Barrier-Focused Approaches to Risk Analysis - Introduction to Bow Tie Analysis

WorkSafeBC Risk Analysis Unit

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Agenda for the session

Learn the process for creating a bow tie

Introduction to Barrier-focused model of accident causation/prevention - *James Reason Swiss Cheese model*

Introduction to Bow Tie Analysis for Hazard/Risk Analysis

Group Exercise – Construct two Bow Tie diagrams
1. Introduction to Barrier-focused model of accident causation/prevention

James Reason Swiss Cheese model
Barrier thinking

Reason's Swiss Cheese Model

"a trajectory of accident opportunity"
Barrier-based approach
What are barriers?

• A barrier (sometimes also called a control) can be any measure that acts against some undesirable force or intention, in order to maintain a desired state.
• Barriers can be hardware systems, design features, work practices etc.
• All barriers are not created equal. Some are better and/or more reliable than others.

Bowtie XP Methodology manual
2. Introduction to Bow Tie Analysis as a Hazard/Risk Analysis Tool
Assessment / Analysis Tools You May See.....

- HAZID
- HAZOP
- What-If
- Checklist
- JHA – Job Hazard Analysis
- FMEA - Failure Mode and Effects Analysis
- LOPA – Layer of Protection Analysis
- Bow Tie Analysis
What is the objective of these analyses?

- **Safe **Design **of Workplace**
  - Eliminate hazards
  - Minimize likelihood / severity of potential incidents
- **Effective Controls** (Barriers)
  - Engineering Controls
    - Passive – burst discs, containment berms, fixed guard, etc
    - Active – sensors, automated valves, light curtains etc
  - Administrative Controls
    - Policies, safe work practices (some written), training
    - Signage
  - Personal Protective Equipment
Controls – important considerations

• All controls have administrative elements
  • Gas sensors need calibration and maintenance
  • Warning alarms require human response
  • Workers need to wear correct PPE at right time

• Often controls are part of a control system
  • Detect, decide and act
    • e.g. gas sensor ⇔ computer ⇔ warning lights & sirens ⇔ worker action

• Controls are never perfect. They can:
  • be inadequate, fail, be absent
Who should be involved?

The more diverse it is, the better it is...

- Maintenance
- Operators
- Technical personnel
- Suppliers
- OH&S
- Process engineers
What is the Bow Tie model?
Hazard and Top Event
Hazard

**Hazard**: A thing, activity, or condition that has the potential to cause harm

Define the context and scope:

- The specific hazardous thing or activity
- The specific hazardous item
- The specific location of hazard
# Hazards types

<table>
<thead>
<tr>
<th>Description</th>
<th>Activity</th>
<th>Condition</th>
<th>Thing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline stored in a tank</td>
<td></td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>Driving chemical tanker truck in urban area</td>
<td></td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>Load suspended by crane</td>
<td></td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>Biogas in the digester</td>
<td></td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>Chlorine gas in a pressurized cylinder</td>
<td></td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>Aging building structure</td>
<td></td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>Transferring propane</td>
<td></td>
<td></td>
<td>√</td>
</tr>
</tbody>
</table>
What’s the hazard?
Top Event

**Top event:** (Major Unwanted Event)
1. Loss of control
2. Loss of containment
3. (or both)
Hydrocarbons in the formation during drilling
Influx of hydrocarbons to the surface

Hydrocarbons in the formation during well testing
Loss of containment

Drilling in formation containing H2S
Release of H2S gas to atmosphere

Overhead equipment/Working at height
Dropped/fallen objects
Scope

Too narrow

Ideal range

Too broad
Pictures of biogas process.
Biogas

Biogas in the process

Biogas in digester

Loss of containment

Loss of containment

Loss of containment
Top Event guidelines

- Prior to serious harm being caused
- When normal operation changes to abnormal
- Initiation of the unwanted event (just starting to occur)
- Typically a loss of control or loss of containment
Threats
**Threats**

**Threats:** Factor that can cause the top event (i.e. the triggering action or condition).
Threats - Guidelines

• All should be stand-alone
• Should independently lead to the top event
• Should not be a failure of a control
• Try to capture all credible threats in analysis
• Be specific:
  ‘Human Error’  – rather, what is the specific action or non-action?
  ‘Poor weather’  – rather, high wind speeds, sub zero temps etc.

• Note:
  ➢ If too generic then controls are vague
  ➢ Threats that are too similar will have the same controls
Threats - Lion
Threats – Oil & Gas

- Over-pressure
- Under-pressure
- Corrosion
- Erosion
- Impact damage
- Vibration

![Diagram showing threats to oil and gas pipelines](image-url)
Threats – Crane

[Diagram showing relationships between WLL overload, impact to crane, load improperly secured, and dropped load.]
Consequences
Consequences

Can be various harmful outcomes to:

- Person/s
- Equipment/Facility
- Organization
Risk Controls
Barriers / Controls
Barriers / Controls

Prevention barriers (Left)
• To prevent the onset of the top event
• Sometimes lessen the effect of the top event
• Include: ‘detect, decide and act’

Mitigation barriers (right)
• Reduce / mitigate the severity of the consequence (after top event has happened)
• Sometimes stop the consequence /outcome from happening

EFFECTIVE, INDEPENDENT AND AUDITABLE
Prevention Barriers
-Lion Example

Lion goes through enclosure wall

Lion goes over enclosure wall

Lion goes under the enclosure wall

Lion in enclosure at zoo
Loss of containment
Mitigation Barriers – Lion Example

1. Lion in enclosure at zoo
2. Loss of containment (escape from enclosure)
3. Emergency response plan – including...
4. Training and drills for lion recovery – including...
5. Injury to public/non ER staff
6. Injury to Emergency Response staff
## Prevention or Mitigation?

<table>
<thead>
<tr>
<th>Top Event/Threat/Consequence</th>
<th>Barrier / control</th>
<th>Characterization?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss of containment – gasket leak</td>
<td>Appropriate gasket fitted to specifications</td>
<td>PREV</td>
</tr>
<tr>
<td>Tank overflow – hydrocarbons affect environment</td>
<td>Dike/Berm</td>
<td>MIT</td>
</tr>
<tr>
<td>Loss of control of car – driver impacts dashboard</td>
<td>Air bag</td>
<td>MIT</td>
</tr>
<tr>
<td>Loss of containment – major environmental pollution</td>
<td>Detect leak and deploy spill response equipment</td>
<td>MIT</td>
</tr>
<tr>
<td>Tank overflow – faulty level gauge</td>
<td>Secondary High-High level indicator</td>
<td>PREV</td>
</tr>
<tr>
<td>Dropped object - overloaded</td>
<td>WWL sensor on crane</td>
<td>PREV</td>
</tr>
<tr>
<td>Tank rupture - overpressurization</td>
<td>Pressure relief valve</td>
<td>PREV</td>
</tr>
</tbody>
</table>
Hierarchy of Controls

- Elimination: Physically remove the hazard
- Substitution: Replace the hazard
- Engineering Controls: Isolate people from the hazard
- Administrative Controls: Change the way people work
- PPE: Protect the worker with Personal Protective Equipment
Barriers / controls

**Administrative barriers can include:**
- Specific policies, safe work procedures, practices

**Barriers do not generally include:**
- Generic instruction
- Generic training
- Generic competency
- Generic inspections

*However, specific instruction, training, and inspections are an integral part of barrier verification and maintenance*
Barriers selection – other considerations

• Are barriers appropriate?
  • Good engineering practice
  • Meet applicable legislation, standards
• Are barriers specific enough to be verified, monitored?
• Are they vulnerable to a common failure mode?
  • i.e. power loss defeats all controls for a threat?
• Do they cover a range of engineering and administrative controls?
  • Include both passive and active controls?
• Do they include both prevention and mitigation controls?
Escalation Factors – In Brief

• Bow Tie Analysis can explore how a barrier could fail

• This may lead to:
  • Measures to minimize potential for barrier failure
  • OR additional barriers may be added (Layers of Protection)
  • OR barrier may be replaced with a more reliable one
Escalation Factors

- Lion example
Critical Controls
How Do We Expect Employers to Manage Major Hazards?

- Identify hazards and major incidents
- Identify credible causes of incidents (threats)
- Implement controls to ensure health and safety
- Identify critical controls
- Ensure critical controls are effectively managed
What is a critical control?

“A control that is crucial to preventing or mitigating a high consequence event is critical”
Critical control criteria:

1. Is the control crucial to preventing or minimizing the consequences of an event?
2. Is it the only control or is it backed up by another control in the event the first fails?
3. Would its absence or failure significantly increase the risk despite the existence of other controls?
4. Is the control effective for multiple threats or does it mitigate multiple consequences? Does it repeat in the barrier lines for multiple threats?
Preventing the undesired event and mitigating the consequences

Controls that are crucial to preventing or mitigating the consequences of an event occurring, despite the existence of other controls (ICCM).
Risk Management Resources

• Established standards and other risk management documents include:

  • OHSAS 18001:2007 (ISO 45001 SMS standard due to be published in Q1 of 2018)
  • CSA Z1000-14 – Safety Management Standard
  • CSA SZ1002-12 – Risk Assessment Standard
  • ISO 31000 – Risk Management Standard
    • ISO 31010 – Risk Management : Risk Assessment Techniques
  • HSG 65 (HSE) – Managing for Health & Safety - Risk Management Section
References:


• BowTie XP Bowtie Methodology Manual. Revision 16 – July 2017

• A Barrier Focused Approach: *How to get started with process safety*, Vol 2. Enform 2016


• Managing the risks of organizational accidents. James Reason
Further Reading on Risk
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