Bow-tie Modelling in Effective Safety Risk Control

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Objectives

- To appreciate the bow-tie concept and its underlying relationship with the risk management system
- To share the key elements for effective safety risk control
- To illustrate the key steps of constructing bow-tie model and how it can be used to strengthen the existing safety management system

Common Risk Terminologies

- Hazard: Any situation that has a potential to cause harm
- Risk = Frequency/Probability x Severity
- Risk management is the process of:
  - Making decisions about accepting or altering risks.
  - Restricting and maintaining risks within tolerable limits at proportionate cost where elimination of risks is not possible

Risk Management is about…

- What can go wrong?
- How bad can it get?
- How often?
- Is it acceptable?

→ *How can we prevent recurrence of incident based on latest available technology?*

Common Hazard Identification Technique

- HAZard and OPerability Studies (HAZOP)
- Structured What-IF Technique (SWIFT)
- Failure Modes and Effects Analysis (FMEA)
- Failure Modes, Effects and Criticality Analysis (FMECA)
- Fault Tree Analysis (FTA)

Why do you need a model?

- Satisfying legislative requirements
- Meeting client operational needs
- Complying with international standards or good practices
- Evaluating design options
- Addressing specific safety concern
- Supporting frequency and consequence estimation
- Demonstration of as low as reasonably practicable (ALARP)
- Identifying safety critical items and systems
- Prevent incident from recurrence etc

Selection of Approach and Level of Details

- Objective / subjective
- Simple / complex
- Technical / non-technical
- One-off assessment / continual improvement
- Qualitative / quantitative / semi-quantitative
- Life cycle approach
- Novelty
- Uncertainty
- Stakeholders concern
- Cost and business factors
- Organisation structure

Selection of Approach

- *"To make a demonstration means to show, justify or make the case / argument through the information given"*

- *"You should clearly identify in the safety report all safety critical events and the associated initiators. Safety critical events are those that dominate the contribution to risk, so they should be identified by your risk analysis"*

- *"Safety critical events are key to identifying suitable control and protection measures for preventing hazardous events or limiting their consequences. However, the failure of these protection measures must also be considered in assessing whether the residual risks are ALARP or whether more needs to be done."*

[HSE Guidance on Preparing Safety Report 1999]

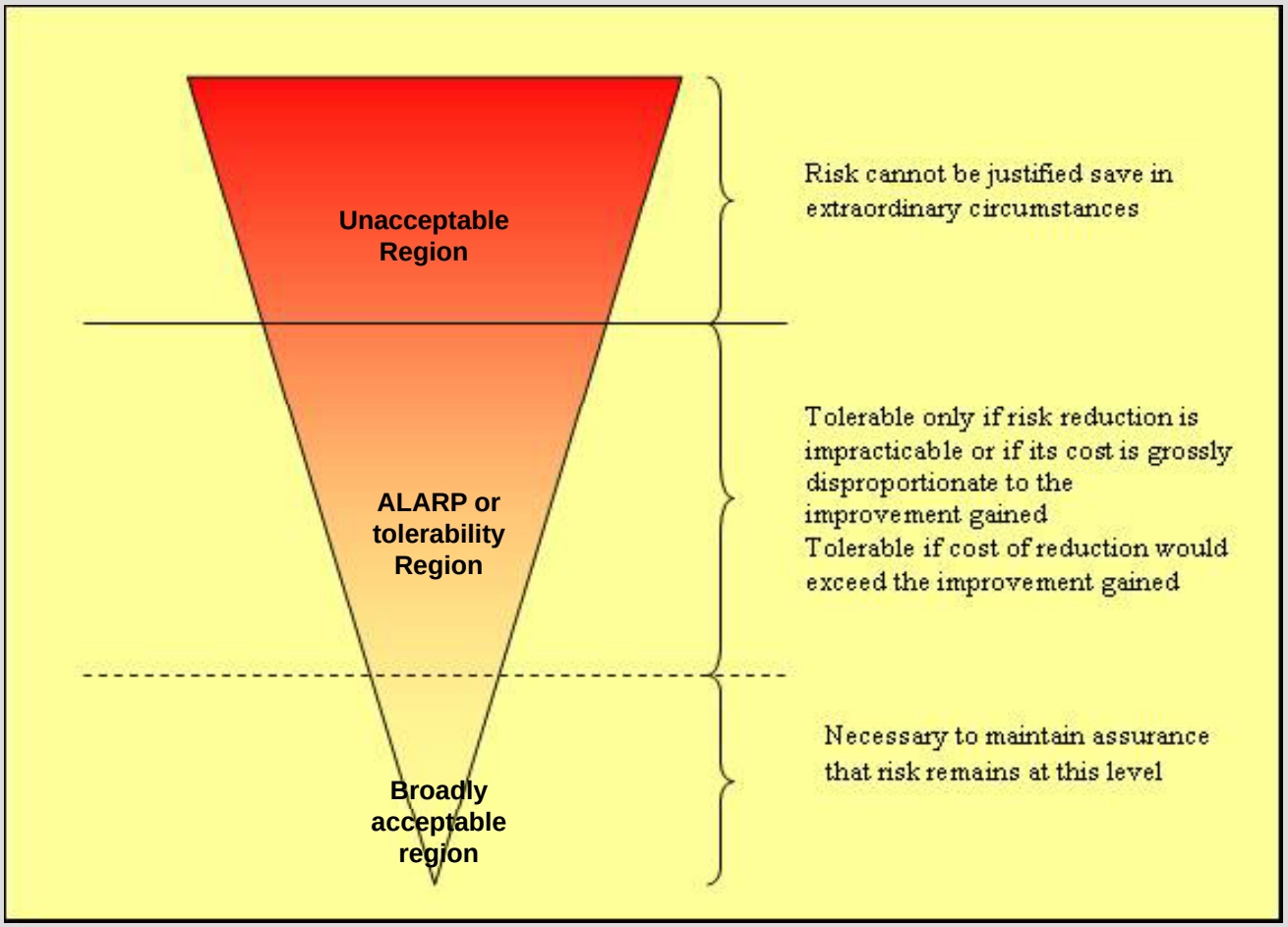
Common Difficulties and Pitfalls

- Each tool has its strengths and weaknesses, and is not always obvious which to select
- Hard to select a single tool to satisfy all needs e.g. satisfying both legislative requirements and operational needs at a time
- Problems in communicating risks with senior management, frontline and the public

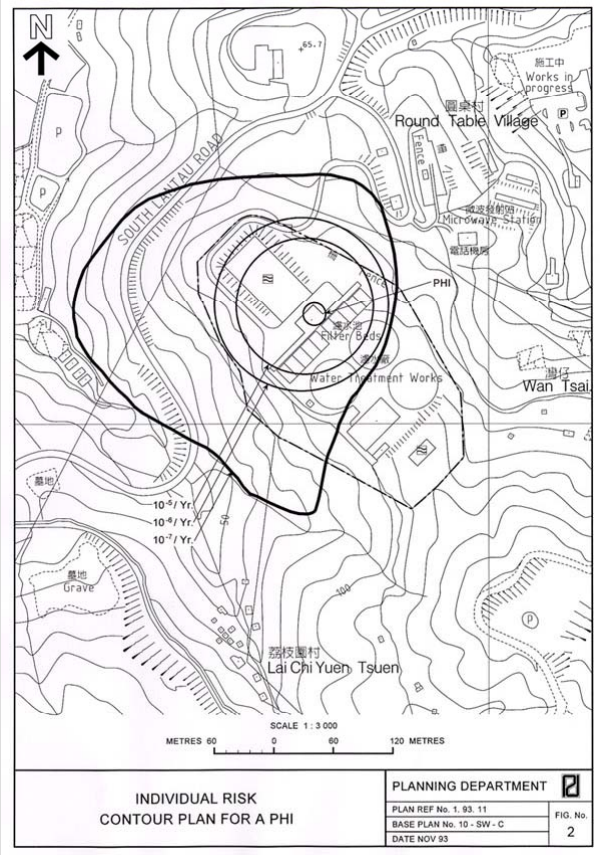
Common Difficulties and Pitfalls

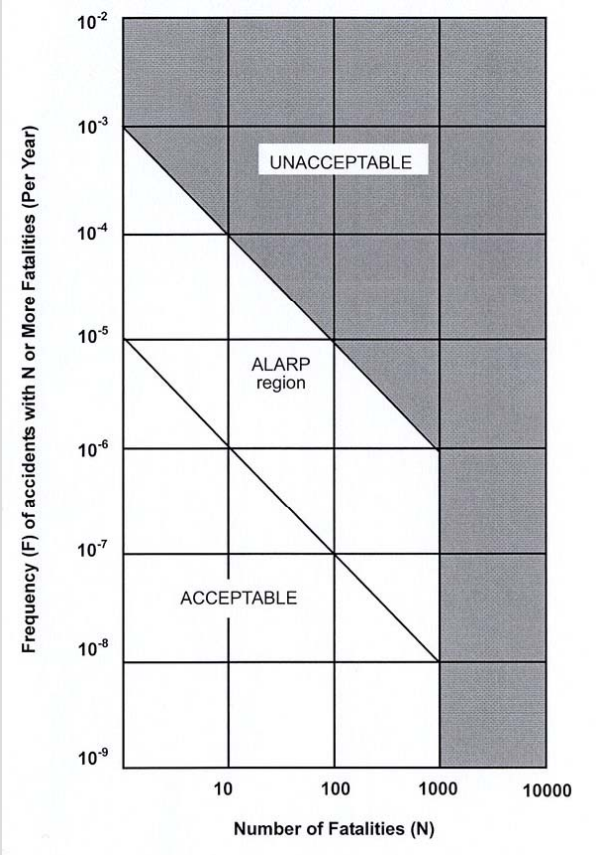
- Increasing size and inconsistent application of risk register
- Tend to focus on hazards only; there is not enough focus on the actual effectiveness of controls and how they relate to accident sequence
- Unclear responsibilities for the management of controls
- Often used to justify not to do something
- Misunderstanding or misapplication of quantitative risk assessment
- Fails to link the critical controls to safety management system

ALARP Principle



Individual Risk Contour Plan and Societal Risk Criteria for a PHI in HK



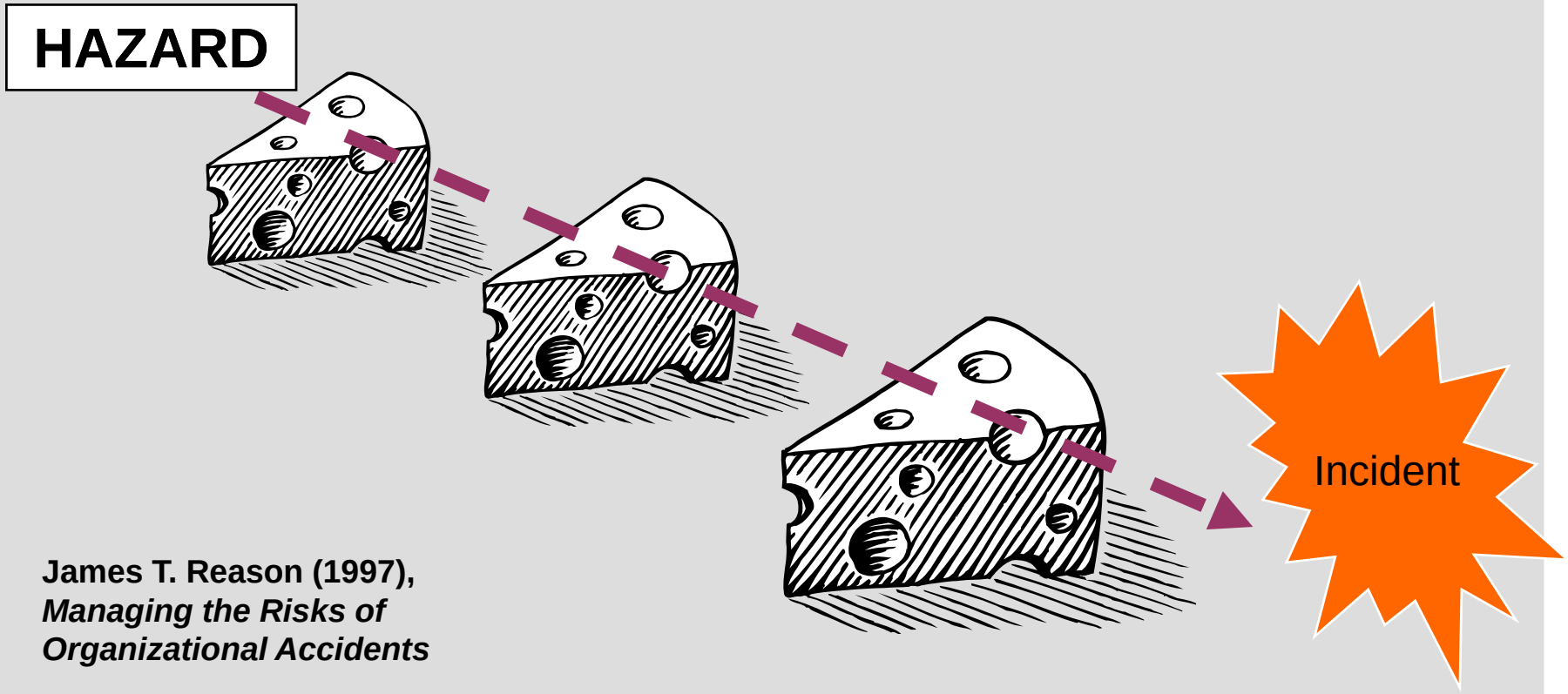


What is Bow-tie?

- Powerful technique in risk and control measures assessment
- Structured approach for risk analyis of events where quantification is not possible or desirable
- Combines causes and consequence analysis into one diagram. The diagram when plotted resembles a bowtie
- The theory behind the bow-tie approach could be found in the Swiss Cheese model of Reason and concepts of layer of protection
- Earliest mention of concept by ICI in 1979 and Royal Dutch/Shell Group was the first company fully integrate the method into business practices

Swiss-cheese Model for Accident Causation

- Each slice of cheese represents a safety barrier or precaution relevant to a particular hazard



James T. Reason (1997),
Managing the Risks of Organizational Accidents

Case Study – Bhopal Disaster in India

Background

- December 1984
- MIC tank alarms had not worked for 4 years
- Vent gas scrubber had been out of service for 5 months
- Missing of slip-blind plate
- Leaking carbon steel valve

Event

- Exposing more than 500,000 people to toxic gas and an estimate of 25,000 died

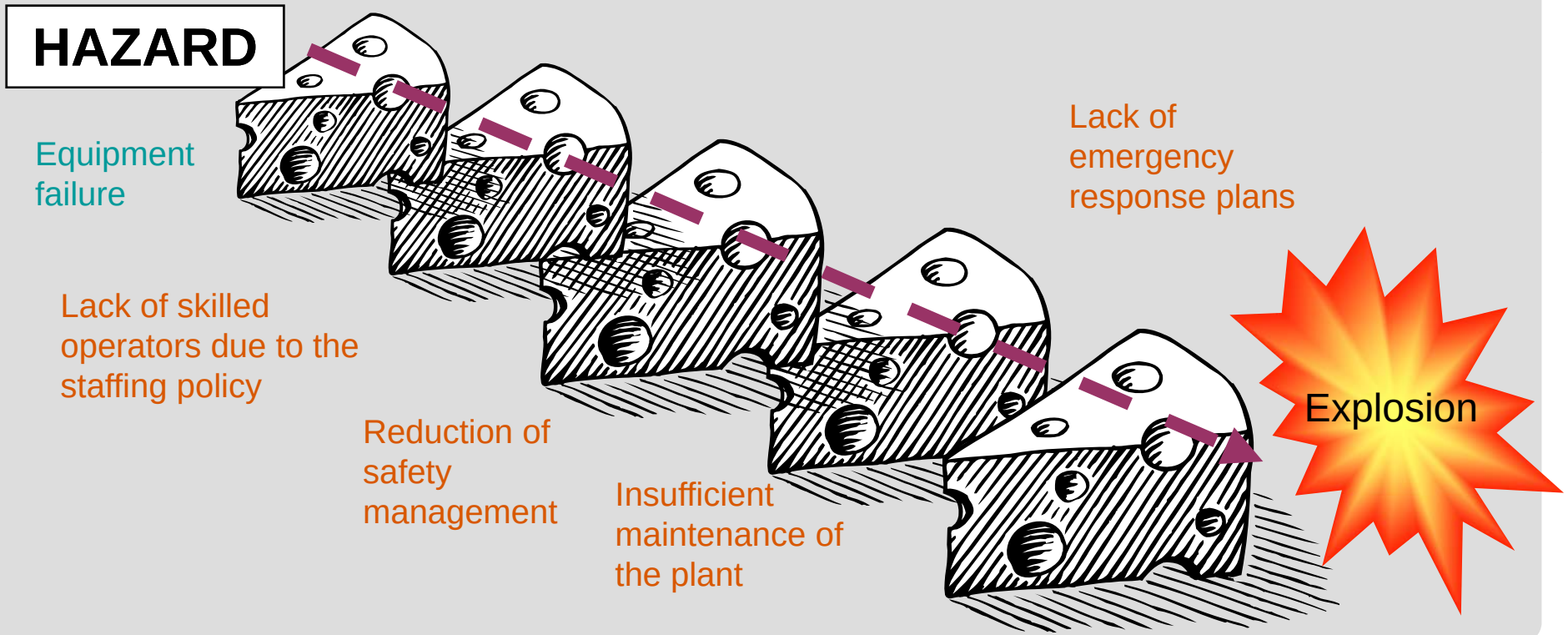
Case Study – Bhopal Disaster in India

Major Findings

- Plant production process and MIC storage
- Work conditions and reduce expense
- Culture difference
- Serious communication problems and management gaps

Case Study – Bhopal Disaster in India

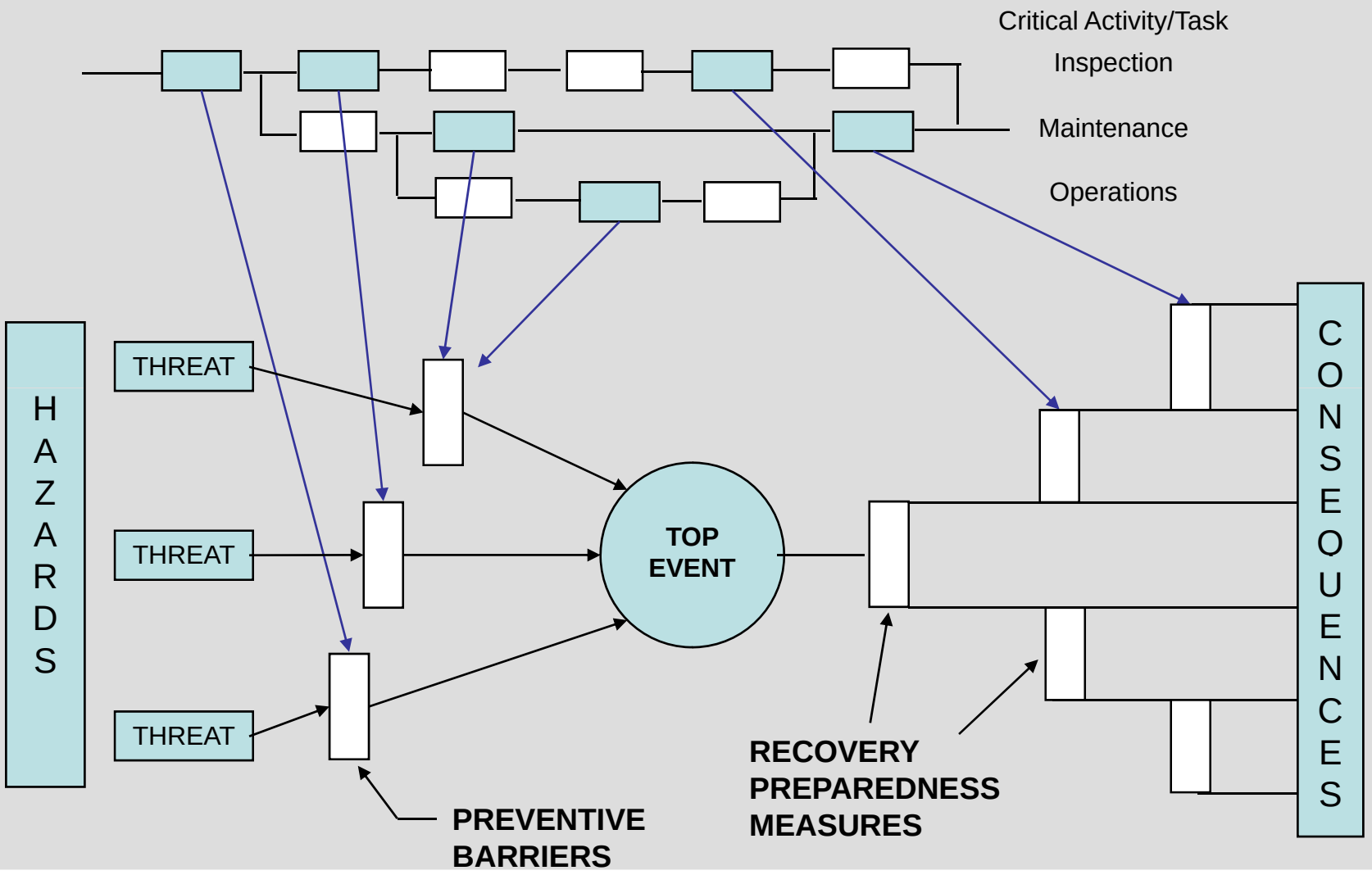
- Equipment failure happened just before the incident was not the only cause of the incident



Case Study – Bhopal Disaster in India

- Many accidents could be prevented by identifying a series of preventable events and their causes
- We need to focus not only on the quantity of controls but also the quality of controls *(ensure critical parts of the system are implemented and managed properly!!!)*

What is Bow-tie?



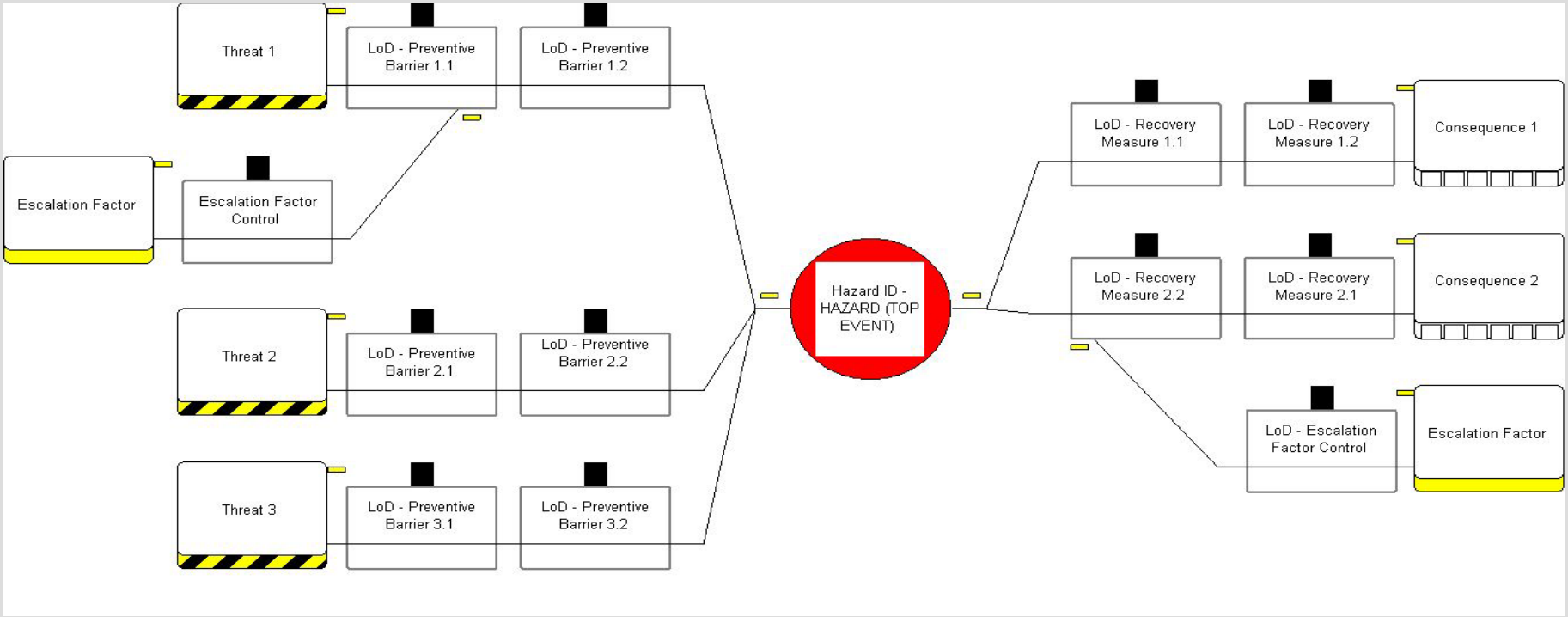
What are the advantages of bow-tie diagram?

- Just learn it first, develop one and then ask!

Common Hazard Information in Hazard Log / Risk Register

- Hazard ID
- Hazard description
- Cause
- Consequence
- Control measure
- Probability / frequency
- Severity
- Risk ranking
- Risk owner

Bow-tie Construction (Example)



Bow-tie Construction (Example)

Hazard	Any situation that has a potential to cause harm
Top Event	The ‘release’ of hazard.
Threat	Any possible cause that will potentially release a hazard and result in a undesirable top event.
Preventive Barrier	A protective measure to prevent threat(s) from releasing a hazard.
Recovery Measure	A preparedness measure to recover or reduce risks if the top event occurs or measure to limit the severity of the outcome.
Consequence	Condition/event(s) that result from the release of hazard / top event.

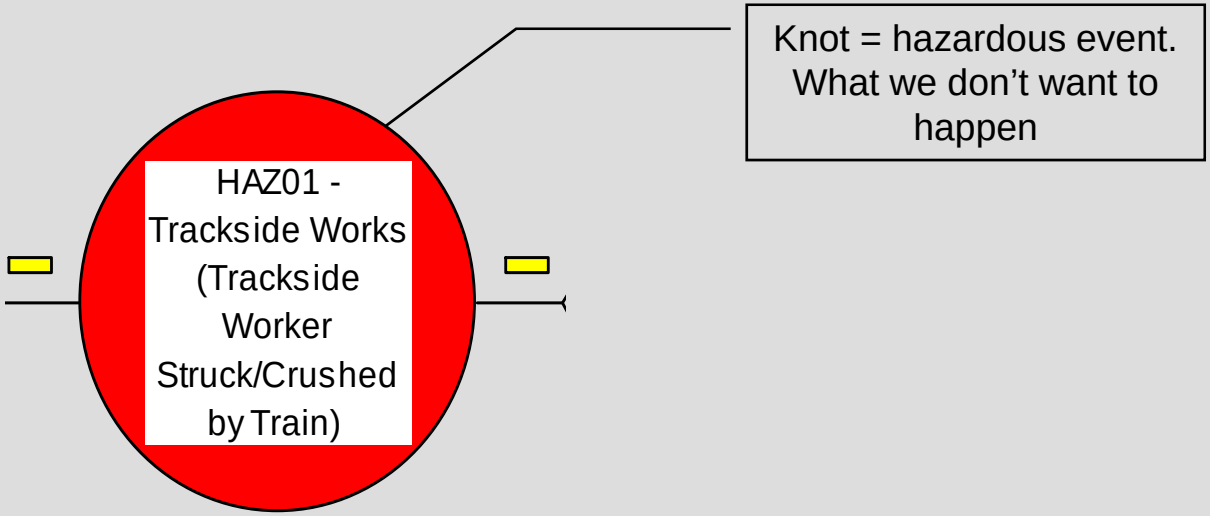
Steps for Bow-tie Modelling

1. Develop a bow-tie model to show the problem clearly including HAZARD and TOP EVENT
2. Identify the THREATS that can cause the problem
3. Display the BARRIERS to prevent the problem occurring
4. Describe the potential CONSEQUENCES
5. Identify the RECOVERY MEASURES required should the problem occur
6. Identify ESCALATION FACTOR and ESCALATION FACTORS CONTROL
7. Identify TASKS and RESPONSIBILITIES
8. Link the controls to SAFETY MANAGEMENT SYSTEM

Example – Identify Hazard and Top Event

Hazard: Trackside Works

Top Event: Trackside Worker Struck/Crushed by Train



Example – Identify Threats

Enter the threats that could cause the event to occur (left hand side), for example

- Driver/track machine operator error
- Worker error – inattention
- Unsafe / inappropriate system of work employed by workers
- Inappropriate lighting
- SPAD

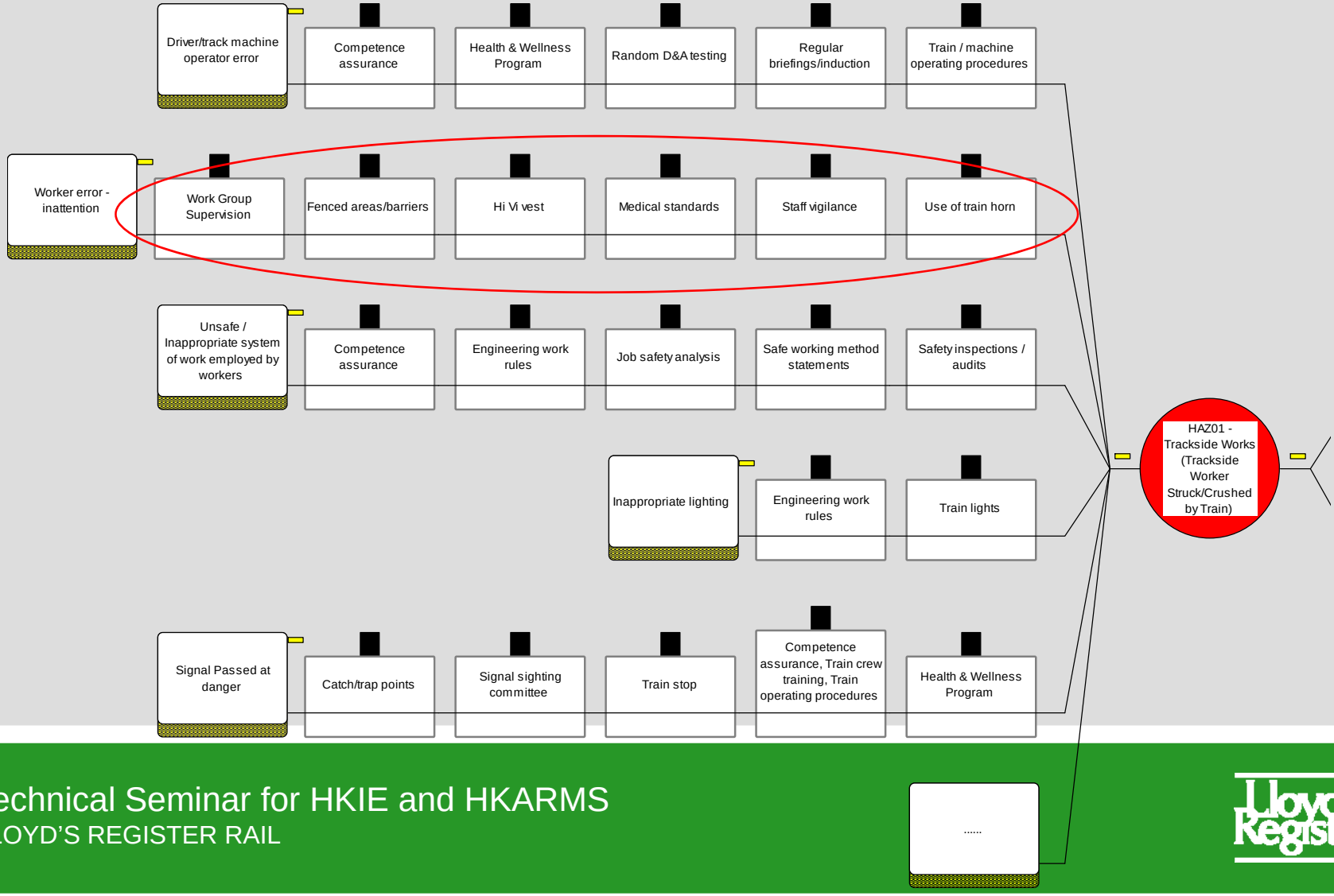
Example - Identify Consequences

Enter the consequences of the event occurring (right hand side)

- Fatality
- Injury
- Damaged equipment
- Etc.

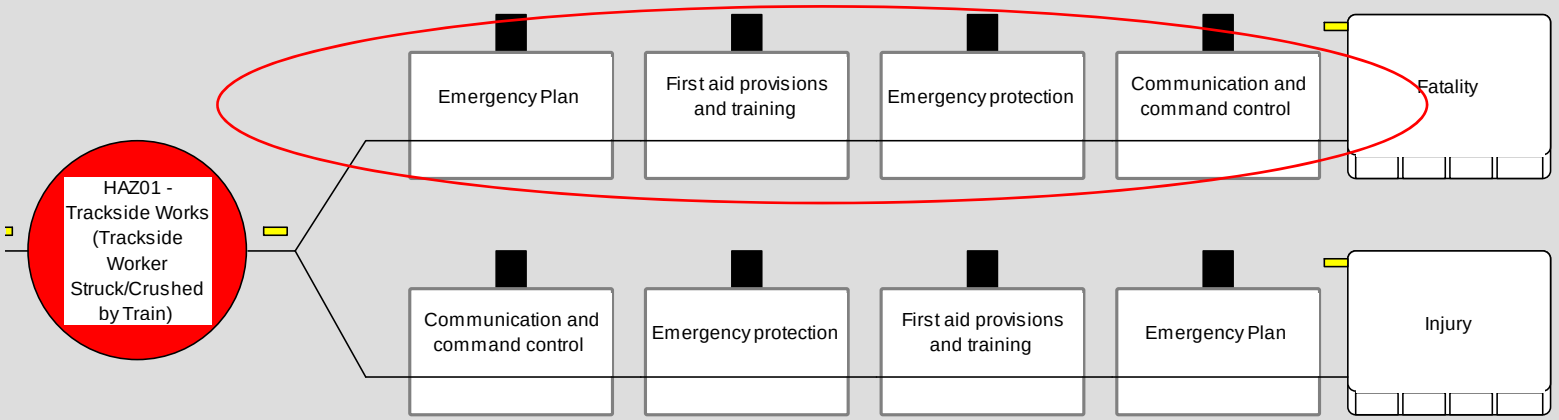
Example – Identify Preventive Barriers

Enter the barriers to prevent the event occurring (between threat and top event)



Example – Identify Recovery Measures

Enter the recovery measures to mitigate against the consequences



Hierarchy of Control Consideration

- Elimination Controls
- Preventive Controls
- Reduction Controls
- Mitigation Controls

Key Factors Affecting Quality of Controls

- Importance
- Relevance
- Specificity
- Effectiveness
- Reliability
- Compliance

Other Considerations in Bow-tie Models

Escalation Factor- Condition that leads to loss of preventive barrier(s) or loss of recovery preparedness measure(s)

Escalation Factor Control - Control(s) put in place to manage conditions that lead to loss of preventive barrier(s) or recovery preparedness measure(s)

Outputs of Bow-tie Modelling

- Better understanding of incident/accident sequences
- Easy to conceptualise and visualise
- Better communication process, 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

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?
- Is the staff competent for doing the task?

Key Notes for Bow-tie Modelling

- Understanding of existing risk decision making process
- Decision framework based on stakeholder and operational needs should be developed to maximise the strength of each tool
- Develop links between risk register and bow-tie diagrams
- Develop criteria for evaluating barrier effectiveness and importance
- The bow-tie model is not intended for use in quantification of risks, however, it supports frequency and consequence analysis and allow detailed quantified risk analysis to be developed

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