist spread through:
tyloses (ring porous)
gums (diffuse porous)
resins (conifers)
Weakest wall (many pathogens can successfully breach it)
Compartmentalization of Decay in Trees

Stage 1: **Wall 2**
- **Inward Spread**
- Growth increments
- Marginal parenchyma & latewood vessels + tracheids (thick walled)

CODIT is a Model with Walls

Alex Shigo, Modern Arboriculture

Compartmentalization of Decay in Trees

Stage 1: **Wall 3**
- **Lateral Spread**
- Radial Parenchyma
- High energy reserves
- Strongest reaction wall in many species

CODIT is a Model with Walls

Alex Shigo, Modern Arboriculture

Compartmentalization of Decay in Trees

Stage 2: **Wall 4**
- **Barrier Zone**
- Formed after wounding
- Separates infected wood from new healthy wood
- Size a function of wound size, time of year wounded, and genetics

Compartmentalization of Decay in Trees

Reaction Zones

<table>
<thead>
<tr>
<th>Wall</th>
<th>Weak</th>
<th>Strong</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1A</td>
<td>1B</td>
</tr>
<tr>
<td>2</td>
<td>2A</td>
<td>2B</td>
</tr>
<tr>
<td>3</td>
<td>3A</td>
<td>3B</td>
</tr>
</tbody>
</table>

CODIT is a Model with Walls

Alex Shigo, Modern Arboriculture

Compartmentalization of Decay in Trees

Walls 1, 2, 3 present at wounding
- Strengthened by wounding
- anti-microbial toxic compounds (chemical resistance)
- ahead of the advancing pathogen
- Chemical changes discolor the wood
- Energy consuming process
- stored carbohydrates
- converted to chemical resistance
- Dynamic
- changing in spatial orientation
- invading organisms

CODIT is a Model with Walls

Alex Shigo, Modern Arboriculture

Compartmentalization of Decay in Trees

Reaction zone walls 2 & 3 within a compartment

CODIT is a Model with Walls

Alex Shigo, Modern Arboriculture
Barrier Zones
chemically strong
physically weak
Upon drying cracks can form at the barrier zone
Note all 4 protection zones (Walls 1, 2, 3 and the Wall 4)

Stage 2:  
Wall 4
Barrier Zone
Separates decayed from healthy wood
Note: heartwood formed to the outside of the hollow

Tree limits the spread of decay fungi to the wood present at the time of wounding.
This maintains its mechanical strength.

Two Major Types of Decay Causing Fungi
White Rot
- capacity to degrade all cell wall components
- even lignin
Brown Rot
- degrade only polysaccharides
- cannot degrade lignin

Detecting Defects
1. Visual Tree Assessment (VTA Process)
2. Sounding
3. Resistograph
4. Increment borers
5. Small diameter drill bits (1/8”)
6. Sonic Tomography

Measuring shell thickness: increment borer
Measuring shell thickness: portable drill (1/8" bit)

Many Ways to Find Decay

The Resistograph

Many Ways to Find Decay

Sonic Tomography
Speed/time of sound wave travel is a function of density
Decay reduces tissue density

Many Ways to Find Decay

Branch Bark Ridge

Branch Collar

How to Prune a Tree: At the Branch Collar
How to Prune a Tree: Natural Target Pruning

How to Prune a Tree: Appearance Fresh Wound

How to Prune a Tree: Appearance Old Wounds

How Not to Prune a Tree: Avoid the Flush Cut

How Not to Prune a Tree: Damages Trunk Wood

Avoid the Flush Cut

Avoid the Flush Cut

How Not to Prune a Tree: Elliptical Wound Response
Paint pruning wounds?

Avoid Point
Some Exceptions
Such As Oak Wilt

How Not to Prune a Tree: No Paint, Few Exceptions

Intermission

INTRODUCING A New 'Variety' of Tree Care Options

WAA / DNR Annual Conference Program

INTERMISSION

Tree Structure and Risk Management: Part 2

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Act III: What is Risk Management (What to Consider)
Not the way to Start the Day, or End it for that Matter

Infrastructure Risks to Arborists

Eden Prairie resident, armed with gun, chases off tree trimmer

Last update: February 5, 2010 - 6:31 AM A tree service worker hired by the city of Eden Prairie to remove a diseased tree faced a woman with a shotgun who told him to leave, according to a criminal complaint filed Thursday in Hennepin County District Court. Kimberly Ann Sisak, 39, was charged with making terrorist threats, a felony. She was released Thursday from the Hennepin County jail after posting bail and is scheduled to be in court Friday, jail records said.

When the worker went to the house on Tuesday, he rang the doorbell twice and got no answer, the complaint said. He went to the back yard to find the tree, which was marked with orange paint, and found that the letters “F U” also written on the tree. As the worker started to size up the tree, Sisak came out with the shotgun across her body and asked him what he was doing, according to the complaint. When he said he was with the city to remove the tree, she told him to leave and followed him as closely as 15 or 20 feet, it also said.

When police searched Sisak’s home they found papers that Sisak owned the shotgun, as well as letters and notices about the tree, the complaint said. One letter said that if the tree wasn’t removed by Jan. 18, the city would hire a contractor to do so.

People Risks to Arborists and Urban Foresters

Tree Failure Affects the Poor and Wealthy

Tree Failure is Not a Modern Problem

Trees Can Block Sightlines … Vehicular Hazard

Most Trees Fail During Loading Events
84% storm-damaged trees had pre-existing defects (Gary Johnson, UMN)

Tree Failure is Predictable and Preventable

Football Failure is Also Predictable

Spruce (not a palm) Tree in Crookston, MN

For the Tree or To the Tree?

Tree Biomechanics and the Tree Dance

Tree Design a Compromise

Photoreception vs Structural Integrity

Large canopy needs support

C. Mattheck, Trees: The Mechanical Design

What Caused This?

Normal or Not?

Seasonal needle drop

_Everyyearus ithappensus_

This is Not Normal

_Biological experiment goes haywire in South America_

_Amazing trees WALK 2 miles a day!_

...and they're headed our way, say experts!
Innovations in Arboriculture

Devine Intervention (Photos by Joe Hoffman)

Critical Survey Questions to Ask

• What to look at
• When to look
• How often to look
• How to survey

Conducting Tree Risk Assessment

How to Survey

• Level of complexity
• Get what you pay for
• Predictable and Preventable Results?

Can You Defend Your Actions or Lack of?

Innovations in Hot Tubs

Do Not Try This at Home, Professional Stuntmen

What’s a vector?

• 1978 Dodge Ram Charger
  – To carry
  – (i.e., a mode of transportation)

• A quantity completely specified by a magnitude and direction (Math)

• An organism that carries pathogens from one host to another (Pathology)

Vector Supplemental Inventory (VSI)
akas Windshield Survey
VSI: Sometimes Very Easy to Observe Dead & Defects

VSI Sometimes Misses Crack(s) and Extensive Decay When Not Visible From road

Potential VSI Miss Could Become a CSI Episode

Nobody Wants Death by Tree

Photos by Jacob Ryg

Document Tree Inspections

Documentation is Evidence

Document Corrective Actions

Not Documenting Can be Taken as Did Not Do

Document Resident Complaints

Documentation Reduces Disagreements
Tree Size: Large Trees >16?  Less Urgent

Inspection Thresholds: Tree Size and Failure

Defects: visible signs of potential to fail

Defects are a Visual Que

Targets
People
Utilities
Buildings
Cars
Playground
etc. (what's the worst that can happen)

People and Infrastructure are Targets

Ques to Que in on: Has Construction Occurred
- Grade Change (Fill and Removal)
- Soil Compaction
- pH alteration
- Root Severing
- Trunk and Branch Wounding
- Hydrology Changes

Have Recent Changes Occurred

Hydrology and Changes

Off-Site Norway Spruce or Water Table Change?

Weather: Species Response to Moisture Stress and/or Drought

Acclimation to Environmental Factors
Sunscald Damage to Trees

One Sycamore: Two Viewpoints

Viewed from one side.
Viewed from the opposite side.

Often Two Sides to a Story

Green Facade: A Menacing Danger

Full green canopy ≠ Structurally sound tree

Appearances can be Misleading

Tree Risk Management (TRM): Minimizing Risk

Establish a clear risk management policy

The city of Metropolis has an active policy to maintain the safety of public lands from potentially hazardous trees. The City will strive to eliminate, in a timely fashion, any tree deemed hazardous. When available fiscal and human resources limit the ability of the city to remove high risk trees, priority shall be placed on trees deemed to carry the highest risk. The standard for rating the hazardfulness of a tree will be the International Society of Arboriculture’s 12 point hazard evaluation system. The Superintendent of Forestry will administer this program and have final judgment in all matters concerning the mitigation measures taken for any tree deemed hazardous.

Tree Risk Management: Minimizing Risk

What did it say
- City has a policy
- Timely removal of hazardous trees
- Prioritization of removal
- Rating system
- Administer of the program

You Can Stop Trees from Killing

Since 2008, cash-strapped San Jose has stopped funding maintenance on street trees in public “rights of way,” pushing the responsibility solely onto homeowners even as city officials press ahead with plans for 100,000 new trees over the next dozen years.

The above fatality happened the same day of the kick-off USFS Urban Tree Risk Management workshop (9/5/2003).
An Approach

Orderly
Systematic

Frequency
- Very High Risk Zone
- High Risk Zone
- Moderate Risk Zone
- Low Risk Zone

Develop a Risk Rating Map

Most Frequent
- Very High Risk Zone
- High Risk Zone
- Moderate Risk Zone
- Low Risk Zone

Very High Risk Zone

Less Frequent
- Very High Risk Zone
- High Risk Zone
- Moderate Risk Zone
- Low Risk Zone

High Risk Zone Added

Lesser Frequent
- Very High Risk Zone
- High Risk Zone
- Moderate Risk Zone
- Low Risk Zone

Moderate Risk Zone Added

Least Frequent
- Very High Risk Zone
- High Risk Zone
- Moderate Risk Zone
- Low Risk Zone

Low Risk Zone Added

Storm Damage Preparedness
Now is not the time to start planning!
Now is the time for recovery and returning order

Tree Risk Management Helps Storm Damage Preparedness
An Integrated Approach

TRM is Part of Integrated Urban Forest Management

Prioritizing “Levels of Risk”

- Some need “immediate” attention
- Some placed on the “back burner”
- Some regarded as “acceptable,” e.g.,

Pot Holes
Uneven Sidewalks
Bridges

What is a Reasonable Protocol

Tree Risk Assessment

Failure Considerations
- Potential to Fail (Defects)
- People of Infrastructure (Target)
- Environment Conducive to Failure

All trees have the potential to fail, but not all trees are high risk

Sliding Scale (Potential to Fail) based on defect and force required to induce failure

Detect & Assess

What is a Reasonable Protocol

One Risk Rating System

Low = No defect or structural integrity not impacted

Medium = Defect present, but action not warranted

High = Failure likely action needed

A Qualitative System

Risk Assessment Guidelines

A Quantitative System

USFS Risk Rating System

<table>
<thead>
<tr>
<th>Prob. of Failure</th>
<th>Size of Part(s)</th>
<th>Prob. of Target</th>
<th>Risk Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - low</td>
<td>1 - &lt;4&quot;</td>
<td>1 - occasional use</td>
<td></td>
</tr>
<tr>
<td>2 - medium</td>
<td>2 - 4-20&quot;</td>
<td>2 - intermittent use</td>
<td></td>
</tr>
<tr>
<td>3 - high</td>
<td>3 - &gt;20&quot;</td>
<td>3 - frequent use</td>
<td></td>
</tr>
<tr>
<td>4 - extremely high</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Act IV: Applying Risk Management (what to consider)

Factors Influencing Tree Failure
1. Defects (type, size, location)
2. Species (growth patterns, successional stage)
3. Size/Age (large vs. small, old vs. young)
4. Site (prevailing winds, soil drainage)
5. Maintenance Practices (target pruning vs. topping)

Are you Tree Literate

A New Environment

Location in Forest or Open Grown

A New ‘Variety’ of Tree Care Options

Interior Grown Tree

Become Edge Tree

Note where failure occurred

All Defects are Not the Same

Location of Defect: On long limbs loading force increases as you approach the base of the limb

Tree Defects to Consider

Decayed Wood

Cracks

Root Problems

Weak Branch Unions

Cankers

Poor Tree Architecture

Dead Trees, top, branches

Decay is a Loss of Wood and Strength
Defect Type - Decay

Decay: Shell Thickness

Closed shells need at least 1 inch of sound shell for each 6 inches of stem diameter.

<table>
<thead>
<tr>
<th>Stem diameter (inches)</th>
<th>Shell thickness (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>18</td>
<td>3</td>
</tr>
<tr>
<td>24</td>
<td>4</td>
</tr>
<tr>
<td>48</td>
<td>8</td>
</tr>
</tbody>
</table>

1 inch rule
Or 1/3 rule

Remember to measure shell thickness and diameter in the same place.

Shell thickness can be affected by canker-rot fungi. Near the fruiting body, wood is decayed and vulnerable to failure.

Always Exceptions to Rule

2 inch rule
or 2/3 rule

Remember to measure shell and diameter in the same place.

Tree Defects to Consider

- Decayed Wood
- Cracks
- Root Problems
- Weak Branch Unions
- Cankers
- Poor Tree Architecture
- Dead Trees, top branches

Crack = a separation of the wood fibers

Cracks
Shear cracks separate the stem into two halves.

Cracks associated with other defects have a high failure potential.

Cracks: Double the Odds of Failure

Cracks

Horizontal Cracking: Extremely High Risk

Inrolled cracks are formed when wounds don't close properly.

Horizontal Cracking: Extremely High Risk
Cracks with High Failure Potential

1. Crack goes completely through stem or branch
   * Movement in each section may be detected
2. Stem has 2 cracks on the same segment
3. Crack in contact with another defect (decay, weak branch union, etc.)
4. Branch 4" or larger with a crack
5. Horizontal Cracks

Defect Type – Root Problems

Reduction in crown vitality/health with no other apparent causes may often indicate root problems

- Signs of Mechanical Root Problems
  - Lean
  - Soil Heaving
- Evidence of Root Cutting in ZRT
- Mushrooms
- Girdling Roots (>40% of Circumference)
- Major Decay (>40%) in Support Roots

Root Problems: Critical Root Radius Can Vary

Visual Evidence of Damaged Surface Roots

Root Problems: Often Not Easy to Observe

What Would Happen if You Break Concrete When You Plant Trees
Root Problems: Three Sided Damage

Root Problems: Four Sided Damage

Detecting Decay in Roots

Tree is unsafe if more than 33% of support roots are decayed/missing

Root Problems: Thresholds

Defect Type - Lean

High Risk Trees
1. Excessive lean – 30-40 degrees
2. Recent lean with soil upheaval
3. Leaning tree with horizontal cracks on upper side and buckling on lower side
4. Leaning tree with crack through center
5. Leaning tree with crack, canker, or decay on lower side
6. Recent prolonged soil saturation with leaning trees

Loss of anchoring becomes apparent when a tree develops a new lean.

Soil mounding
Broken roots

Leaning Trees: Risk Varies Look for Ques

A leaning tree with a crack is in imminent danger of failing.
Tree Defects to Consider

- Decayed Wood
- Cracks
- Root Problems
- Weak Branch Unions
- Cankers
- Poor Tree Architecture
- Dead Trees, top branches

Defect Type – Weak Branch Unions

Lateral branch is equal in diameter to the main stem

Why did these trees fail during an ice storm?

1. Branch is larger in diameter than stem
2. Branch with a S:B ratio ~ 1 that originates in lower 1/3 of the canopy and extends into the upper 1/3 of the canopy
3. Scaffold branch with large upright secondary branches
4. Large weak union with included bark

Included Bark Compounds the Problem

Remove when young

Weak Unions with High Failure Potential
Defect Type - Canker

Canker = area of dead bark/cambium often affecting wood beneath it.

Annual Cankers – typically no structural impact
Perennial Cankers – affect structural integrity
Cankers with high failure potential:
1. Canker in hot spot, ½ tree’s circumference
2. Canker + decay in tree’s hot spot
3. Canker connected to crack, weak branch union

Defect Type - Cankers

Defect Type – Poor Architecture

1. Branch out of proportion with rest of tree
2. Branch with sharp twist or bend
3. Multiple branches or co-dominants arising from 1 location on stem
4. Tree was topped
5. Tree growing at a sharp angle (lean)

Defect Type – Dead Top, Snags

Dead tops break off at union of live and dead tissues
Dead limbs break off near point of attachment

All dead tops and branches have a high failure potential and should be removed
Why Did This Tree Fail

Are You Qualified?

Determine when actions need to be taken

Treatment Options:
- Treat the Tree

Treatment Options:
Close the site often not practical in urban settings

Modern Regression in Arboriculture
Treatment Options:

Basal Prune a High Risk Problem

Basal Pruning Gone Bad

The End!