Managing the Intolerable

Fred Henselwood, NOVA Chemicals
Gerry Phillips, GC Phillips Consulting
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

\[ Risk = \left( \frac{5}{6} \times 0 \right) + \left( \frac{1}{6} \times 9X \right) - X \]
\[ Risk = 0 + 1.5X - X \]
\[ Risk = 0.5X \]

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

\[
Risk = \frac{1}{10} \times 10,000
\]

\[
Risk = 1,000
\]

-$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

<table>
<thead>
<tr>
<th>Positive Return</th>
<th>Negative Return</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can Afford to Lose the Bet</td>
<td>Make the Bet</td>
</tr>
<tr>
<td>Can’t Afford to Lose the Bet</td>
<td>Pass on the Bet</td>
</tr>
</tbody>
</table>

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 95\(^{th}\) percentile for a one sided hypotheses (19 times out of 20)
- Z-score of 0 represents the 50\(^{th}\) percentile (expected value)
Expand based on Frequency

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

\[
Tolerance = Severity(Freq. + Z \times Std.Dev._{Freq.})
\]

Focus on the uncertainty associated with random chance
- Assumption – random chance dominates over the uncertainties associated with severity and frequency
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, \( \mu \) is the expected number of events
Poisson Equation Properties

- Expected value is $\mu$
- 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 $\mu$ dominates over $\mu^{1/2}$ yielding the traditional measure of risk ($\mu > 1$)

$Tolerance = \mu \times Severity \quad (\mu \gg \mu^{1/2})$

For frequent events the classic risk assessment approach is unchanged
For Uncommon Events

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

$$Tolerance \approx \mu^{1/2} \times \text{Severity} \quad (\mu << \mu^{1/2})$$

- 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 make sense
  - Develop a strategy based on the **Variability**
Implications

- Need for two risk standards
  - Is a Risk Acceptable? $\mu X$
    (Consider the Expected Value)
  - Is a Risk Tolerable? $\mu X^2$
    (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

Increasing Likelihood

Increasing Severity
Expected Value Approach

- Increasing Likelihood
- Increasing Severity
- Acceptable Risks
- Unacceptable Risks

Line = \( \mu X \)
Expected Value Approach

Acceptable Risks

Unacceptable Risks

Increasing Likelihood

Increasing Severity
Proposed Risk Approach

Increasing Likelihood

Increasing Severity

Expected Events

Unexpected Events

Acceptable Risks

Unacceptable Risks

Line = X

Acceptable Risks
Proposed Risk Approach

- Expected Events
- Unexpected Events

- Acceptable Risks
- Unacceptable Risks

Region of Intolerable Risks

Line = \( \mu X^2 \)
Proposed Risk Approach

- Increasing Likelihood
- Increasing Severity
- Expected Events
- Unexpected Events
- Acceptable Risks
- Unacceptable Risks
- Region of Intolerable Risks
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