Assessing risk controls using bow-ties

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Concept

causes

preventive barriers

top event

protective barriers

impacts
Concept

causes

fault tree

top event

impacts

event tree

no flow to receiver
no flow from component B
no flow into component B
no flow from component A1
no flow from source 1

component A1 blocks flow

no flow from component A2

component A2 blocks flow

no flow from source 2
History

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

- Probably originated in ICI (a UK chemical company) 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
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

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

Inappropriate lighting
- Engineering work rules
- Train lights

Health & Wellness Program

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

LPG cylinders are designed to BS5045 Part 2 as Transportable Gas containers
W-2.3.01 (Tan)

Fork lift truck drivers are trained and have their competence assessed
W-4.1.03 (Prod)
Consequences and mitigation controls

- Emergency Plan
- First aid provisions and training
- Emergency protection
- Communication and command control
- Fatality
- Injury

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

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

- Operator Intervention - Work Permit
  - W-2.4.01 (Prod)

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

- Electrical Equipment

- Task Related Ignition Sources

- Electrical Storm - lightning

- Fire / Explosion

9/21
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
Example: work in confined space
Example: work at height

H01 - Working at height (Fall or Dropped Object)

- Scaffolding not available
  - Const Manager

- Provision of Access Equipment
  - Const Manager

- Poor quality scaffolding
  - Const Manager
  - HSE Coordinator
  - Discipline Super.

- Unsafe mobile work platform
  - Const Manager
  - HSE Coordinator
  - Discipline Super.

- Unsafe ladders
  - Const Manager
  - HSE Coordinator
  - Discipline Super.

- No edge protection
  - Const Manager
  - HSE Coordinator
  - Discipline Super.

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

- Scaffolding Passport
  - Const Manager

- Design & Construction to RF Legislation
  - Const Manager
  - HSE Coordinator
  - Discipline Super.

- Site Inspection by Contractor
  - Const Manager
  - HSE Coordinator
  - Discipline Super.

- Site Inspection by Company
  - Const Manager
  - HSE Coordinator
  - Discipline Super.

- Use of Correct PPE
  - Discipline Super.
  - HSE Coordinator
  - Discipline Super.

- Personal Awareness in Induction
  - HSE Coordinator
  - Discipline Super.

- Work Planning
  - Discipline Super.

- First Aiders
  - HSE Coordinator
  - Discipline Super.

- Field ER Plan
  - HSE Coordinator
  - Discipline Super.

- Contractor Safety Procedures
  - HSE Coordinator
  - Const Manager
  - Discipline Super.

- Ladder "passport" & inspection
  - Const Manager
  - Const Manager
  - Discipline Super.

- Use of Safety Harnesses
  - Const Manager
  - Const Manager
  - Discipline Super.

- Event:
  - Fall or Dropped Object

Control Types:
- Company Requirements
- RF Requirement

Location/Grouping: General

Serious Injury/Fatality

First aid training not adequate

Liaise with CMO to provide additional first aid training for contractors First Aiders.

Head Const HSE

First aid training not adequate

HSE Coordinator

Const Manager
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>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Task 01.01</strong></td>
<td>Making live and Closing of Hot Work Permits</td>
</tr>
<tr>
<td></td>
<td>Ensure that all permits are signed out 'made live' and closed by the Authorised Person</td>
</tr>
<tr>
<td></td>
<td>Permit register, Records of Hot Works, Safety Meetings</td>
</tr>
<tr>
<td><strong>Task 01.02</strong></td>
<td>Ensure that Hot Work is in compliance with permit conditions</td>
</tr>
<tr>
<td></td>
<td>Ensure that permit is in compliance with MSN 102L and work is undertaken in safe manor</td>
</tr>
<tr>
<td></td>
<td>Permit register, Walk round check/inspection of works, Pre-job briefing sign off, Safety meeting actions, Daily records</td>
</tr>
<tr>
<td><strong>Task 02.04</strong></td>
<td>Ensuring that lifting gear is tagged and colour coded</td>
</tr>
<tr>
<td></td>
<td>Ensure that lifting gear is coded as per procedure MSN 205L, Ensure competence of certifying contractor</td>
</tr>
<tr>
<td></td>
<td>Audit and Inspection, Sign off from certifying company</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>
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<tr>
<td></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>
<tr>
<td></td>
<td>Visual check, Audit of Portable appliances</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

Typical Competence Assurance System Job Profile

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>
</tr>
</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>
</tr>
<tr>
<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>
</tr>
<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**

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