Risk Assessment
and
Process Safety Management

CSChE PSM Award Presentation

Presented by
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Who We Are

- Canadian consulting company, founded in 1999
- Principal Consultant: Dr. Ertugrul Alp, P.Eng.
  - Over twenty-five years experience serving the chemical, resource, energy, transportation, and steel industries, developers, and government clients.
  - Ph.D. in Mechanical Engineering, University of Waterloo (1978)
- Experience:
  - Westinghouse Canada, Atomic Power Division, Manager, Analysis and Modelling
  - Concord Environmental (later Bovar Environmental), Principal, Manager, Air Quality and Risk Assessment
  - Arthur D. Little, Associate Director, Safety and Risk Practice Leader in Canada
- Chair: MIACC Risk Assessment Expert Committee, 1994-1999
- Member: CSA Risk Management Standard Technical Committee
- Member: CCPA/CSChE Process Safety Management Committee (1999-…)
- Past Chair: CSChE PSM Division
- Past Chair: CSChE PSM Division Risk Assessment Expert Committee
- Member: Canadian Advisory Committee for developing the new ISO-31000 Risk Management Standard
- Recipient of 2007 CSChE PSM Award
Sample Client List

- Abitibi-Consolidated
- Alberta Envirofuels
- AT Plastics
- BC Hydro
- Cameco
- Canadian National
- Canadian Pacific Railway
- Canexus/Nexen
- Crompton Corporation
- Cytec Canada
- Çayeli Bakır İşletmeleri
- Dofasco
- Emshih Developments
- ETI Canada
- Gaz Metropolitain
- Industrial Accident Prevention Association
- Imperial Oil
- Inmet Mining
- Nalco Canada
- Noranda Falconbridge
- North Atlantic Refining
- Ontario Ministry of Consumer and Business Services
- Ontario Ministry of Environment
- Ontario Ministry of Health
- Ontario Ministry of Labour
- Ontario Ministry of Natural Resources
- Ontario Power Generation (through SENES)
- Orica/Orica Canada
- Petro-Canada
- Shell Canada
- Suncor
- Talisman Energy
- TransCanada Corporation
- Transport Canada
- TUPRAG Mining
Chemical Process Risk Assessment Entails…

- Study of unintentional releases, fires, explosions at petrochemical plants, pipelines, etc., in terms of their causes, consequences, and likelihoods, in short, the **risks**
  - Propane BLEVE and fireball
  - Cyclohexane release and VCE
  - H₂S release

Why do these studies?

- Amine overhead drum
- Butane and propane storage
Flixborough, 1974 – Was not the first, or the last…

Plate 34 Flixborough, UK, 1 June 1974: wreckage of reactor train following vapour cloud explosion (Courtesy of the Health and Safety Executive)
Bhopal, 1894 – 20 years later, still making headlines

➢ In The Economist,
   ◀ of all places dedicated to PSM and Risk Management !!!

Bhopal's deadly legacy

Nov 25th 2004 | BHOPAL
From The Economist print edition

The suffering and the lawsuits continue

TWENTY years after lethal gases from a Union Carbide pesticide factory billowed across a densely populated shanty town in the Indian city of Bhopal, both the dilapidated plant and its highly contaminated surrounding areas stand as monuments to governmental and corporate inaction. Compensation has still not been fully paid to over 500,000 victims, the plant has not been dismantled and toxic waste estimated to amount to several thousand tonnes remains on the site, polluting local water supplies. Legal cases are continuing in both Bhopal and New York against the American company, which was taken over by Dow Chemical in 2001, and against Warren Anderson, Union Carbide's chairman in the early 1980s, whom India has tried and failed to extradite and whose effigy will be burned in Bhopal at ceremonies to mark the anniversary.
Toulouse, 2001 – Shock to the European PSM Legislation

- Calls for “Risk Removal” !!!
  - “Risk Management is not sufficient” !!!

Ammonium Nitrate Explosion in Toulouse – France
21 September 2001
There’s always something to learn!

Lake Wabamun
2005

Missouri 2002

Oakville
2003
BP Texas City, 2005

INVESTIGATION REPORT

REFINERY EXPLOSION AND FIRE
(15 Killed, 180 Injured)

Key Issues:
- Safety Culture
- Regulatory Oversight
- Process Safety Metrics
- Human Factors

BP
Texas City, Texas
March 23, 2005

Report No. 2005-041-TX
March 2007

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So,... why do we do these risk studies?....

So that we can understand the causes, consequences and likelihoods, the *risks* ...

And why understand all this?

So that we can *manage* these risks

“Process Safety Management” entails the things we do for managing the risks of chemical processes
Outline

- PSM as part of Risk Management
  - Some History
- Risk Fundamentals
  - Components of Risk
  - Analysis – Ranking – Evaluation – Assessment
  - Quantification of Risk – Risk Parameters for Measuring Risk – Risk Metrics
  - Presentation of Risk and Ranking/Evaluation Tools
    - Risk and Risk Density Contours, Risk Maps, Risk Profiles
- Risk Analysis Tools
  - CSChE Guidelines, Some History
- Use of PSM Risk Assessments, Some Challenges
- Land Use Risk Assessments, Some History
- Further thoughts on PSM Risk Metrics
- Importance of “Understanding of the physical system” and “Organizational Culture”
- Summary and Conclusions
PSM and Risk Receptors

- “Process Safety Management” entails the things we do for managing the risks of chemical processes.

- More specifically, PSM is what an operator* of a chemical process does to ensure the process runs and delivers its products without unplanned interruptions, including those that could:
  - Kill or injure people, and/or
  - Damage the environment,
  - physical systems,
  - reputation,
  - societal/regulator goodwill,
  - market share.

- *Operator: organization, and the individuals in the organization.

- People, environment, physical systems, reputation, etc. are “Risk Receptors”.

- Note that PSM focus, while sharing many of its goals and methods, is distinctly different from Occupational Safety and Health Management.
PSM as Part of Risk Management

- Any organization makes efforts to manage its risks
  - Chemical process risk
  - Technological risk
  - Market risk
  - Political risk
  - …

- PSM focus is chemical process risk
  - PSM is therefore part of the broader risk management efforts of an organization that runs a chemical process
Management of Chemical Process Risks

- Elements of PSM (e.g., US OSHA PSM Regulations 1992, CCPA/ACC Responsible Care 1985/6, MIACC 1990s, CSChE 2002)
  1. Employee Participation
  2. Process Safety Information
     - Hazards Information for Hazardous Chemicals Used
     - Process Technology Information
     - Process Equipment Information
  3. Process Hazards Analysis (also termed “risk analysis”)
  4. Operating Procedures
  5. Training
  6. Contractors
  7. Pre-Startup Safety Review
  8. Mechanical Integrity
  9. Hot Work Permit
 10. Management of Change
 11. Incident Investigation
 12. Emergency Planning and Response
 13. Compliance Audits
 14. Trade Secrets
Development of PSM Principles and Tools in Canada

- The initial PSM efforts in the 1980s and 1990s stressed the importance individual PSM elements.

- Earlier this decade, the emphasis turned to management systems for PSM (CCPA, ACC, 2005).

- In Canada, Responsible Care Guidelines were developed by CCPA in the late 1980s as a response to Bhopal (1984).

- Major Industrial Accidents Council of Canada (MIACC) PSM Committee produced the first two editions of the “PSM Guidelines” and the “Site Self-assessment Tool” (1999).

- The Process Safety Management (PSM) Division was formed as a subject division of the Canadian Society for Chemical Engineering (CSChE) October 14, 2000.

- Products of the PSM Division (so far)
  - Guidelines for Site Risk Communication, 2005
  - Risk Assessment – *Recommended Practices* for Municipalities and Industry, CSChE 2005 (more on this later)
Management of Chemical Process Risks (2)

- Other than PSM, what else do we do to control chemical process risks?
  - Emergency Management
    - Operator and community together
    - What the operator does for EM is usually considered as part of its PSM efforts
      - “More on that some other day!”
  - Land Use Planning
    - Often, community alone! (planners, politicians, and emergency responders)
    - More on this later in the presentation
Risk Concepts

- One can look at risk from different perspectives:

  **Risk “Source” Perspective** ("where undesirable events can occur")
  - facility risk
  - chemical risk
  - transportation risk
  - nature risk
  - project risk
  - market risk
  - political risk
  - currency risk
  - ...

  **Risk “Receptor” Perspective** ("those who can be impacted")
  - public
  - employees
  - community
  - production
  - property
  - reputation
  - environment
  - elected representatives
  - customers
  - Shareholders
  - ...

  **“Integrated” perspective**
  - integrated risk
  - financial risk
  - enterprise risk

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Risk and Decision Making

- The concept of risk includes six components:
  - Benefits of an activity that we undertake (or wish to undertake)
  - Hazard inherent in that activity, which is otherwise deemed beneficial
  - An undesirable event, which brings out the hazard
  - Adverse consequence of the undesirable event
  - Uncertainty of whether the undesirable event will happen or not (likelihood/ probability/ frequency)
  - Perception about the combination of the above

- We base our decisions on perception.

- Accurate understanding of the inherent hazards, the undesirable events that can occur, and their consequences and likelihood, will lead to:
  - more balanced perceptions;
  - and hence to:
  - better decisions in “managing the risks of that activity”
Risk and Decision Making

- “Understanding the inherent hazards, the undesirable events, and their consequences and likelihood” is:
  - Risk Analysis
  - \[ \text{Risk} = f[\text{hazard, event, consequence, frequency}] = C_{he} \times f_{heC} \]

- “Making judgments about the importance of the undesirable events (perception component; by taking into account the benefits of the activity, costs of the activity, risks of the activity, benefits of risk control measures, costs of risk control measures)” is:
  - Risk Evaluation

- “Risk Analysis”, together with “Risk Evaluation”, is termed “Risk Assessment” (CSA Definition)

- Risk assessment is then a tool for PSM decision making, in:
  - designing and constructing new facilities/operations, and
  - improving existing facilities/operations
  by considering costs and benefits of risk control measures.
Definition of Risk – Causes and Controls (Layers of Protection)

Risk

Layers of Protection (Prevention) → Undesirable event → Likelihood of Event → Consequences

“Inherent Hazards” → Causes → Undesirable event → Likelihood of Event → Consequences

Example
Toxicity of material - in storage tank
Spill - Loss of life/ property, Environmental damage, Damage to reputation of facility owners/ emergency responders/ regulators

The likelihoods depend on the number and quality of Layers of Protection
Quantifying Risk

- **Undesirable event**
  - An event which has the potential for causing adverse effects on people, property/production or the environment
  - An event (or condition) that can result in reputational or material financial loss or prevent the organization from achieving its business objectives

- If more than one type or a range of consequences are possible, then total risk due to an “undesirable event” is calculated by:
  \[
  Risk \text{ from undesirable event} = \sum_k \sum_i (\text{Consequence}_{i,k} \text{ of undesirable event} \times \text{Likelihood of Consequence}_{i,k} \text{ of that event})
  \]
  - \( k \) = receptor type, e.g., people safety, environment, production, reputation
  - \( i \) = consequence level, e.g., small, medium, large, extreme

- Here, “risk” is the **residual risk** with a **given set of controls**.

- Total risk from a chemical process (or facility) is the sum of the risk from all events that can take place in that facility.
  \[
  Risk \text{ from facility} = \sum_e R_e
  \]
Parameters for Measuring Risk – Risk Metrics

- **Four fundamental parameters**

  1. Risk to a *single individual receptor* of a given type of risk receptor (e.g., people) exposed to a given risk source (e.g., chemical facility)
     - Individual risk (considers ability to escape/take cover, and/or fractional time of exposure to the risk source)
     - Geographical risk (assumes no escape/take cover, and exposure 100% of the time)

  2. Risk to *all individual receptors* of a given type of risk receptor exposed to a given risk source ("group risk")
     - Societal risk (considers ability to escape/take cover, and/or fractional time of exposure to the risk source)
     - Aggregate risk (assumes no escape/take cover, and exposure 100% of the time)
     - Societal or aggregate risk *intensity/density* (risk per unit length/area/volume of risk source or exposed to the risk source)
Parameters for Measuring Risk – Risk Metrics

3. Value-normalized risk
   - Average aggregate risk per unit of value exposed to the risk source (e.g., aggregate risk per worker-year)

4. Excess aggregate risk
   - Deviation of risk due to a risk source, from its “fair share”
   - Fair share: average aggregate risk per risk source

- Used since 2001 by Alp & Associates for governments and industry

- Reference:

   Risk Measures for Allocating Audit and Inspection Resources

   Paper # 694

   Prepared by Ertugrul Alp, PhD, PEng
Presentation of Risk – Individual/Geographical Risk

- Risk Transects
- Risk Contours on a geographical map

A full QRA is the required analysis approach for this type of application.
Use of Individual Risk Information for Land Use

Risk Acceptability Criteria for Land-use Planning (Proposed; extension of MIACC, 1995)

Annual Individual Risk (chance of fatality per year)

- 100 in a million (10^{-4})
- 10 in a million (10^{-5})
- 1 in a million (10^{-6})
- 0.3 in a million (0.3 \times 10^{-6})

<table>
<thead>
<tr>
<th>Risk source</th>
<th>No other land use</th>
<th>Manufacturing, warehouses, open space (parkland, golf courses, etc.)</th>
<th>Low density commercial buildings/offices, low-density residential</th>
<th>All other uses (high-density residential, office towers, etc.) excluding sensitive institutions</th>
<th>Sensitive institutions (hospitals, nursing homes, schools, transport hubs, etc.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allowable Land Uses</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Implications of Land Use Risk on PSM

- Typically, if a risk assessment shows that the facility risk does not meet risk-based land use planning criteria, then either
  - A new land use development around an existing risk source does not take place
    - Who pays?
  - or
  - The facility (existing or proposed) will be forced to consider additional PSM-type risk control measures
    - Again, who pays?!?

- Too often, land use development around an existing facility goes unchecked until it is too late, and the facility is forced to invest in additional PSM-type risk control

- Again often, future potential facility expansion is not considered in a risk assessment while evaluating a new development proposal
  - Once a new development decision is made based on risk of the existing facility, future growth of industry is restricted and/or further PSM requirements need to be imposed on the operator if future expansion is attempted
Presentation of Risk – Societal/ Aggregate Risk

- Risk Map (frequency distribution or fN)
  - Focus: Single event risk to exposed group (societal/aggregate risk)
  - Also termed a “risk matrix”
  - This is a tool for categorizing and ranking different event types of concern
  - *Not* a good tool for risk evaluation against absolute criteria (more on this later)

- Risk Profile (complementary cumulative frequency distribution or FN)
  - Focus: Overall facility risk to exposed group (societal/aggregate risk)
  - Good tool for risk acceptability evaluation against absolute criteria – but only for point sources of risk such as chemical plants, *not* for line sources such as pipelines
  - *Not* useful for risk categorizing and ranking different event types
### Example risk evaluation matrix – separate risk receptors

<table>
<thead>
<tr>
<th>Frequency Guidelines (company basis)</th>
<th>Description</th>
<th>Action Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f \geq 10$/year (larger than or equal to $10$/year)</td>
<td>Happens several times per year in each facility</td>
<td>Immediate action</td>
</tr>
<tr>
<td>$1$/year $\leq f &lt; 10$/year (between $1$ and $10$/year)</td>
<td>Happens several times per year in company</td>
<td>Action in one week</td>
</tr>
<tr>
<td>$0.1 = f &lt; 1$/year (between $1/10$ years and $1/10$ years)</td>
<td>Expected to occur several times in the company lifetime</td>
<td>Action in one month</td>
</tr>
<tr>
<td>$0.01 = f &lt; 0.1$/year (between $1/100$ years and $1/10$ years)</td>
<td>Expected to occur in the company lifetime</td>
<td>Action in six months</td>
</tr>
<tr>
<td>$0.001 = f &lt; 0.01$/year (between $1/1000$ years and $1/10$ years)</td>
<td>Has happened in this industry</td>
<td>Action in a year</td>
</tr>
<tr>
<td>$f &lt; 0.001$/year (less than $1/1000$ years)</td>
<td>Has never happened in this industry</td>
<td>Monitor</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Frequency</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>U</td>
<td>U</td>
</tr>
<tr>
<td>5</td>
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<td>U</td>
<td>U</td>
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<tr>
<td>4</td>
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<td>5</td>
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<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Risk Level</th>
<th>Action Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>U</td>
<td>Immediate action</td>
</tr>
<tr>
<td>5</td>
<td>Action in one week</td>
</tr>
<tr>
<td>4</td>
<td>Action in one month</td>
</tr>
<tr>
<td>3</td>
<td>Action in six months</td>
</tr>
<tr>
<td>2</td>
<td>Action in a year</td>
</tr>
<tr>
<td>1</td>
<td>Monitor</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Consequence</th>
<th>Frequency</th>
<th>Action Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>Negligible</td>
<td>Minor first aid</td>
</tr>
<tr>
<td>Environmental</td>
<td>No impact</td>
<td>Release to on-site environment</td>
</tr>
<tr>
<td>Financial/Damage</td>
<td>C $&lt; 10k$</td>
<td>$10k \leq C &lt; 100k$</td>
</tr>
<tr>
<td>Political/Regulatory/Reputation</td>
<td>None: No complaints or suspicions of public concern</td>
<td>Low: Second-hand knowledge of public concern</td>
</tr>
<tr>
<td></td>
<td>Medium: Complaints to regulators or authorities requiring management involvement</td>
<td>High: Negative national or international news coverage of protests, or irreparable damage to reputation</td>
</tr>
</tbody>
</table>
Risk Analysis Techniques for Estimating Event Societal/Aggregate Risk

- Qualitative techniques in conjunction with a risk matrix for risk categorization/ranking
  - Identify events and develop knowledge/experience-based estimates of consequence and likelihood
    - Screening Level Risk Assessment
    - HAZOP
    - FMEA

- Semi-quantitative techniques in conjunction with a risk matrix for risk categorization/ranking
  - Starting with events identified using a qualitative technique, develop quantified estimates of likelihood; combine with knowledge/experience-based estimates of consequence
    - LOPA
    - Fault trees
    - Event trees

- Quantitative techniques in conjunction with a risk matrix for risk categorization/ ranking
  - Starting with events identified using a qualitative technique, develop quantified estimates of consequence and likelihood
Use of Societal/Aggregate Risk Information in PSM

- Use a risk map to show events in their respective risk matrix cells

- This provides a ranking of the importance of different events, and risk controls

- Very useful for prioritizing PSM-type risk controls in an operating plant or during design
Use of Aggregate Risk Information in PSM (2)

- Two possible concerns with the use of risk matrices

1. While use of a standardized risk matrix across an organization is desirable for evaluation of risk acceptability, problems of scalability arise when it is applied on a facility or organization-wide basis
   - Consider a risk matrix which says a fire resulting in $1000 damage is in the acceptable range if its likelihood is $10^{-2}$ per year.
   - Consider application of this criterion to a single gasoline station.
     - It is OK to have such a fire with a frequency of 1/100 per year in that single gas station.
   - Now apply the same criterion to 100 gas stations.
     - It is OK to have such a fire with a frequency of 1/100 per year in all the gas stations.
     - This implies that each gas station is limited to an allowable frequency of 1/100/100 = 1/10,000 per year for such a fire.
     - Is this consistent with the intent of the risk matrix?
   - The same difficulty applies when standard risk matrices are used for individual pieces of equipment during design HAZOPs and LOPAs.
   - How is the industry responding to this challenge?
Use of Aggregate Risk Information in PSM (3)

- Two possible concerns (2)

2. Use of a risk matrix is open to abuse

- One could quite legitimately (without violating any mathematical rules) combine different types of events together, or refine their definitions to create separate event types, to make the picture look catastrophically bad or very rosy.

- Consider a facility manager who is under pressure to cut maintenance budgets and he/she does not want to
  - A risk analysis identifies hundreds of different types of events of various causes in different areas of the facility, and ranks them using the company matrix
  - The manager plots them on a risk map, that shows that all the events comfortably fall in the “acceptable” risk zone, i.e., there is room for cutting budgets
  - The manager combines events that are of a similar nature (e.g., pump leaks with fires) from all areas of the plant; this reduces the number of events on the risk map, but increases the likelihood of each, thus pushing some of these new events into the “unacceptable risk” zone
    - Good excuse to show that he/she should not cut budgets, but actually needs more budget to bring the risk to acceptable levels

- How is the industry responding to this challenge?
Use of Aggregate Risk Information in PSM (4)

- Two possible concerns (3)

2. Use of a risk matrix is open to abuse (continued 2)
   - The reverse (e.g., defining new events by splitting each original event into its causes) is available for a manager who wants to collect brownie points (albeit probably only temporarily, but who knows, he/she might get promoted before the bottom falls out!)
   - Again, how is the industry responding to this challenge?
A Partial Solution to the Risk Matrix Challenges

- Use FN plots (as opposed to the fN plots, which risk maps are)
  - Due to the cumulative nature of the information, the type of abuse that is possible with risk maps/risk matrices is not possible with FN plots
  - Requires development of corporate FN criteria

- FN plots do not solve the scalability problem
  - Meaningless for line sources of risk, such as pipelines


Risk quantification for meteorology- and direction-dependent hazards due to point and linear risk sources

Ertugrul Alp and Michael J. Zelensky
BOVAR-CONCORD Environmental, 2 Tippett Road, Downsview, Ontario, Canada M3H 2V2
Example Off-Site Societal Risk Guidelines for Land Use

- Unfortunately, applicable only to point sources (e.g., chemical plants, but not pipelines)
Example Corporate Aggregate Risk Guidelines

- Frequency (F) of Events with C or Higher Consequences
- Or Frequency of Exceeding a Given Loss

Consequence C (million $)

- De Manifestis
- Gray Region
- De Minimis

(events/year)
Use of PSM Risk Assessments for Corporate Decision-Making & Board Oversight

- Risk assessments that are routinely done for PSM purposes are for purposes of operational-level decisions
  - They focus on potential causes of events to develop appropriate prevention measures

- The events that are identified are categorized using a corporate risk matrix, and the results are typically presented on risk maps
  - Typically, the likelihood ranking is done for each cause/consequence pair

- This level of segregation is too detailed for corporate level decision making

- Aggregation of cause/consequence pairs, and possibly of events with like consequences, is needed to see the corporate picture
  - It is difficult to decide where to stop the aggregation to get a good picture of the corporate exposure

- Use of FN diagrams can address this problem, and should be used for corporate decision making
Presentation of Societal/Aggregate Risk Intensity/Density: Operator’s (risk source) Perspective

- Example: Societal risk (created by the risk source) per unit length of rail corridor

Reference:

INFOR vol. 33, no. 1, Feb. 1995

RISK-BASED TRANSPORTATION PLANNING PRACTICE: OVERALL METHODOLOGY AND A CASE EXAMPLE *

ERTUGRUL ALP

BOVAR-CONCORD Environmental, 2 Tippet Rd. Downsview, ON M3H 2V2
Presentation of Societal/Aggregate Risk Intensity/Density: Risk Receptor Perspective

- Example: Societal risk per unit area exposed to the risk source
  - Reference: Dutch methodology, 2005
Available Canadian Guidance for Risk Assessment

- Risk Assessment – Recommended Practices for Municipalities and Industry, CSChE 2005
  - Good overview of risk assessment techniques (qualitative/quantitative, consequence, frequency, risk)
  - Developed in the late 1990s by MIACC; does not include information on LOPA, SIL, SVA
  - Describes the state-of-the-art QRA approach, in particular to support Land Use Planning

  - A primary reference of the above CSChE “Recommended Practices”
  - Describes the fundamental equations for risk quantification
  - Also describes the scalability problem with FN

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Risk Assessment – Recommended Practices for Municipalities and Industry

- Risk quantification for meteorology- and direction-dependent hazards due to point and linear risk sources

Ertugrul Alp and Michael J. Zelensky
BOVAR-CONCORD Environmental, 2 Tippett Road, Downsview, Ontario, Canada M3H 2V2
Risk Assessment for Land Use Planning – Historical Development in Canada – And the Future

- Risk-based land use planning first received attention by MIACC (Major Industrial Accidents Council of Canada) after Bhopal

- "Risk-based Land Use Planning Guidelines", 1995
  - No updates yet, proposed extension for sensitive receptors
  - Has current validity

  - Based on “Risk Assessment Guidelines for Municipalities and Industries – An Initial Screening Tool”, 1997 (although this is the publication date, its development goes back to 1993)
  - Which, in turn, is based on the 1988 Dutch Guide
  - All three are considered out-of-date

- The QRA methodology described in “An Initial Screening Tool” has been superseded by “Risk Assessment – Recommended Practices for Municipalities and Industry”, CSChE 2005

- An update of the MiniGuide is planned based on the “Recommended Practices”
Further Thoughts on Risk Metrics

- Recall: OSHA Injury Frequency Rate and Injury Severity Rate
  - These are normalized on a “per 200,000 worked hour” basis, i.e., per 100 worker-years
  - The frequency rate is not very useful (it is just an incident count, without reflecting how bad each incident is)
  - The severity rate measure is a value-normalized risk, focusing on worker injury only
    - Average aggregate risk of injury per unit of value (worker) exposed to the risk source (e.g., aggregate risk of injury per worker-year)
Further Thoughts on Risk Metrics (2)

- New proposals for PSM metrics (CCPS, 2007)
  - PSM incident frequency rate (again not very useful, it is just a count)
  - PSM incident severity rate
  - Both are normalized on a “per 200,000 worked hour” basis, i.e., per 100 worker-years
  - The PSM incident severity rate is also a value-normalized risk, focusing on PSM incidents

- This is a step in the right direction

- It is suggested that the excess aggregate risk parameter be also explored as a PSM metric
How to make it work:

Requirements for Success
Requirements for Success …

The stakeholder-centered integrated risk management approach: Meeting the needs of stakeholders

1. Understand Stakeholder Needs
2. Design Business Processes to meet those needs
3. Build the Resources and the Organization to carry out the Business Processes

Key Business Processes

Implements stakeholder satisfaction and balance…

… by improving critical business processes …

… and aligning resources and organizational characteristics

Stakeholders:
- Employees
- Contractors
- Owners
- Community
- Environment
- Regulators

ALP & ASSOCIATES
Requirements for Success …
in Achieving Superior PSM Performance…

In this context, “integration” means:

- Consideration of all stakeholders’ needs, and the exposures to potential hazards, in an integrated manner,
- Integration of risk management processes into day-to-day and strategic decision making,
- Integration of risk management responsibilities into the line management structure, and
- Integration of risk-based thinking into the design of physical assets, allocation of budgets, and training of human resources

so that the needs of the stakeholders can be balanced in the long run.
Requirements for Success …

in Achieving Superior PSM Performance…

1. Executive management (top-down) commitment to risk-based decision making for balancing the needs of the stakeholders (“safety” culture),

2. (Bottom-up) Awareness throughout the ranks about their risk management responsibilities and accountabilities (“safety” culture),

3. A line organization structure conducive to effective communication and cooperation, with risk management responsibilities built into the performance criteria of all personnel (“safety” culture),

4. A risk management process model that is understood by all, …
5. Availability of integrated risk assessment and cost/benefit analysis tools of various sophistication, which can be used as suitable during the daily or strategic decision making process (these tools are used to understand the level of risk using appropriate risk metrics, and to evaluate suitability of control actions),

6. Appropriate risk control strategies (PSM),

7. Sufficient human and physical resources,

8. A common risk management standard that reflects the values of the organization and the requirements that are asked of it.
Importance of Understanding the Risk
The physical system
Inherent Hazards
Possible Undesirable Events
Their Possible Consequences
Their Likelihood
Buncefield Oil Storage Depot

- December 11, 2005
- Overfilling of Gasoline Storage Tank, Spill into Dyke, Generation of Heavy Gas Vapour Cloud, Vapour Cloud Explosion and Tank Fires

- Until this event, the UK HSE worst case scenario for such storage tanks was a tank fire!
- A similar explosion had occurred in France in 1991!
Evaporation of the lighter components (e.g., butanes, pentanes, hexanes) results in vapour generation. The approximate extent of the vapour cloud is up to 2 m in height.
Importance of “Organizational Culture”

Importance of Using the Right Risk Metrics

Importance of Management of Change (including Organizational Change)
BP Texas City Refinery Explosion – US CSB Report

- Event: Raffinate splitter tower overfilled with liquid, overfilling the blowdown drum; liquid released from open vent stack (not connected to a flare system)

- Many “technical findings”, e.g.,
  - The tower level indicator showed that it was declining while it was actually overfilling;
  - The redundant high level alarm did not activate;
  - etc.

- 9 “organizational findings”, e.g.,
  - Cost cutting, failure to invest and production pressures from BP Group executive managers impaired process safety performance;
  - BP Board of Directors did not provide effective oversight …;
  - Reliance on the low OSHA recordable injury rate as a safety indicator failed to provide a true picture of process safety performance and the health of the safety culture;
  - …
  - BP Texas City did not effectively assess changes involving people, policies and the organization that could impact process safety
**BP Texas City Refinery Explosion – US CSB Report (2)**

- Most fatalities and injuries occurred in portable trailers/buildings.
- Most were contractors, not essential in the start-up operation of the area plant units.

Figure 12. Blast overpressure map depicting the areas of highest blast pressure (10+, 5+, and 2.5+ psi).
Recommendations related to:

- Safety Culture
- Trailer Siting
  - API to develop new guidelines to ensure that occupied *trailers and similar temporary structures* are placed safely away from hazardous areas of process plants
  - The new API 753 Guidelines on “Management of Hazards Associated with Location of Process Plant Portable Buildings” was developed and published in December 2006 (draft) and June 2007 (final)
- Blowdown Drum and Stack
  - API to revise “Recommended Practice 521, Guide for Pressure Relieving and Depressuring Systems,” to identify the hazards of this equipment, to address the need to adequately size disposal drums, and to urge the use of inherently safer alternatives such as flare systems
  - API 521 5th edition was published in January 2007
BP Texas City Refinery Explosion – Baker Report

Report of the BP Independent Refineries Safety Review Panel

10 Recommendations:

- Process Safety Leadership
- Integrated and Comprehensive PSM
- Process Safety Knowledge and Expertise
- Process Safety Culture
- Clearly Defined Expectations and Accountability for Process Safety
- Support for Line Management
- Leading and Lagging Performance Indicators for Process Safety
- Process Safety Auditing
- Board Monitoring
- Industry Leader
Summary and Conclusions
Summary and Conclusions

- Process Safety Management is a significant component of the broader Risk Management efforts of an organization that operates chemical processes.

- Within PSM, risk analysis provides an objective basis for comparing various hazards, alternatives and risk control measures (i.e., PSM, EM, land use planning).

  - There are Canadian CSChE guidelines on available risk assessment techniques, CSChE PSM guidelines and land use planning guidelines.
Summary and Conclusions (2)

- We have several risk parameters – PSM metrics – to demonstrate and track level of risk.
  - Individual/geographical risk
  - Societal/aggregate risk and risk intensity
  - Value-normalized risk
  - Excess aggregate risk

- Risk matrices are very commonly used for categorizing societal/aggregate risk for purposes of ranking and risk acceptability evaluation
  - However, there are challenges in their proper use as risk evaluation tools in facility level applications and corporate level decision making (abuse potential and scalability)
  - Risk matrices (fN) should be used in conjunction with risk profiles (FN) to partially address these challenges (abuse potential)
- It is essential to understand the physical system and its chemistry
  - No amount of risk assessment will save you unless this prerequisite is in place.

- Importance of culture in achieving PSM success cannot be overemphasized.
THANK YOU!