Transforming trees

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SIRT
Strategic Integrated Research in Timber

Forest Products Research Institute

Introduction to timber grading

The European system of machine strength grading

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What are material grades?

- Material properties are uncertain
- They vary from piece to piece
- …and within pieces
- This is true of all materials
- …although the degree of certainty differs
- Material is assigned to “classes”
- …which are described by characteristic material properties

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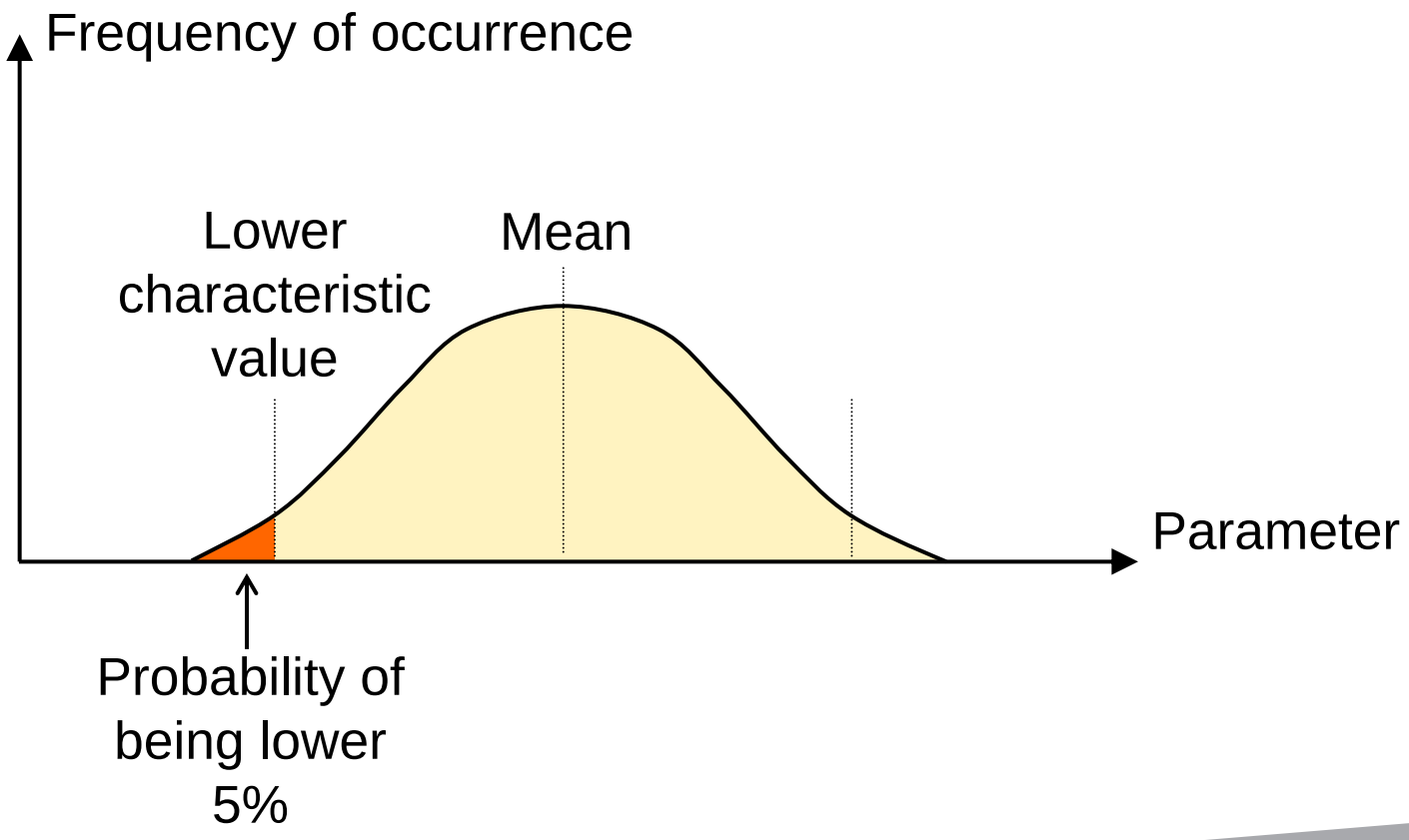
Characteristic values



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Timber

- We don’t manufacture it – trees do
- They have their own priorities
- Variable
  - Between species
  - Between origins
  - Between trees
  - Within a tree
- So how can we assign timber to classes?

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Grade-determining properties?

- Strength
  - Usually bending strength
- Stiffness
  - Usually bending stiffness
- Density
  - Also an indirect measure of strength in some elements of timber design
- All other properties are derived from these 3 properties

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Critical property?

- Strength classes are defined by
  - Strength (lower 5th percentile)
  - Stiffness (mean)
  - Density (lower 5th percentile)
- The limits are general across species
  - Softwoods (C grades)
  - Hardwoods (D grades)
  - (other grade systems exist)

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Critical property?

- To comply with the grade, characteristic values must be met (at least)
- For a species and grade combination usually one property is limiting
  - Strength
  - Stiffness
  - Density
- So strength grading isn't *always* about predicting strength

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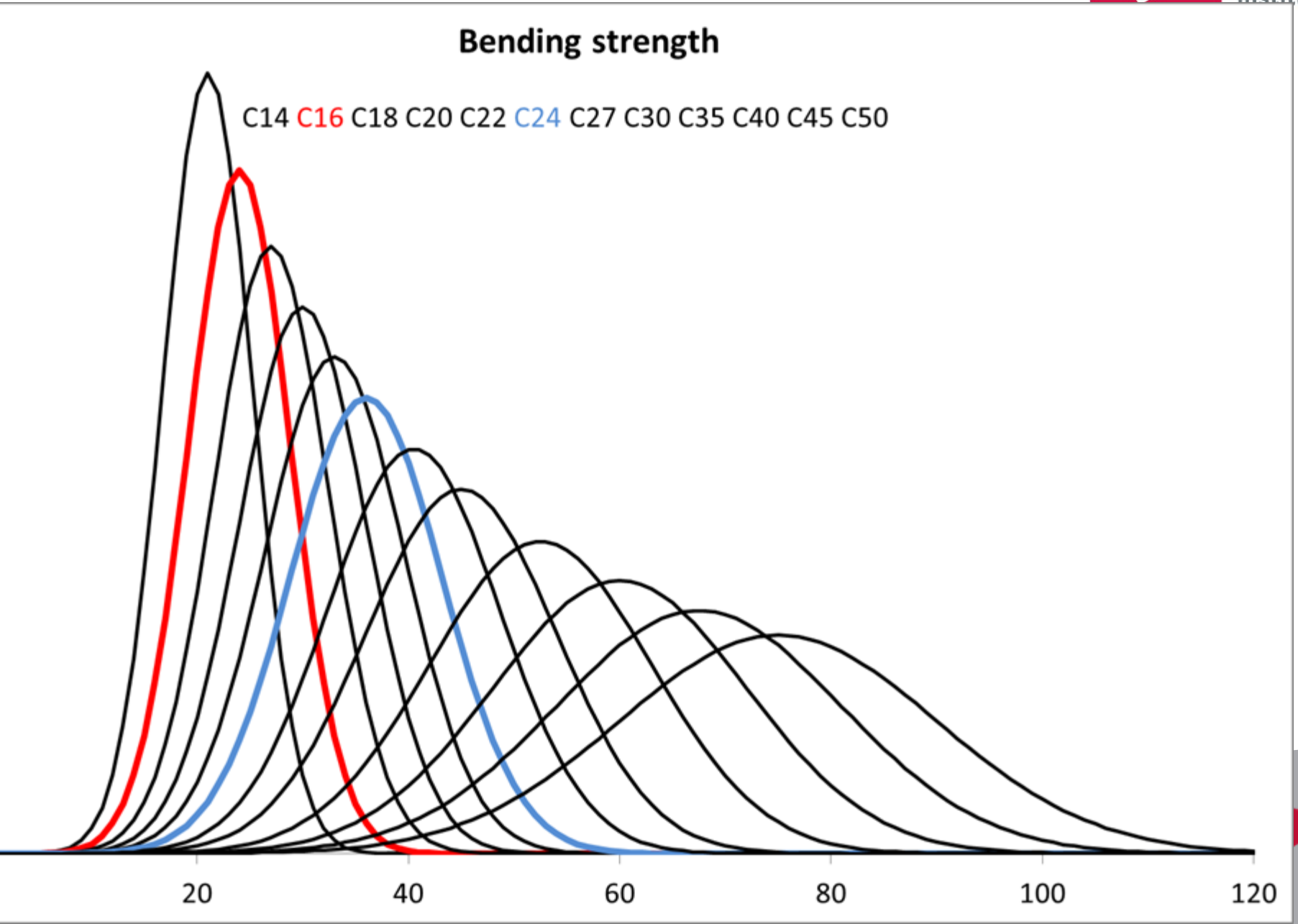

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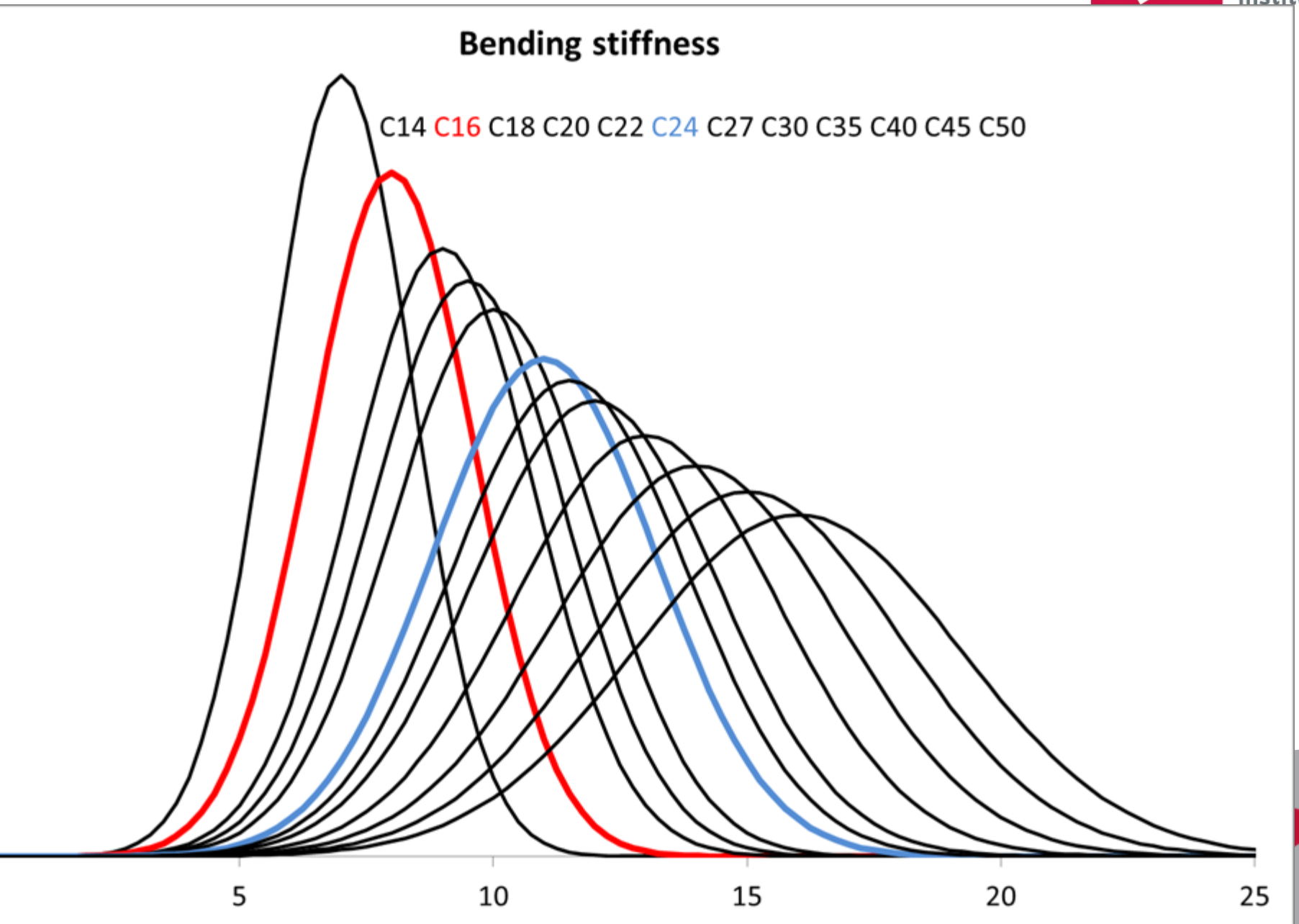

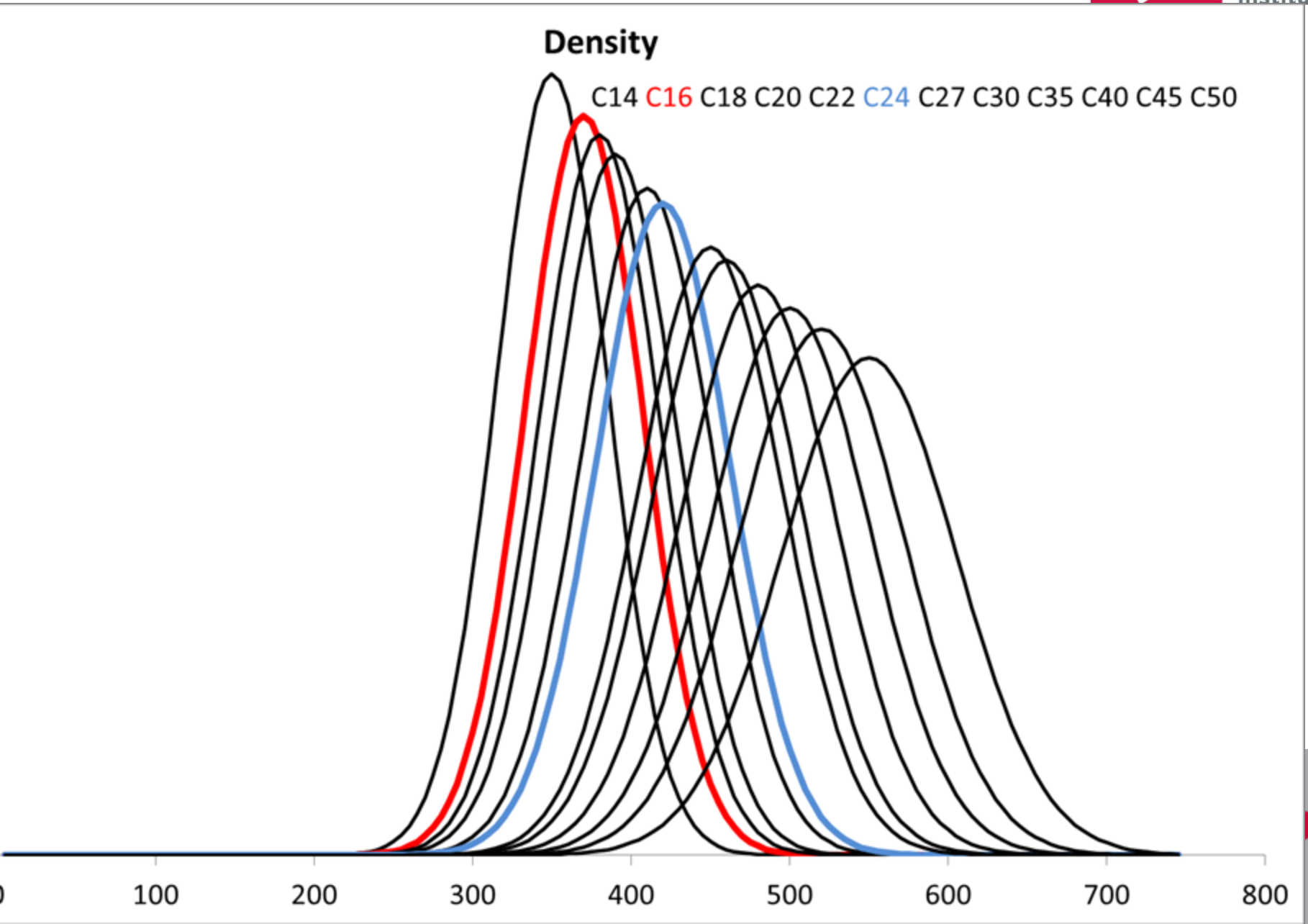
Density
C14 C16 C18 C20 C22 C24 C27 C30 C35 C40 C45 C50
100
200
300
400
500
600
700
800

How do we predict strength?

- Can only be measured destructively
- But strength is correlated with:
  - Stiffness
  - Density
  - Knots
  - Grain e.g. ring width
    - Rate of tree growth & radial position
  - Species
  - Origin

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How do we predict stiffness?

- Stiffness can be measured non-destructively
  - Mechanical bending (within elastic range)
  - Dynamic stiffness (vibration or time of flight)
- It is also correlated with
  - Density
  - Knots
  - Grain e.g. ring width
    - Rate of tree growth & radial position
  - Species
  - Origin

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How do we predict density?

- Density can be measured non-destructively
  - By weighing and measuring dimensions
  - Using x-rays (and similar methods)
  - Pin indent
  - But is confounded by moisture content
- It is also correlated with
  - Stiffness
  - Grain e.g. ring width
    - Rate of tree growth & radial position
  - Species
  - Origin

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Grading methods for timber

- Visual grading
  - Manual inspection (can be machine assisted)
  - Based only on what we can see (and infer)
  - Of limited accuracy…
  - …due to the parameters being measured
  - …and the human element
  - …so assignment to grades is conservative
  - A slow process using trained people
  - But can be verified afterwards

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Grading methods for timber

- Machine grading
  - Relates an ‘indicating parameter’ to the critical grade-determining parameter(s)
  - Better accuracy than visual grading…
  - …due to the parameters being measured
  - …and the automation
  - …so assignment to grade is less conservative
  - Fast but expensive equipment
  - Cannot really be verified afterwards

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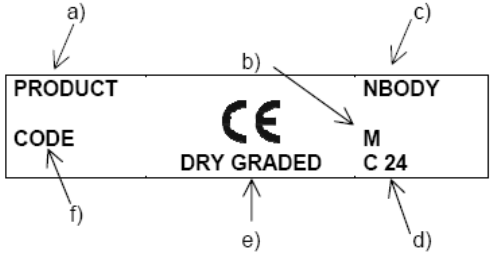
What? Cannot be verified?

- Timber is stamped with the grade mark



a) Producer identification
b) Letter 'M'
c) Identification number of notified body
d) Strength class or grade and grading
e) If appropriate
f) Code number to identify documentation

- But it is not possible to tell if an individual piece has been correctly assigned to a grade
- Because a piece can correctly belong to any grade

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How can that make sense?

- Timber grading does not operate on a piece by piece basis
- Pieces are individually assigned to classes
- …but it is the population of timber in that class that matters
- Packages of timber should meet the characteristic values …on average

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So does this make timber bad?

- No
- In fact this applies for all materials
- There is always some uncertainty
- It’s why we have material partial safety factors in design

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So how do we machine grade?

- Now many types of grading machines
  - Bending stiffness
    - Bending about the minor axis
  - Dynamic (acoustic/vibration)
    - Essentially a measure of stiffness
    - May or may not include density
  - X-rays
    - A combination of knots and density
    - Perhaps with optical camera
  - Mixtures of the above

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The indicating property (IP)

- Ideally want a good predictor of the critical grade-determining property
- Generally, additional measures improve IP
- But... It’s a compromise with cost

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Approved grading machines

- Many devices can predict grade-determining properties
- …but that does not make them grading machines
- Machines must be approved by CEN TC124 TG1 according to EN14081
- To ensure operation is reliable
- …including the human element

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Bending graders

- Measure mechanical stiffness
  - Through application of defined load
  - or defined deflection
  - Minor axis
  - Accounting for pre-existing bow
- Relatively slow (with dynamic errors)
- Limited by cross-section
- Cannot measure the whole piece

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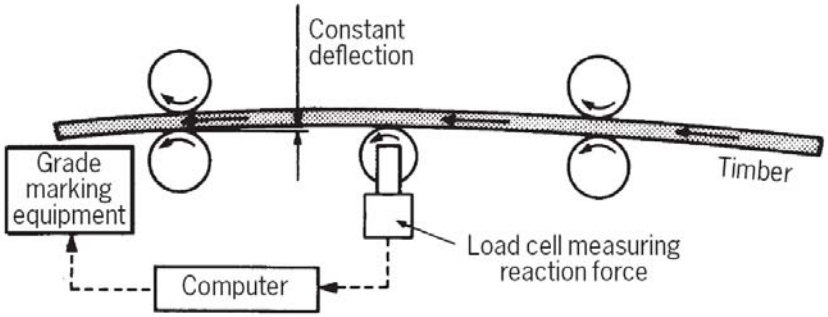
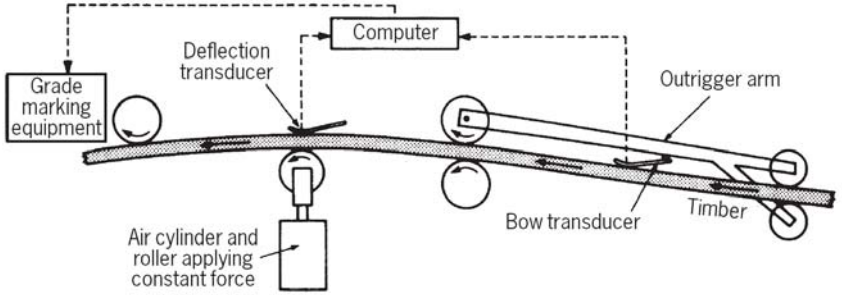
Bending graders

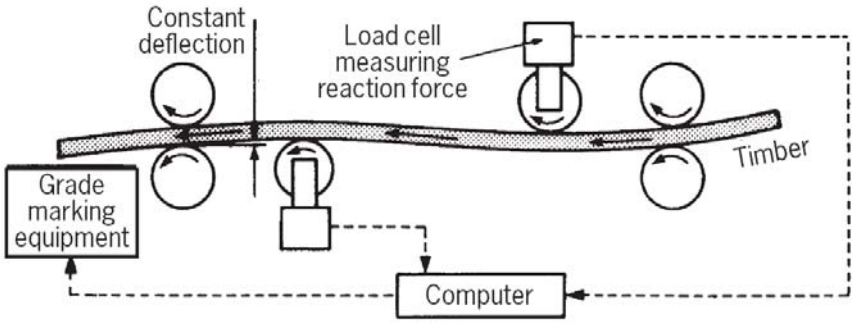
Cook-Bolinder



Computermatic



Timgrader



Figures from BRE Digest 476 “Guide to machine strength grading of timber”

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Acoustic graders

- Measure acoustic velocity
  - Through axial or transverse vibration
  - Or time of flight (including ultrasonic)
  - May or may not include density ($MoE_{dyn} = \rho v^2$)
- Fast
- Can be hand-held
- Measure the whole piece
- …but all at once

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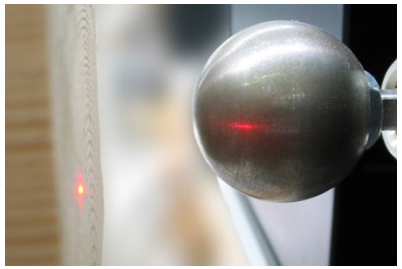
Acoustic graders

ViSCAN (MiCROTEC)



MTG (Brookhuis)

Precigrader (Dynalyse AB)

Triomatic (CBS-CBT)

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X-ray graders

- Measure
  - Clear wood and average density
  - Knot size and location
- Very fast (and permit board splitting)
- …but big and expensive
- Measure the whole piece
- …and all parts of it individually
- But not great at predicting stiffness

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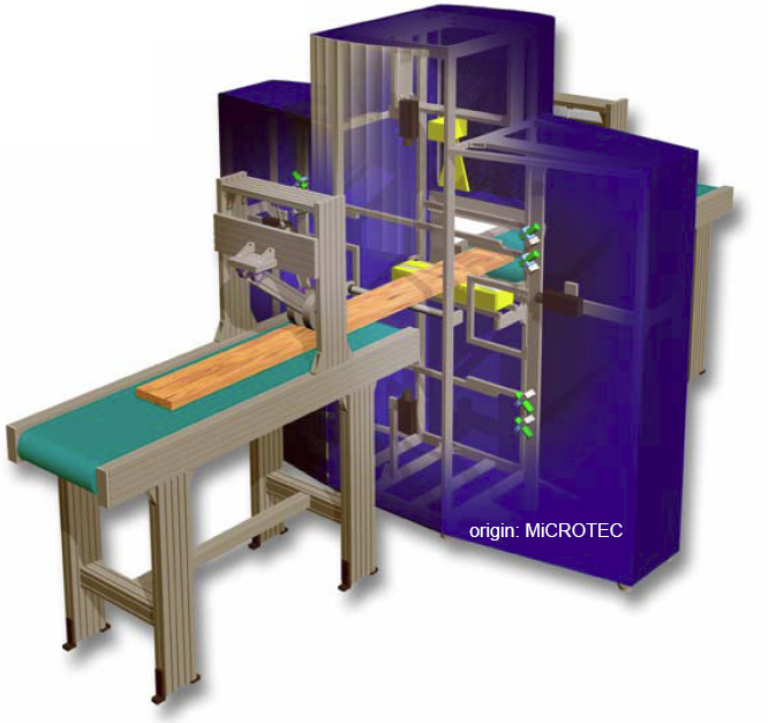
X-ray graders

GOLDENEYE 702 (MiCROTEC)



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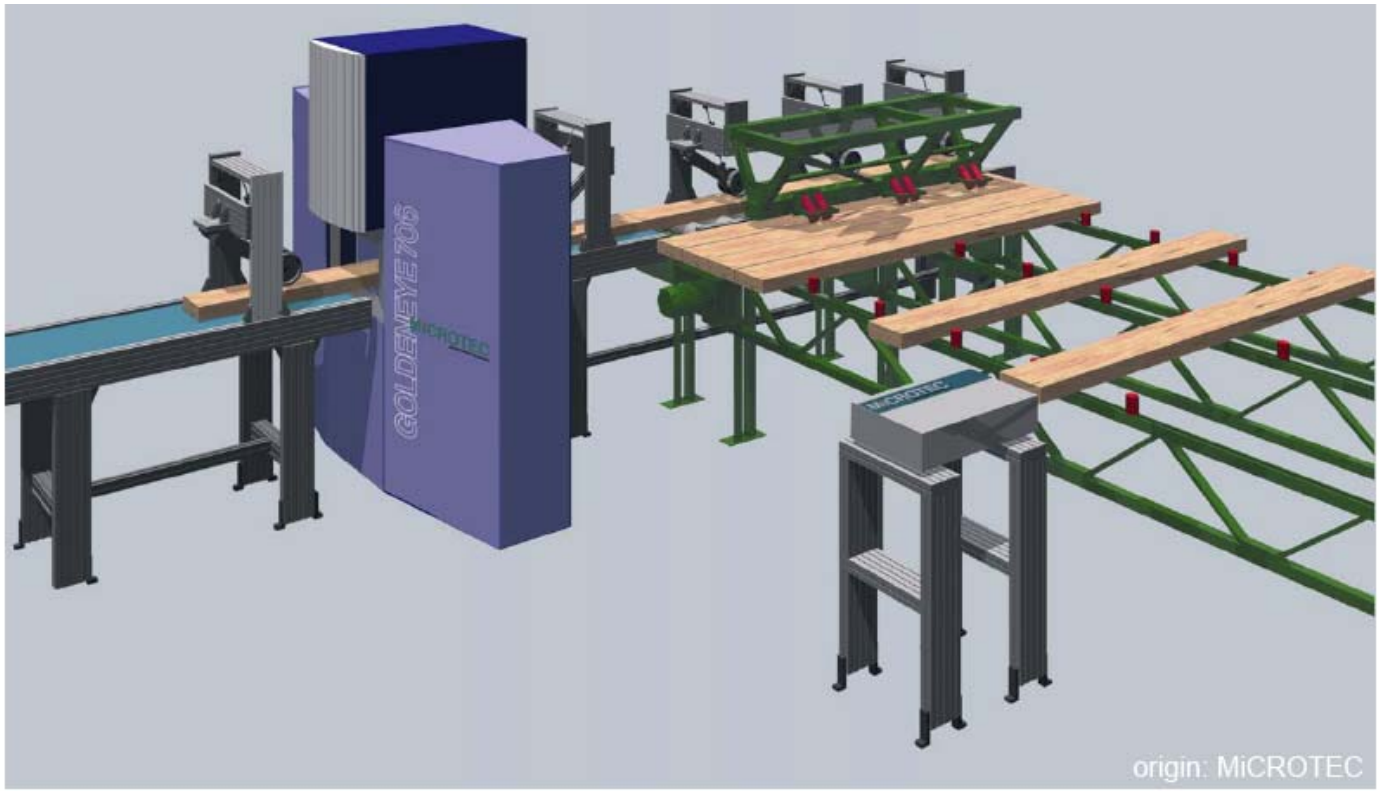
Combination graders

GOLDENEYE 706 (MiCROTEC)



But that's not everything yet

- "Visual" override
  - Distortion (might be by machine)
  - Fissures (cannot be detected by machine)
  - Wane
  - Soft rot and insect damage
  - Knots and slope of grain on any portion that cannot be machine graded (i.e. the ends of the timber for bending type machines)
  - Anything else that causes concern

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Two types of machine grading

- Output control
  - Periodic destructive testing of output from grader
  - Testing element is costly
  - But adapts the machine settings to optimise yield
  - Appropriate for large sawmills with few species
- **Machine control**
  - Sawmills don't normally test the output
  - Relies on strict assessment and control of machines
  - No regular fine adjustment of machine settings
  - Appropriate for UK sawmills (& most European ones)

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How are settings developed?

- The relationship between IP and the three grade determining properties varies
  - from species to species
  - from region to region
- Grading machines measure IP differently
- And so…

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How are settings developed?

- Machine output control settings are required for each combination of:
  - Species (or group of similar species)
  - Growth area
  - Strength grading machine
  - Strength grade combination

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The procedure

1. Obtain a sample of timber that represents the population to be graded
   Species or species group throughout the growth region
   Production practice (cutting patterns and dimensions)
   Condition in which timber is to be graded (moisture content, finish etc)
   Quality of timber to be graded (i.e. not selected lower or higher quality)
2. Remove pieces that would be rejected under visual override rules
3. Pass the timber through the grading machine for which settings are required
4. Condition the timber to the in-service moisture content (usually 12%)
5. Test to EN408 to obtain strength, stiffness and density at the worst defect
6. Relate the IP to the strength, stiffness and density (as EN384 and EN14081)
7. Present the derived settings and calculations in a report to CEN TC124 TG1
8. Settings are approved, rejected or required to be revised and resubmitted

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The grading dataset

- Minimum of 450 pieces
- From four subsample areas
- With no less than 100 pieces in each
- More pieces means less uncertainty
  - Better yields
  - More grade combinations possible
- Typically ~1000 pieces

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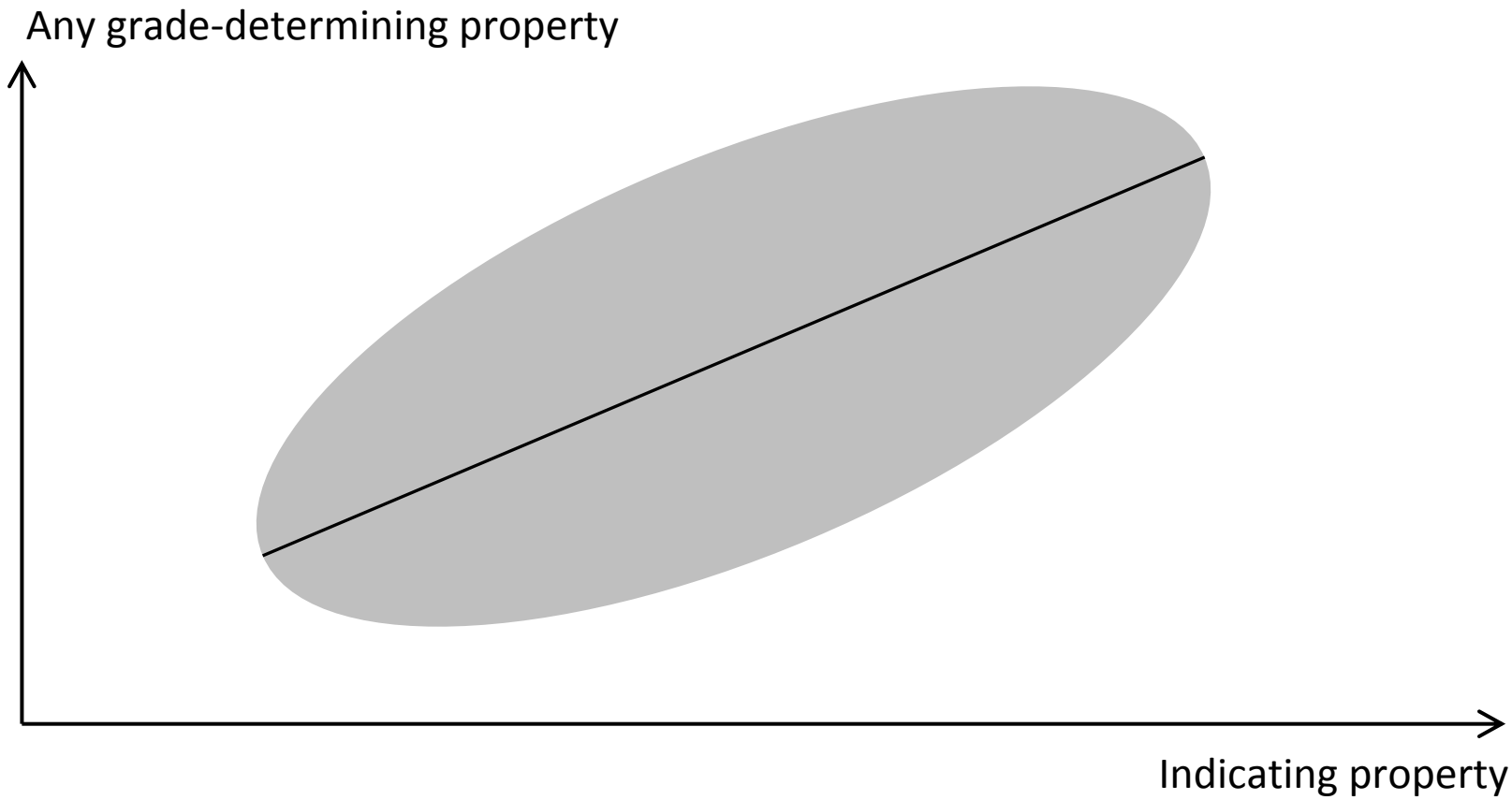
The results…



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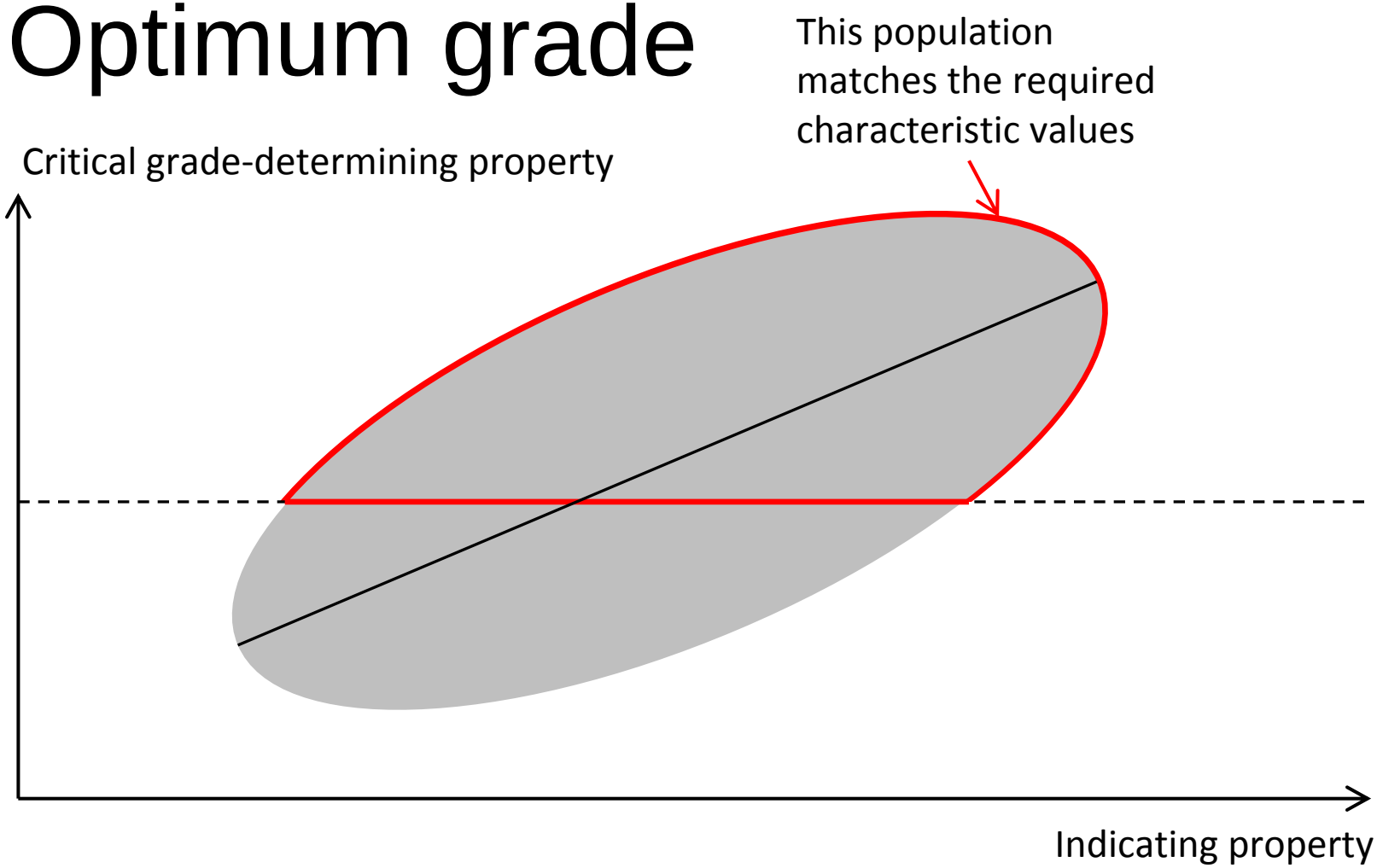
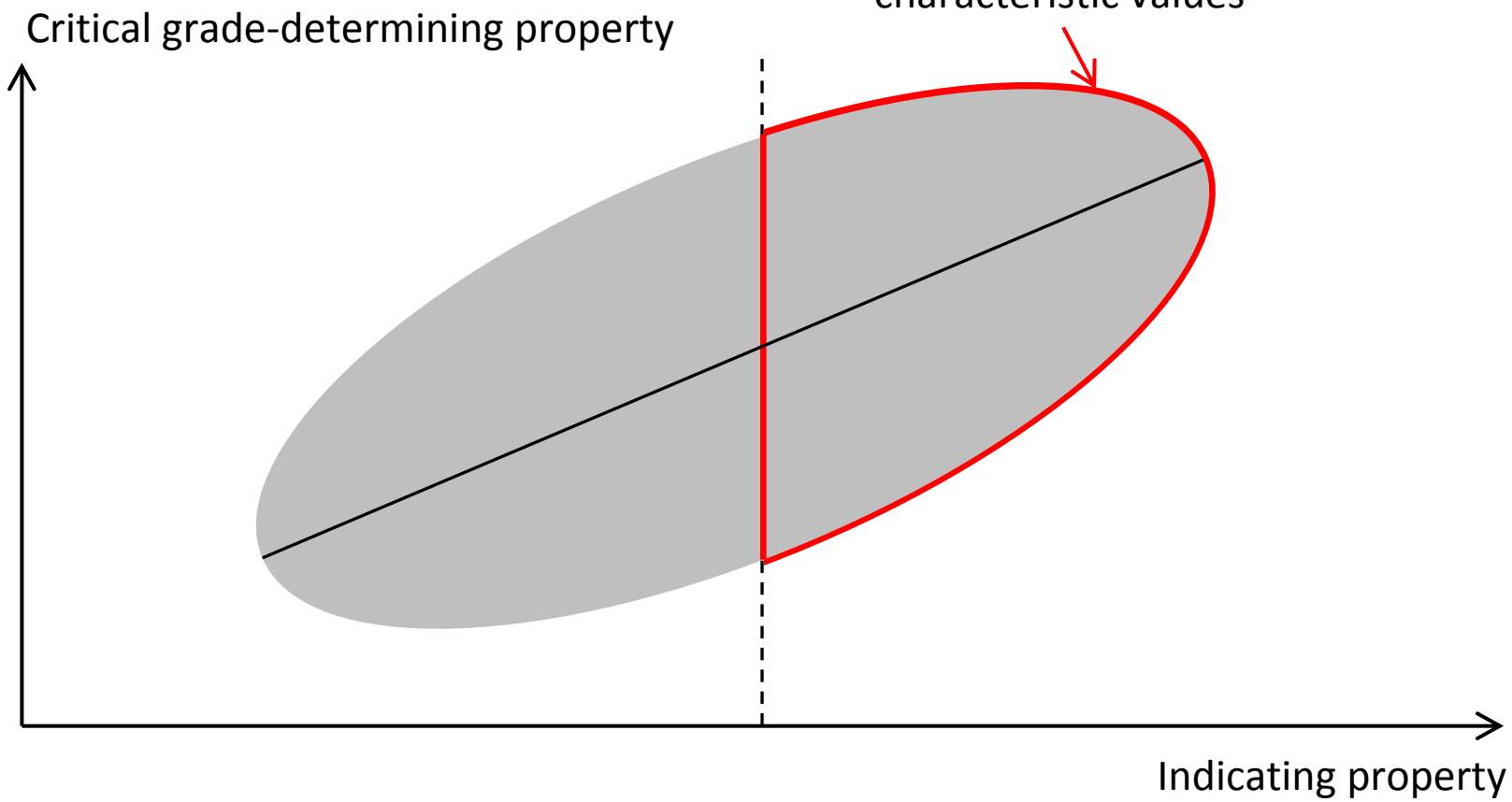
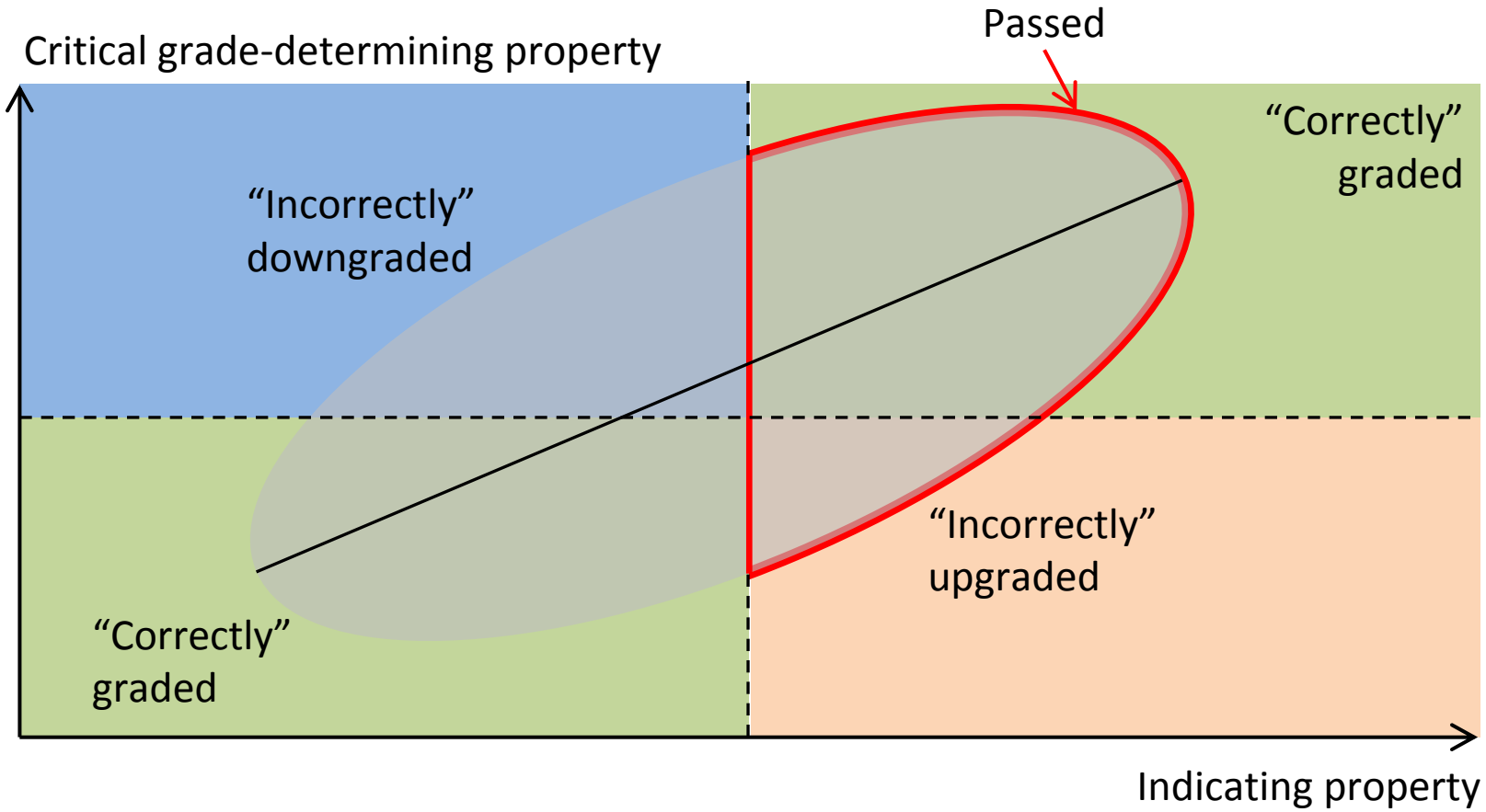
Optimum grade



Using IP


This population matches the required characteristic values
Critical grade-determining property
Indicating property

Cost matrix



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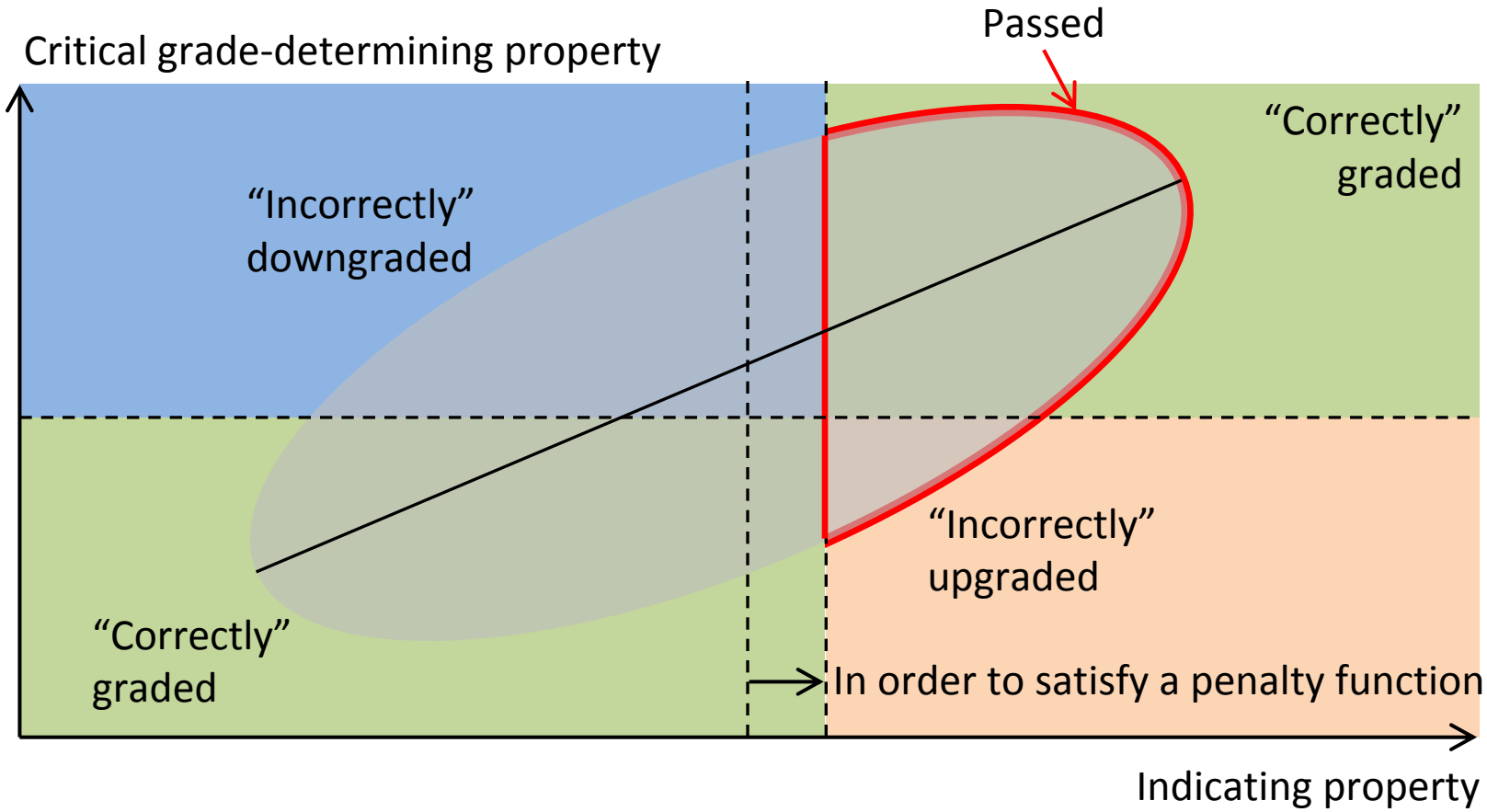
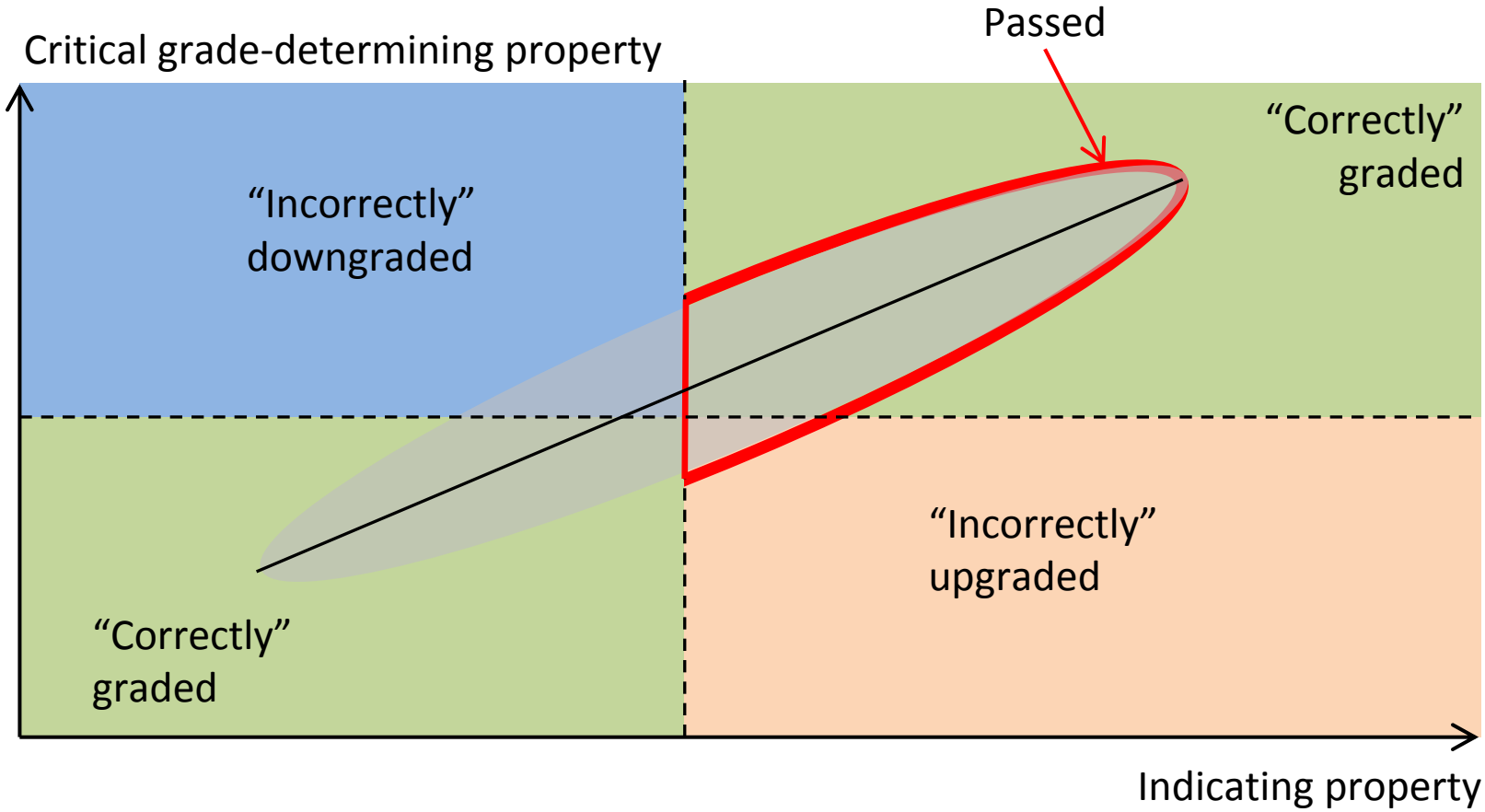
Cost matrix


Critical grade-determining property
Passed
"Correctly" graded
"Incorrectly" downgraded
"Incorrectly" upgraded
"Correctly" graded
In order to satisfy a penalty function
Indicating property

Why a powerful IP is better



Summary

- Machine strength grading does not operate on a piece by piece basis
- It is not proof-loading
- Machine strength grading isn't always about strength

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