Assessing risk controls using bow-ties

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History

- A graphical and mostly qualitative method to **assess risk** and **analyze barrier effectiveness**

- Probably originated in ICI in the late 1970s
  - based on notions of defence in depth, fault tree analysis, event-tree analysis and Reason’s Swiss cheese accident causation model

- Royal Dutch Shell was first major company to integrate bow-ties into business practices

- Gained popularity as an intuitive graphical manner of **presenting accident scenarios** and **explaining importance of barriers**
Hazard

Start by identifying the **hazard** and the **top event** (typically some form of loss of control or loss of containment)

Example:

▷ Hazard: mechanical energy of train during trackside works

▷ Top event: trackside worker struck by train

Knot = hazardous event.

What we don’t want to happen
Threats and preventive controls

- Driver/track machine operator error
- Competence assurance
- Health & Wellness Program
- Random D&A testing
- Regular briefings induction
- Train / machine operating procedures

- Worker error - inattention
- Work Group Supervision
- Fenced areas/barriers
- Hi Vi vest
- Medical standards
- Staff vigilance
- Use of train horn

- Unsafe / Inappropriate system of work employed by workers
- Competence assurance
- Engineering work rules
- Job safety analysis
- Safe working method statements
- Safety inspections / audits

- Signal Passed at danger
- Catch / trap points
- Signal sighting committee
- Train stop
- Competence assurance, Train crew training, Train operating procedures
- Health & Wellness Program

- Inappropriate lighting
- Engineering work rules
- Train lights

HAZ01 - Trackside Works (Trackside Worker Struck / Crushed by Train)
Threats and preventive controls

- **Hazardous Site: Failure of Stored cylinders**
  - 5.4.4.5 Propane
    - Dropped / Fallen Object
      - Cylinders only moved when strapped in purpose designed pallets (Company Handling)
        - W-4.2.06 (Prod)
    - Fork lift truck drivers are trained and have their competence assessed
      - W-4.1.03 (Prod)

- **Vehicle Impact**
  - LPG storage area designed to HSE Guidelines to minimise vehicle impact possibility
    - W-1.1.06 (Design)
  - LPG cylinders are designed to BS5045 Part 2 as Transportable Gas containers
    - W-2.3.01 (Tan)
Consequences and mitigation controls

HAZ01 - Trackside Works (Trackside Worker Struck/Crushed by Train)

Emergency Plan
First aid provisions and training
Emergency protection
Communication and command control

Fatality

Communication and command control
Emergency protection
First aid provisions and training
Emergency Plan

Injury
Consequences and mitigation controls

Hazardous Site: Failure of Stored cylinders

- 5.4.4.5 Propane

LPG storage area designed to HSE Guidelines to minimise ignition sources

- W-1.1.02 (Design)

Quantity of LPG stored limited in accordance with HSE Guidelines

- W-2.1.02

PTW System and Safe System of work minimise ignition sources on site

- W-2.3.08

No smoking policy and monitoring to minimise unnecessary combustibles

- W-2.4.01 (Prod)
- W-5.2.01 (Prod F)

Electrical Equipment

- Design - Electrical Classification
- W-1.1.02 (Design)

Operator Intervention - Work Permit

- W-2.4.01 (Prod)

Task Related Ignition Sources

Copy of Design - Electrical Classification

- W-1.1.02 (Design)

Electrical Storm - lightning
Escalation factors

▷ Escalation factor: a condition that **leads to increased risk** by defeating or reducing the effectiveness of controls

▷ Controls are seldom 100% effective

▷ An escalation factor cannot directly cause the top event or consequence
  - it increases the likelihood that the scenario will progress because the associated control will be degraded or fail
Escalation factor controls

- Escalation factor control: a control that manages the conditions which reduce the effectiveness of other controls

- Though notion is in theory recursive (escalation factor controls can be themselves affected by escalation factors), recommended to stay with one level of escalation factor controls
Example: poor contractor performance

- Contractor not competent
- Pre Qualification
- Tender reviews
- Contractor monitoring
- Scope of work not clearly defined
- Contract Review/Approvals
- Review MTG's with Contractor

Financial Loss
- Project due to delay

Event: Poor contractor performance
Hazard: H03 - Contract Management
Location/Grouping: General
Example: work in confined space

**Example:**

- **Working in Enclosed Space Procedures**
  - HSE Coordinator
  - Discipline Super.

- **Provision of Forced Ventilation**
  - Discipline Super.

- **Inspection by Contractor**
  - Const Manager
  - Discipline Super.

- **Site Inspection by Company**
  - Discipline Super.

- **Use of correct PPE**
  - Discipline Super.

- **Liaise with CMO to provide additional first aid training for contractors First Aiders.**
  - Head Const HSE

- **Fatalities**
  - First aid training not adequate

- **Event:** Oxygen deficiency
- **Hazard:** H02 - Confined Spaces
- **Location/Grouping:** General

**Control Types:**
- RF Requirement
- Company Requirements
- undefined

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**Location/Grouping:** General

**Control Types:**
- RF Requirement
- Company Requirements
- undefined
Example: work at height

H01 - Working at height (Fall or Dropped Object)

- Poor quality scaffolding
  - Scaffolding not available
    - Const Manager

- Unsafe mobile work platform
  - Equipment Passport & Test Data
    - Const Manager
    - HSE Coordinator

- Unsafe ladders
  - Ladder "passports" & inspection
    - Const Manager
    - Discipline Super.

- No edge protection
  - Use of Safety Harnesses
    - Const Manager
    - Discipline Super.

- Loose tools and equipment
  - Contractor Safety Procedures
    - HSE Coordinator
    - Const Manager
    - Discipline Super.

- Provision of Access Equipment
  - Const Manager
  - Const Manager
  - Site Inspection by Company
  - Discipline Super.

- Design & Construction to RF Legislation
  - Const Manager
  - Const Manager
  - Site Inspection by Company
  - Discipline Super.

- Poor quality scaffolding
  - Scaffolding Passport
    - Const Manager

- Site inspection by company
  - Discipline Super.

- Discipline Super.
  - HSE Coordinator
  - Site inspection by company
  - Discipline Super.

- First Aiders
  - HSE Coordinator
  - Site inspection by company
  - Discipline Super.

- First aid training inadequate
  - First aid training inadequate
  - HSE Coordinator

- Serious injury/fatality
  - Field ER Plans
    - Head Const HSE
    - Liaise with CMO to provide additional first aid training for contractors First Aiders.

- Event
  - Hazard: Fall or Dropped Object
  - Location/Grouping: General
  - Control Types
    - Company Requirements
    - RF Requirement
Applications of the bow-tie tool

- Communicating risks, accident scenarios, importance of barriers
- Can be integrated with semi-quantitative risk analysis techniques such as LOPA
- Identify and assess safety barriers (risk reduction measures)
- Make a link between critical safety tasks and the SMS
- Identify elements for safety audits
Link the tasks to barriers back to SMS

- How will the barrier fail?
- Can we improve the effectiveness of control?
- What tasks or actions do we need to do to make sure the control continues to work?
- Who is currently doing the task?
- Who is currently doing the task?
- Is the staff competent for doing the task?
## Managing critical HSE tasks

<table>
<thead>
<tr>
<th>Client/Project Name</th>
<th>Senior Supervisor</th>
<th>HSE-Critical Role</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Task 01.01</strong></td>
<td>Making live and Closing of Hot Work Permits</td>
<td>Ensure that all permits are signed out ‘made live’ and closed by the Authorised Person</td>
</tr>
<tr>
<td><strong>Task 01.02</strong></td>
<td>Ensure that Hot Work is in compliance with permit conditions</td>
<td>Ensure that permit is in compliance with MSN 102L and work is undertaken in safe manor</td>
</tr>
<tr>
<td><strong>Task 02.04</strong></td>
<td>Ensuring that lifting gear is tagged and colour coded</td>
<td>Ensure that lifting gear is coded as per procedure MSN 205L Ensure competence of certifying contractor</td>
</tr>
<tr>
<td><strong>Task 04.04</strong></td>
<td>Confirm portable electrical equipment is fit for purpose and in possession of integrity certification</td>
<td>Ensure that external electrical equipment is tested on a 3 month cycle and internal equipment is tested on a 6 month cycle as per MSN 23L</td>
</tr>
</tbody>
</table>

Source: *Practical HSE Risk Management – An Introduction to the Bow-tie Method*, Gareth Book, Risktec Solutions
Links with competency management

Verify that competence and control requirements are aligned

Source: Practical HSE Risk Management – An Introduction to the Bow-tie Method, Gareth Book, Risktec Solutions
## Links with procedures and audits

<table>
<thead>
<tr>
<th>Task</th>
<th>Responsible Person/Task Description</th>
<th>Inputs/Documents</th>
<th>Verification</th>
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</thead>
<tbody>
<tr>
<td>ABC-22.05</td>
<td>Area Supervisor – Maintain Safety Signage</td>
<td>Ensure safety related signs are maintained up-to-date and in good order - escape routes - exit signs - fire equipment signs - life saving appliance signs</td>
<td>- Inspection and Audit</td>
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<td>ABC-12.03</td>
<td>HSE – Manager – Management of Hazardous Materials</td>
<td>Ensure correct storage and handling of hazardous materials in accordance with the requirements identified in the MSDS - secure storage - segregation of incompatible chemicals - use of PPE - appropriate means of transport-inventory management</td>
<td>- HSE audit - area inspections - manifests - non compliance reports</td>
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<tr>
<td>ABC-06.03</td>
<td>Site foreman – Weekly area Inspections of process facilities</td>
<td>Carry out weekly inspections of all site areas: - housekeeping - general condition of equipment - general condition of structures - condition of safety equipment - availability of escape routes</td>
<td>- Inspection checklist - Non compliance reports</td>
</tr>
</tbody>
</table>

*Verify procedures for conducting HSE-critical tasks are complete and effective*
Conclusions

▷ Bowtie representation of scenarios provides better understanding of incident/accident sequences

▷ Improves communication, especially between different levels of the organisation

▷ Helps to prioritise the importance of control measures, support the managers / management’s need to oversee a broad spectrum / scope / different types of risk that they own

▷ Link the safety critical activities back to the Safety Management System and effective monitoring and control of risks
Feedback welcome!

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