Making Sense of Risk Tolerance Criteria

2014 Mary Kay O'Connor Process Safety Center International Symposium

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University of
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BLUEFIELD
PROCESS SAFETY

Presented by

❖ **Michael S. Schmidt**

- ◆ **Adjunct Professor, Missouri University of Science and Technology, Rolla, Missouri**
- ◆ **Principal, Bluefield Process Safety, LLC, St. Louis, Missouri**

What we're covering

- ❖ **A brief overview of the steps to establish RTC**
- ❖ **Discussion of each of those steps (an example)**
- ❖ **Some hard questions**

Steps to Establish RTC

- ❖ **Choose impact vectors**
- ❖ **Divide each impact vector into categories separated by orders of magnitude**
- ❖ **Align each impact vector with other impact vectors**
- ❖ **Benchmark impact vectors tolerable frequency**
- ❖ **Assign risk rankings uniformly**

A real risk matrix

Likely (once a month)	Consider action	Consider action	Action required	Action required	Action required
Occasional (once per 10 years)	No action required	Consider action	Action required	Action required	Action required
Seldom (once per 20 years)	No action required	Consider action	Consider action	Action required	Action required
Rare (once per 100 years)	No action required	No action required	Consider action	Consider action	Action required
Unlikely (once per 100 years)	No action required	No action required	Consider action	Consider action	Action required
Safety Impact	Minor injury to employee or in the community	Moderate injury to employee or in the community	Significant injury to employee or in the community	Significant injuries to employees or in the community	Life-threatening injury to employee or in the community
Environmental Impact	Minor release (< RQ)	Moderate release (>RQ)	Significant release (>RQ)	Major release (>RQ)	Severe release (>RQ)
Financial Impact	$10,000 equipment damage or 1 week downtime	$100,000 equipment damage or 2 week downtime	$500,000 equipment damage or 1 month downtime	$20,000,000 equipment damage or 6 months downtime	$20,000,000 equipment damage or 2 years downtime

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Four types of impact vectors

- ❖ **Safety**

- ❖ **Community**

- ❖ **Environment**
  -Several forms possible, one is sufficient

- ❖ **Asset**
  -Several forms possible, all of interest should be converted to cost then summed

What impact vectors chosen?

❖ **Safety or community**

❖ **Environment**

❖ **Asset**
-Equipment damage ($) or downtime (t)

Problems with impact vectors?

❖ **Safety and community should be separate**

❖ **Convert downtime from time to cost ($), then sum all costs**

Note: Not all downtime is equal, not all market share is equal, not all reputation is equal, but all $$ are equal

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Divide vectors into categories

❖ **Well-defined**

❖ **Uniformly separated**

❖ **Orders of magnitude**

Which vectors?

❖ **Safety**

❖ **Community**

❖ **Environment**

❖ **Assets**

Impact categories-safety

- ❖ **Stated categories:**
  - ◆ **Minor injury to employee**
  - ◆ **Moderate injury to employee**
  - ◆ **Significant injury to employee**
  - ◆ **Significant injuries to employees**
  - ◆ **Life-threatening injury to employee**
- ❖ **Well defined?**
- ❖ **Separated by orders of magnitude?**
- ❖ **How would you change it?**

Better categories-plant safety

- ❖ **Less than a first aid (a near miss)***
- ❖ **Less than a recordable injury**
- ❖ **Less than a permanent disabling injury**
- ❖ **Less than a fatality**
- ❖ **Less than 10 fatalities**
- ❖ **10 or more fatalities****

Better categories-community

- ❖ **Less than a complaint (a near miss)***
- ❖ **Less than a first aid**
- ❖ **Less than a medical treatment beyond first aid****
- ❖ **Less than a permanent disabling injury**
- ❖ **Less than a fatality**
- ❖ **One or more fatalities*****

Possible environmental vectors

- ❖ **Socio-political concern**
  - ◆ **Government response**
  - ◆ **Public outrage/media coverage**
- ❖ **Environmental damage**
  - ◆ **Amount released**
  - ◆ **Shoreline contaminated**
  - ◆ **Land area contaminated**
- ❖ **Ecological recovery**
  - ◆ **Time to regain equilibrium**

Impact categories-environment

- ❖ **Stated categories:**
  - ◆ **Minor release (< RQ)**
  - ◆ **Moderate release (> RQ)**
  - ◆ **Significant release (> RQ)**
  - ◆ **Major release (> RQ)**
  - ◆ **Severe release (> RQ)**
- ❖ **Well defined?**
- ❖ **Separated by orders of magnitude?**
- ❖ **How would you change it?**

Which environmental vector?

- ❖ **Socio-political concern**
  - ◆ **Government response**
  - ◆ **Public outrage/media coverage**
- ❖ **Environmental damage**
  - ◆ **Amount released**
  - ◆ **Shoreline contaminated**
  - ◆ **Land area contaminated**
- ❖ **Ecological recovery**
  - ◆ **Time to regain equilibrium**

Better categories-environment

❖ **Improved categories:**
- ◆ **Minor release (< 1 RQ)**
- ◆ **Moderate release (> 1 RQ)**
- ◆ **Significant release (> 10 RQ)**
- ◆ **Major release (> 100 RQ)**
- ◆ **Severe release (> 1000 RQ)**

❖ **Well defined**

❖ **Separated by orders of magnitude**

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Impact categories-damage

❖ **Stated categories:**

◆ **< $10,000 in damage**

◆ **< $100,000 in damage**

◆ **< $500,000 in damage**

◆ **< $20,000,000 in damage**

◆ **> $20,000,000 in damage**

❖ **Well defined?**

❖ **Separated by orders of magnitude?**

❖ **How would you change it?**

Better categories-damage

- ❖ **Improved categories:**
  - ◆ **< $10,000 in damage**
  - ◆ **< $100,000 in damage**
  - ◆ **< $1,000,000 in damage**
  - ◆ **< $10,000,000 in damage**
  - ◆ **> $10,000,000 in damage**
- ❖ **Separated by orders of magnitude**

Impact categories-downtime

❖ **Stated categories:**
- ◆ **> 1 week downtime**
- ◆ **> 2 weeks downtime**
- ◆ **> 1 month downtime**
- ◆ **> 6 months downtime**
- ◆ **> 2 years downtime**

❖ **Well defined?**

❖ **Separated by orders of magnitude?**

❖ **How would you change it?**

Better categories-downtime

❖ **Improved categories:**
- ◆ **< 0.1 weeks (16 hours) downtime**
- ◆ **> 0.1 weeks downtime**
- ◆ **> 1 week downtime**
- ◆ **> 10 weeks (2½ months) downtime**
- ◆ **> 100 weeks (2 years) downtime**

❖ **Separated by orders of magnitude**

Still better categories for assets

❖ **Improved categories:**
  ◆ **< $10,000 in total cost***
  ◆ **< $100,000 in total cost***
  ◆ **< $1,000,000 in total cost***
  ◆ **< $10,000,000 in total cost***
  ◆ **> $10,000,000 in total cost***

***Total cost should include cost of downtime, equipment replacement, and _____.**

Align vectors

❖ **In the West, community safety impacts are considered 10x more severe than when the same impacts occur to plant personnel:**

- ◆ **Less than a first aid in the plant (a near miss)**
  ≈ Less than a complaint from the community (a near miss)

- ◆ **10 or more fatalities in the plant**
  ≈ 1 or more fatalities in the community

Alignment – hard questions

10 or more fatalities in the plant ≈ 1 or more fatalities in the community

- ❖ **What environmental impact category would be as bad?**
- ❖ **What asset impact category would be as bad?**

Safety/asset alignment

- ❖ **Society directly sets the equivalency**
- ❖ **Worker's Compensation – state-by-state**
  - ◆ **Weekly limits: $800 ~ $1000**
  - ◆ **Time limits: 500 ~ 1000 wks**
- ❖ **Society's cap for death benefit for workers:**

   $400,000 ~ $1,000,000

Community/asset alignment

❖ **Society's value of a statistical life (VSL) inferred from wage-risk studies***

❖ **The range from 30 U.S. cities:**

$4,000,000 ~ $10,000,000

* Viscusi, W. Kip (2005, June). *The Value of Life*. The Harvard John M. Olin Discussion Paper Series, No. 517.

VSLs for several countries

- **Taiwan**   **US$0.5 million**
- **South Korea**   **US$0.8 million**
- **India**   **US$1.4 million**
- **Hong Kong**   **US$1.7 million**
- **Australia**   **US$4.2 million**
- **United Kingdom**   **US$4.2 million**
- **Canada**   **US$4.3 million**
- **Austria**   **US$5.2 million**
- **United States**   **US$7.0 million**
- **Switzerland**   **US$7.5 million**
- **Japan**   **US$9.7 million**

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Aligning environmental impacts

❖ **Socio-political concern**
- ◆ **Government response**
- ◆ **Public outrage/media coverage**

What safety or community impact prompts the same response/outrage/coverage?

❖ **Environmental damage**
- ◆ **Amount released**
- ◆ **Shoreline contaminated**
- ◆ **Land area contaminated**

How does the cost to clean up compare to other monetized impacts?

Benchmark to frequencies

- ❖ **Worker safety is the easiest to benchmark to tolerable frequencies**
- ❖ **Scenario risk – 10x less than individual risk**

   so
- ❖ **Tolerable scenario frequency – 10x less than tolerable individual fatality rates**

Indiv. fatality rate benchmarks

1×10^{-3}	**Highest tolerable per HSE**
1×10^{-3}	**Overall adult, allocated to 40 hr work week**
3×10^{-4}	**Overall young adult, allocated to 40 hr week**
1×10^{-4}	**Refinery workers**
3×10^{-5}	**Overall worker in U.S.**
2×10^{-5}	**Chemical workers**
1×10^{-5}	**Professionals/engineers**
4×10^{-6}	**Office, admin, library**

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Likelihood categories

❖ **Stated categories:**

◆ **> once per month**

◆ **> once per 10 years**

◆ **> once per 20 years**

◆ **> once per 100 years**

◆ **< once per 100 years**

❖ **Separated by orders of magnitude?**

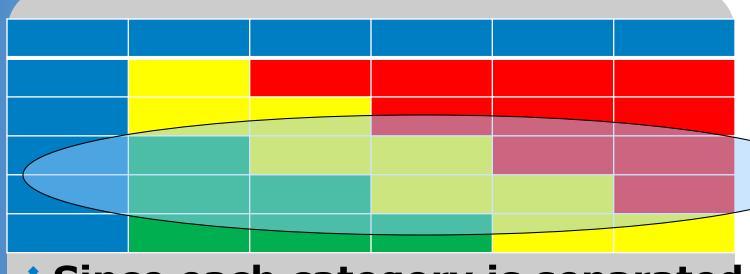❖ **Cover the appropriate range?**

Assign risk ranking uniformly

❖**Assume Row 3 and 4 are correct**

◆**(While any single row could be correct, these are the only *two* rows that could be correct)**

Assign risk ranking uniformly

❖ **Since each category is separated by an order of magnitude, risk zones should follow a staircase**
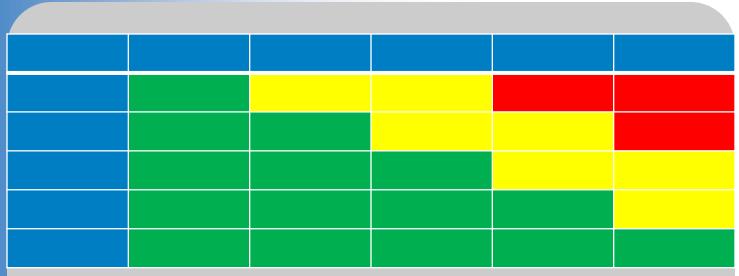
Shift up until there is an out

❖ **Since risk reduction measures typically decrease likelihood, there must be a tolerable likelihood, or risk is never addressed**

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Summary

- ❖ **Establishing risk tolerance criteria first requires choosing appropriate impact vectors**

- ❖ **Impact categories and frequency vectors must be uniformly spaced on a log-log scale, or results are irrational**

- ❖ **When there is more than one impact vector, categories must be aligned**

- ❖ **Risk rankings must be uniformly distributed, or results are irrational**

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Questions?