Managing the Intolerable

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Overview

- Traditional Risk Quantification
  - Theory, Limitations
- Proposed Approach
  - Acceptable, Tolerable
- Implications of the Approach

Dice Game

- Pick the right number win 9 times your original bet
  - Is this a good deal?
  - What is the value of this scenario?
  - Is playing this game a sustainable activity?

Dice Game

- The Math

$$Risk = \left(\tfrac{5}{6} \times 0\right) + \left(\tfrac{1}{6} \times 9X\right) - X$$

$$Risk = 0 + 1.5X - X$$

$$Risk = 0.5X$$

- On Average pay $1 to take home $1.50
  - Over the long-term you Win

Benefits of this Approach

- Decipher good bets from bad bets
- Indicates if an activity is sustainable
  - Can I keep playing the game
  - Only play if you expect to win
- Tells you not to spend more on risks than the value of the risk
  - Allows for decision making ($)

Example

- Unit Fails once in 10 years
- Cost of Failure is $10,000
- Cost to Mitigate is $500/year

$$Risk = {}^{1}\!/_{10} \times 10{,}000$$

$$Risk = 1{,}000$$

- $500<$1,000 - Make the Change

Limitation of this Approach

- Approach isn't consistent with behaviors
  - The goal of insurance companies is to make money so why buy insurance?

Premiums>Risk for insurance companies to exist

- Implication when evaluating facilities
  - "Risk is acceptable" - One View
  - "But what if it does happen" - Another View

Dice Game

- Payout is 9 times your base bet
  - Average return $1 based on a $2 bet
  - Everyone wants to play and play often if the bet is $2
- Does anyone want to play just once if the minimum bet is $1,000,000?
  - Same game, same math, same analysis
  - Bigger consequences

Decision Matrix

	Positive Return	Negative Return
Can Afford to Lose the Bet	Make the Bet	Pass on the Bet
Can't Afford to Lose the Bet	Pass on the Bet	Pass on the Bet

Need to understand both dimensions in order to make an informed decision

Classic Approach Limitations

- Only considers the average return
- Does not consider if you can afford to lose
- Assumes the “Law of Large Numbers” applies

Law of Large Numbers

- Over time observations and theory will converge
  - The more times you flip a coin the closer the ratio of head to tails will be to 1:1
  - If you play a game often enough the element of luck (uncertainty) is removed

Coin Toss

- 10 Trials
  - 6 Heads, 4 Tails (50% more Heads)
- 100 Trials
  - 53 Heads, 47 Tails (12% more Heads)
- 1000 Trials
  - 490 Heads, 510 Tails (4% more Tails)

- Variation is a function of sample size

Acceptable Frequencies

- Drastic consequences often require very small frequencies so as to be acceptable
- Can these frequencies be accurately modeled/estimated at this level?
  - Is there enough experience available to draw upon?
  - Is it reasonable to make decisions at this level?

Dealing with Uncertainty

- Uncertainty is often addressed for risk measurements
  - Frequency (Can be orders of magnitude)
  - Severity (Often better understood)
- Uncertainty related to the variability associated with the event occurrence is often not addressed
  - Timing of the event (Random chance)

Tolerance Approach

- Hedge risk based on uncertainty

$$Tolerance = Risk + Z \times Std.Dev._{Risk}$$

- Z is a measure of the desired confidence
  - Z-score of 1.65 equals the 95th percentile for a one sided hypotheses (19 times out of 20)
  - Z-score of 0 represents the 50th percentile (expected value)

Expand based on Frequency

$$Tolerance = Risk + Z \times Std.Dev._{Risk}$$

$$Tolerance = Severity\left(Freq. + Z \times Std.Dev._{Freq.}\right)$$

- Focus on the uncertainty associated with random chance
  - Assumption – random chance dominates over the uncertainties associated with severity and frequency

Infrequent Events

- Poisson Equation is often used for modeling the number of event occurrences for a given period of time
  - i.e. failures per year

$$p_y(y) = \frac{e^{-\mu}\mu^y}{y!}$$

  - y is the number of events in a given time period, μ is the expected number of events

Poisson Equation Properties

- Expected value is μ
- Standard Deviation is $\mu^{1/2}$

- Explains the Coin Trials
  - Variation (noise) is a function of the square root of the sample size
  - To double the quality of your study you need four times as much data

Risk Tolerance

$$Tolerance = Severity\left(Freq. + Z \times Std.Dev._{Freq.}\right)$$

$$Tolerance = Severity\left(\mu + Z \times \mu^{1/2}\right)$$

$$Tolerance = \mu \times Severity + Z \times \mu^{1/2} \times Severity$$

- Results in the Classic Risk Function plus a Hedge Function

For Common Events

- For highly likely events μ dominates over $\mu^{1/2}$ yielding the traditional measure of risk ($\mu>1$)

$$Tolerance = \mu \times Severity \qquad \left(\mu >> \mu^{1/2}\right)$$

- For frequent events the classic risk assessment approach is unchanged

For Uncommon Events

- For highly unlikely events $\mu^{1/2}$ dominates over μ yielding a new measure of risk ($\mu<1$)

$$Tolerance \approx \mu^{1/2} \times Severity \qquad \left(\mu << \mu^{1/2}\right)$$

- For infrequent events a new equation is proposed for managing risk

What is Uncommon?

- Needs to consider all of the situations a company is involved in
- Needs to consider the life span of the company
- Expected Magnitude vs. Unexpected Magnitude
  - Function of the size of the company

Two Resulting Strategies

- If you can play often and afford to lose the classic approach makes sense
  - Develop a strategy based on the Average

- If you cannot afford to lose or you are not going to play games often the classic approach does not makes sense
  - Develop a strategy based on the Variability

Implications

- Need for two risk standards
  - Is a Risk Acceptable? μX

    (Consider the Expected Value)
  - Is a Risk Tolerable? μX^2

    (Consider the Variance in the Expected Value)
- Two standards should meet at the point between expected and unexpected

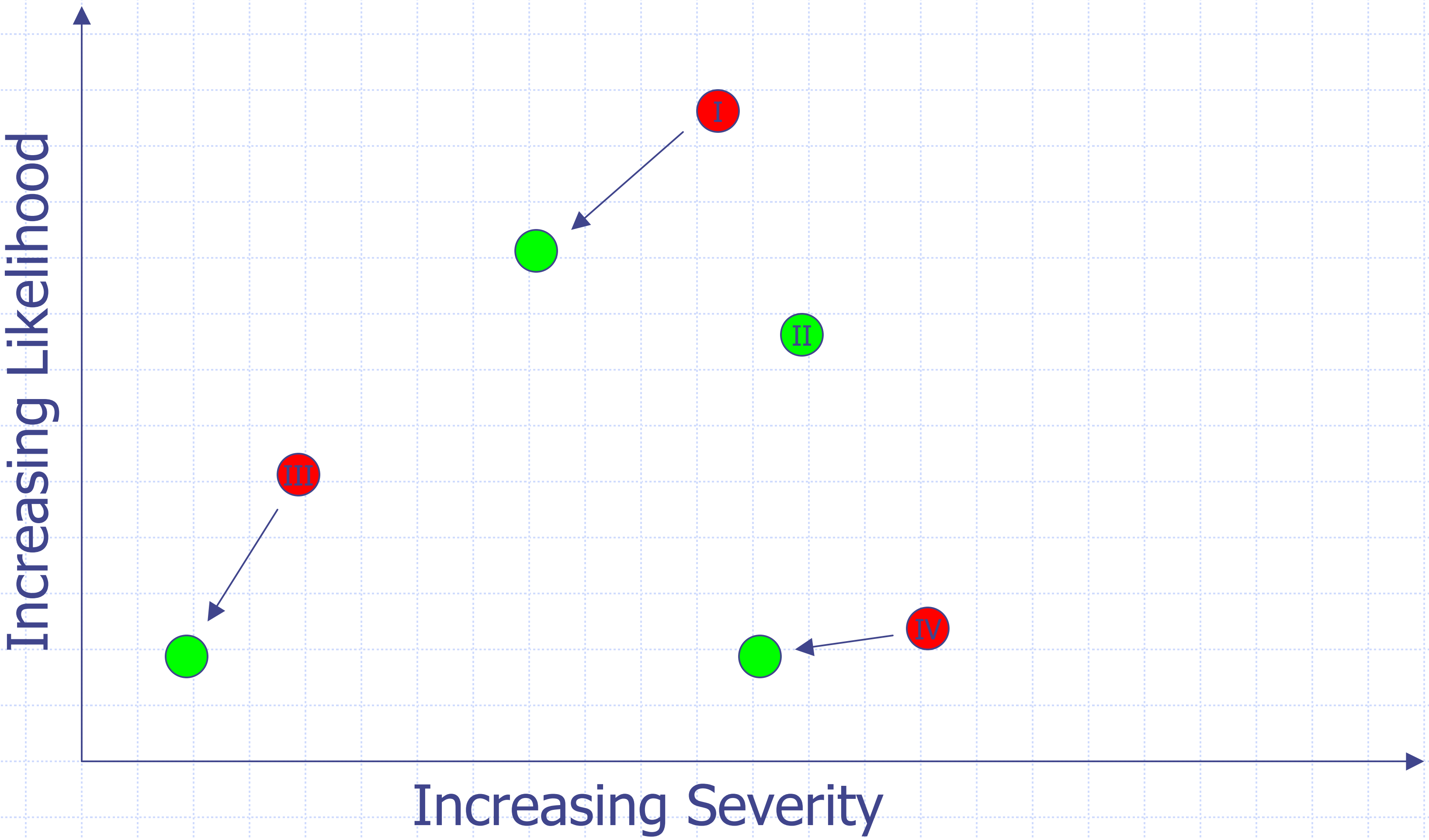
The Two Standards

- Risk Acceptability is independent of the organization
  - Expected Value Theory (Can I win?)
  - Consistent with Industry
- Risk Tolerability should be a function of the organization
  - Variability (Can I Lose?)
  - What is Material to the Organization

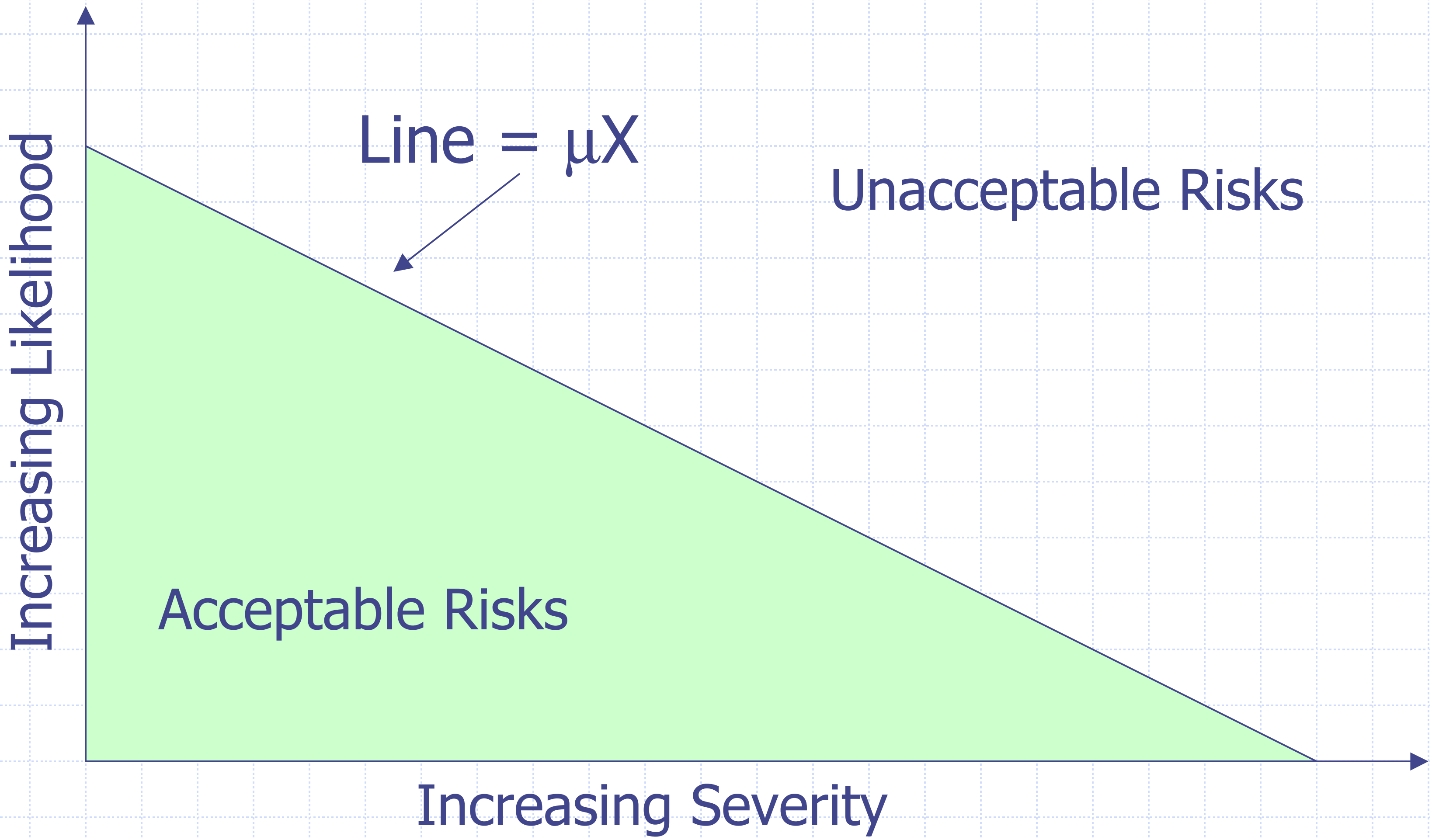
Thresholds (Avoid the Math)

- If everything is acceptable
  - Why do risk assessments? (no change)
- If everything is unacceptable
  - Why do risk assessment? (just change)
- The ideal situation is to have a mix of acceptable and unacceptable findings
  - Why do risk assessment? (strategic change)

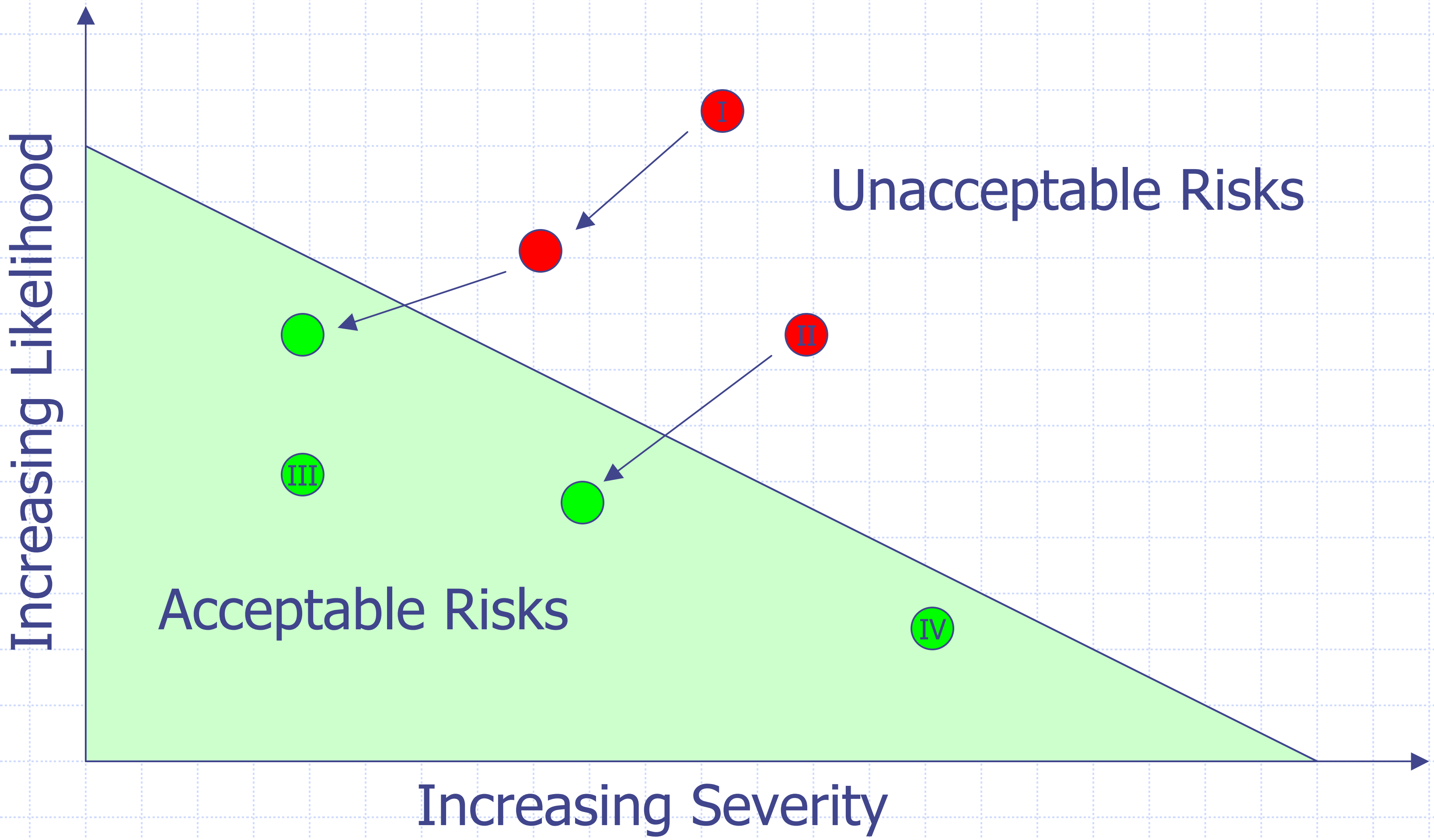
ALARP



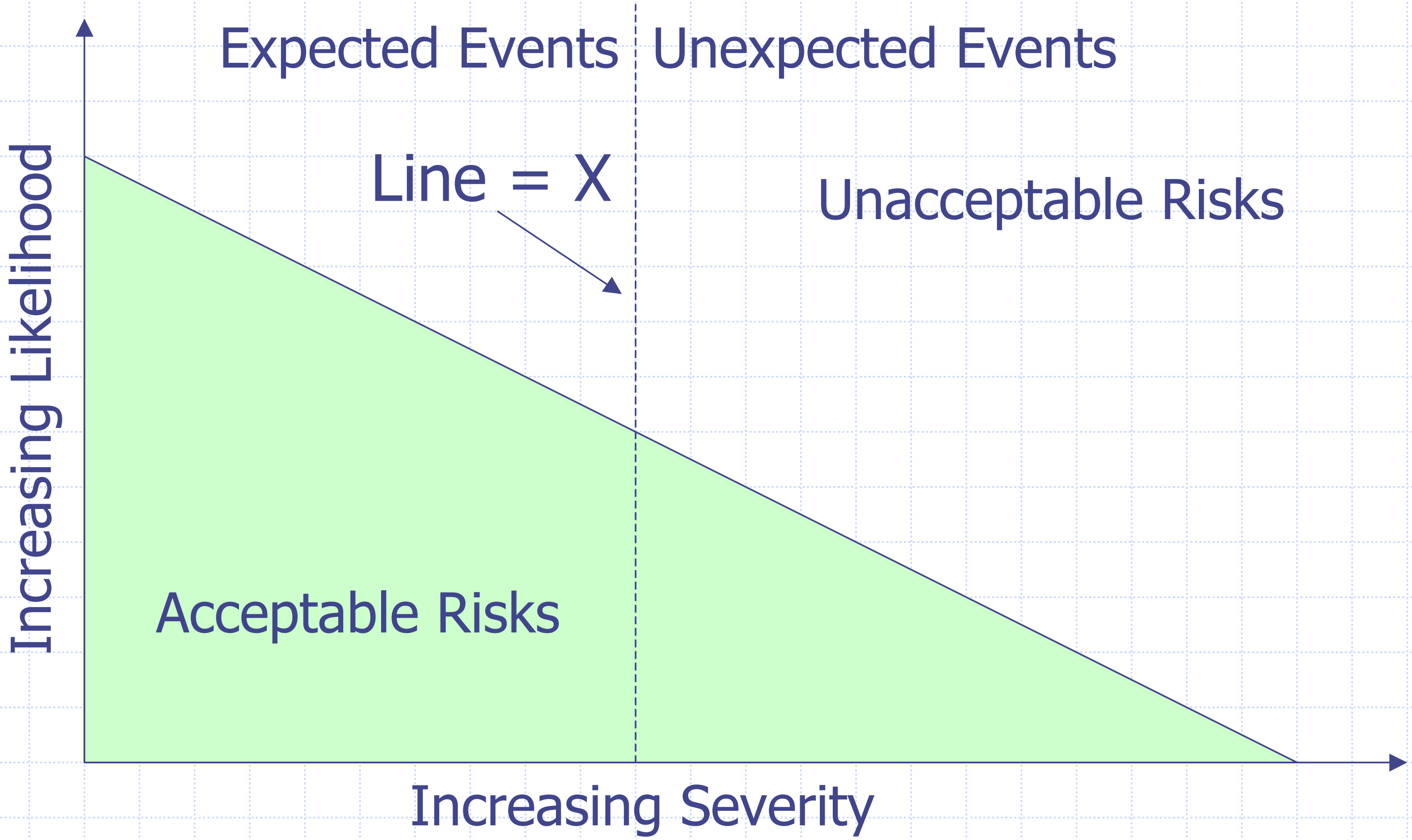
Expected Value Approach



Expected Value Approach



Proposed Risk Approach



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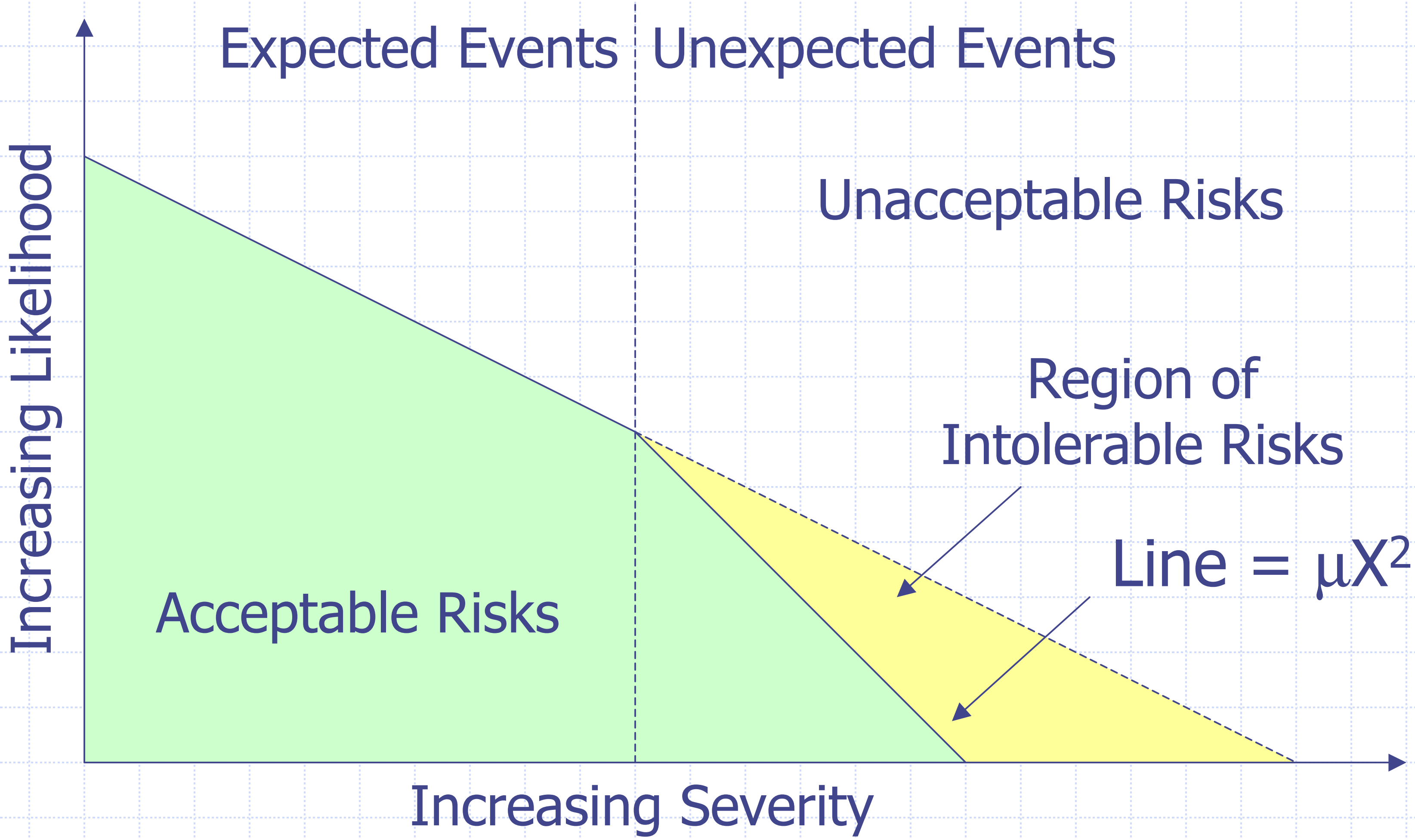

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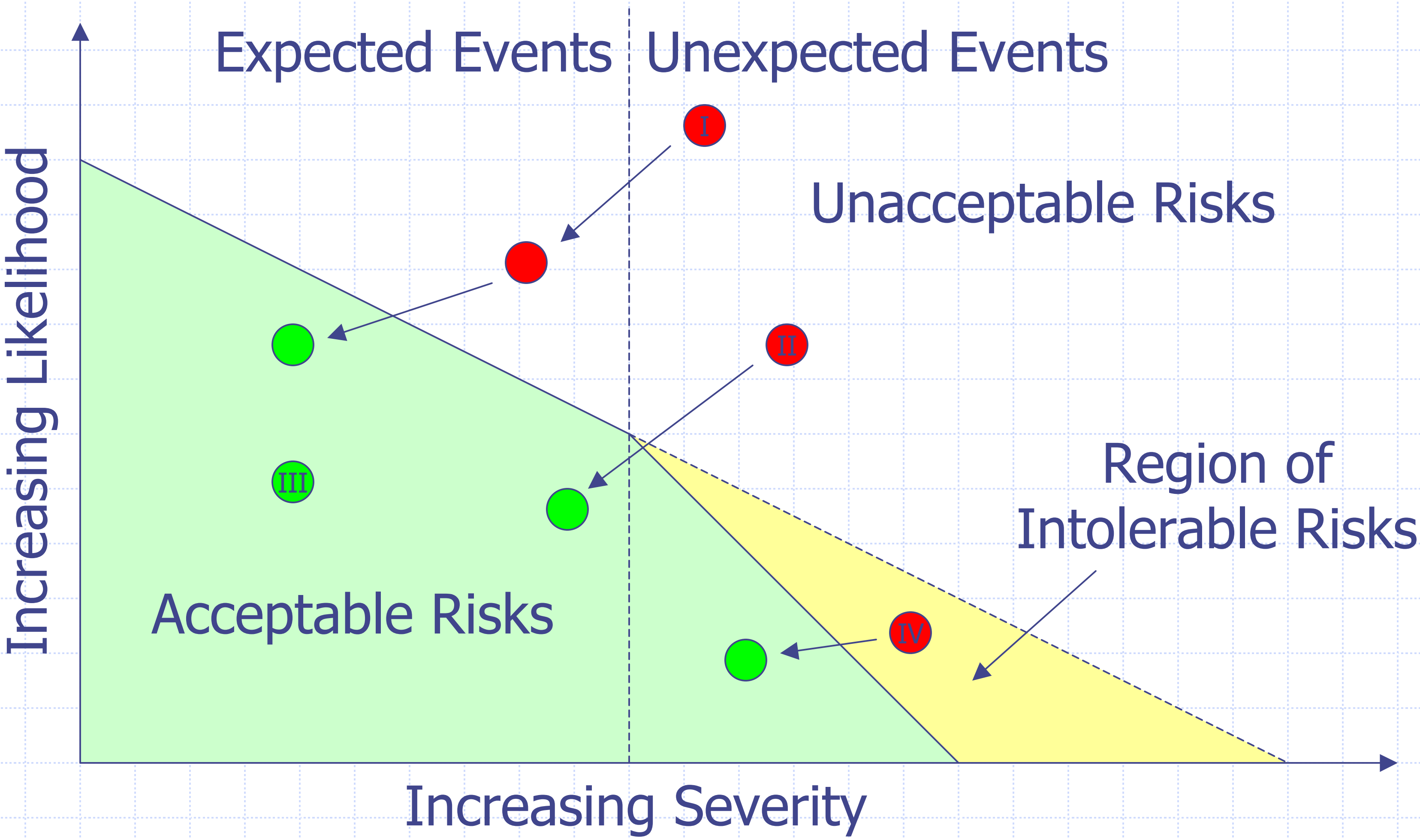

Proposed Approach Summary

- Tolerable Risk and Acceptable Risk are different concepts
  - Both need to be Managed
- Two Strategies are Required:
  - Linear Function - Expected Events
  - Square Root Function - Unexpected Events

Conclusions

- Need to go beyond Acceptability
  - Understand if you can win, if you can lose
- The Law of Large Numbers does not always apply
  - Convergence can not always be expect
- Variability needs to be Managed
  - Risk tolerance should be a function of the size of the company