ProSafe 2015

Qualitative assessment technique for control adequacy

"Applying LOPA approaches for non-process scenarios"

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Overview

1. The importance of control measures
2. Assessing adequacy of control measures using LOPA – a quick summary of independent protection layers (IPLs)
3. Using qualitative terms to rate the effectiveness of controls in a workshop environment and derive an equivalent “LOPA credit” for the controls
4. Using this approach to demonstrate the adequacy of controls measures for non-process scenarios and administrative type controls

Types of Risk Analysis

1. Qualitative
   – Risk matrix
2. Semi-quantitative
   – Layer of protection analysis (LOPA)
   – Risk graphs
3. Full quantitative
   – Fault tree / event tree

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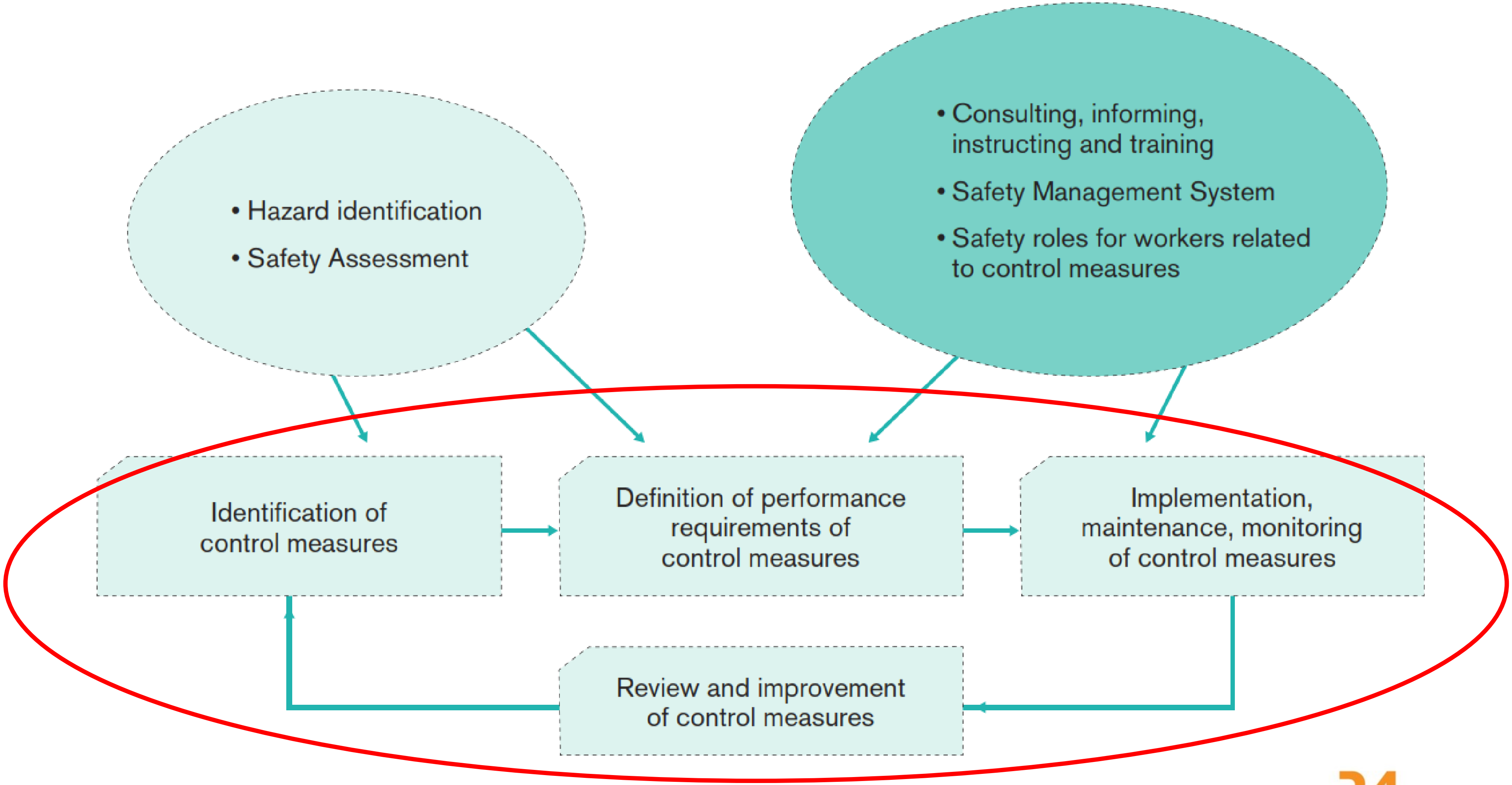
The importance of control measures



Ref.: Worksafe Victoria, Major Hazard Facility Guidance Note

Control Measures

Identify / select
control measures

Identify potential
additional Controls

Adequacy assessments
of controls for each
major incident

Identify / select
potential additional controls

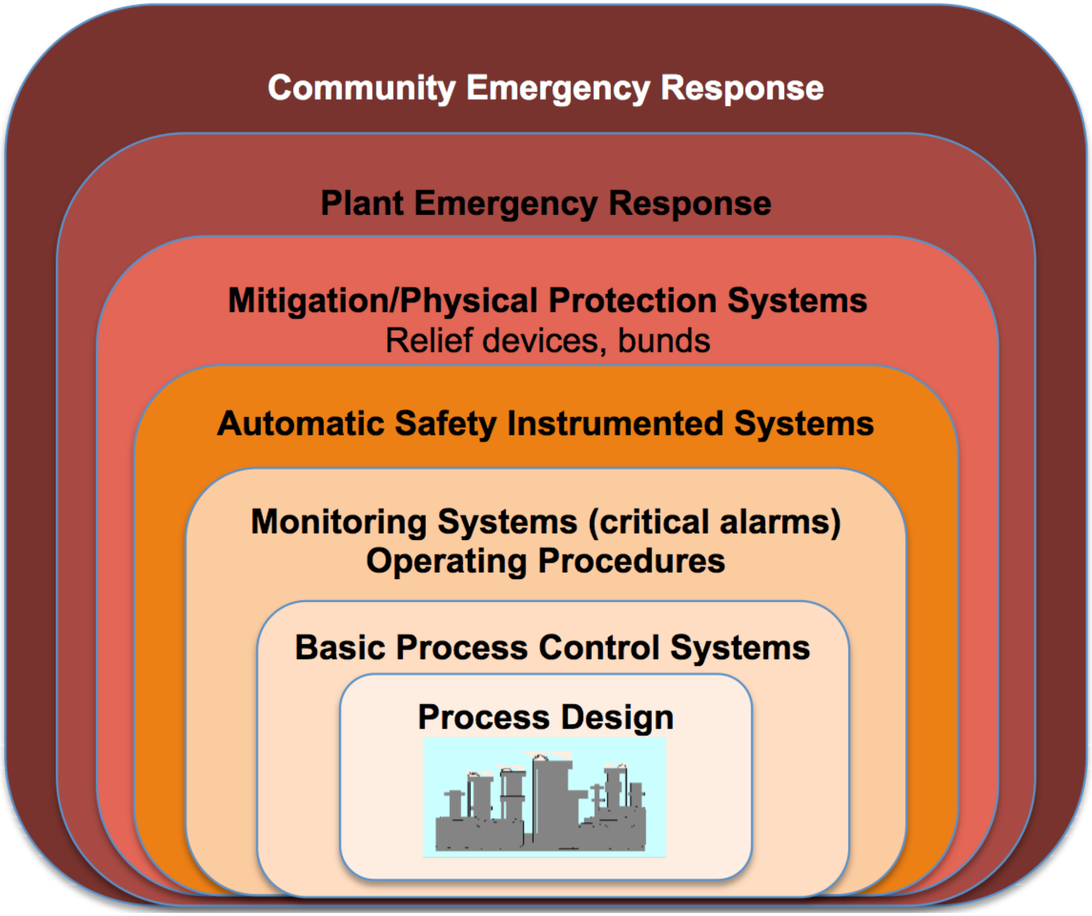
Prepare performance
standards & ensure
procedures / audits
are in place

Five Characteristics of Good Controls

- Implemented
- Applicable (to the hazard)
- Independence
- Reliable
- Monitored & Audited

Layer of Protection Analysis

- Commonly used in the process industries
- Control measures assigned to one of several Independent Protection Layers (IPL)



LOPA

- LOPA is based on the philosophy that for an initiating event, several layers of control or protection can be developed and implemented.
- If one layer fails, there is another layer that would provide the protection function.
- Semi quantitative risk assessment methodology (order of magnitude approximations of risk are employed)

Why LOPA?

- Primary purpose is to evaluate if there are sufficient controls available against an accident scenario
- Protection layers are analysed for their effectiveness (level of risk reduction applied)
- The combined effects of the protection layers are compared to risk tolerance criteria to determine if additional risk reduction is necessary to reach an acceptable level (i.e. an assessment of the control adequacy).

PFDs and Frequency Calculations in LOPA

- In using LOPA, the analyst and workshop team need to be adept at handling frequency calculations
- In LOPA, the effectiveness of controls is expressed through the Probability of Failure on Demand (PFD)
- Typically express these numbers (frequencies, probabilities) using exponents

  E.g. 1×10^{-4}

LOPA "Credits"

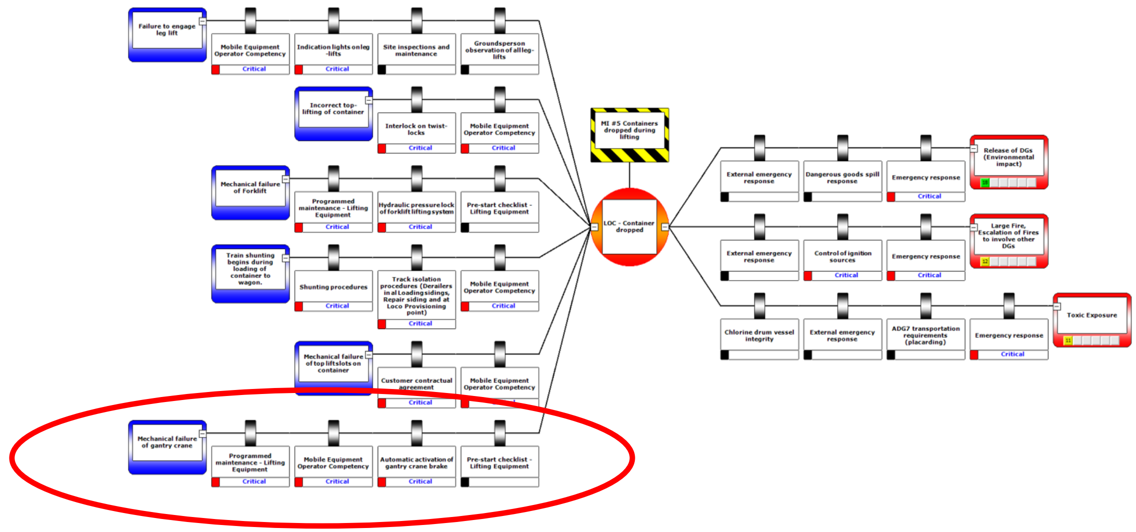
- Often use "credits" when referring to the effectiveness of the IPL
- PFD of 1×10^{-1} = 1 credit (risk reduction factor of 10 times)

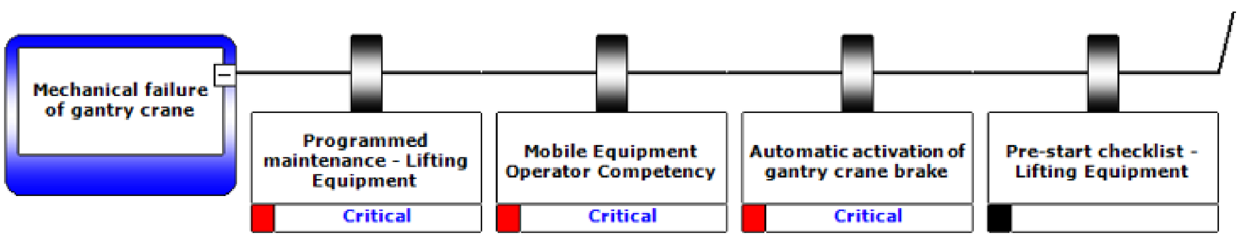
BUT…LOPA does not suit all cases

- Best suited to process scenarios protected by instrumented systems (alarms, trips)
- Difficult to apply to non-process scenarios, particularly where the controls are largely administrative systems
- In a workshop format, the specialised LOPA terminology, frequency calculations and “ruleset” can over-complicate discussions.

Example Qualitative Bowtie Scenario – Logistics Operation

- Dropped container – flammable/toxic material





Adopting “LOPA thinking” for non-process scenarios

- Provide an assessment of the overall control adequacy
- Provide an “equivalent” estimate on the risk reduction factor that is provided by the suite of controls
- Utilise simple to understand, qualitative terms to assess the controls

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Deriving an equivalent "LOPA Credit"

Control Effectiveness Rating:

- Start with an control type providing a "rating" broadly calibrated to typical LOPA values
- Assess other "inherent" factors that influence the effectiveness of a control measure and use a simple qualitative rating on each to adjust the rating
- Consider the level of performance monitoring and system auditing in place to support the on-going control effectiveness
- Consider applicability and independence within the specific scenario

Control Measures - Inherent Factors

For each control, assess;

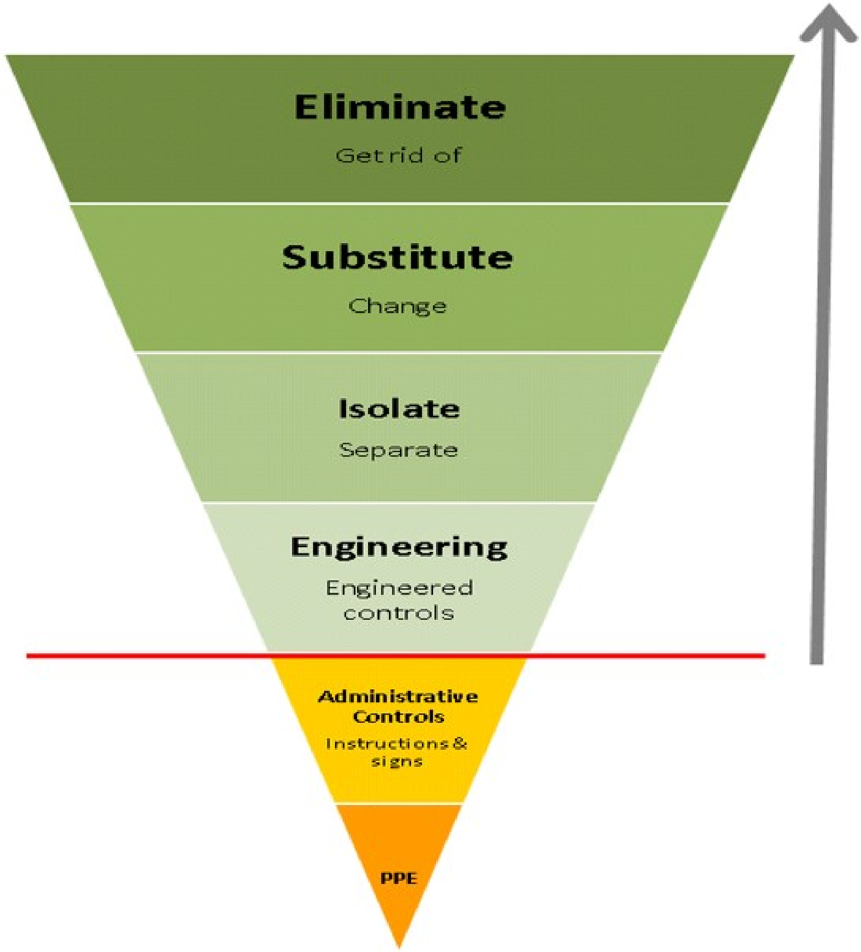
- Control type
- Implementation level
- Reliability
- Monitoring and auditing

Control Measures – Scenario-Specific Factors

For each scenario where a control is used, assess;

- Control applicability (to the specific scenario)
- Control independence (within the scenario)

Control Types - Risk Control Hierarchy

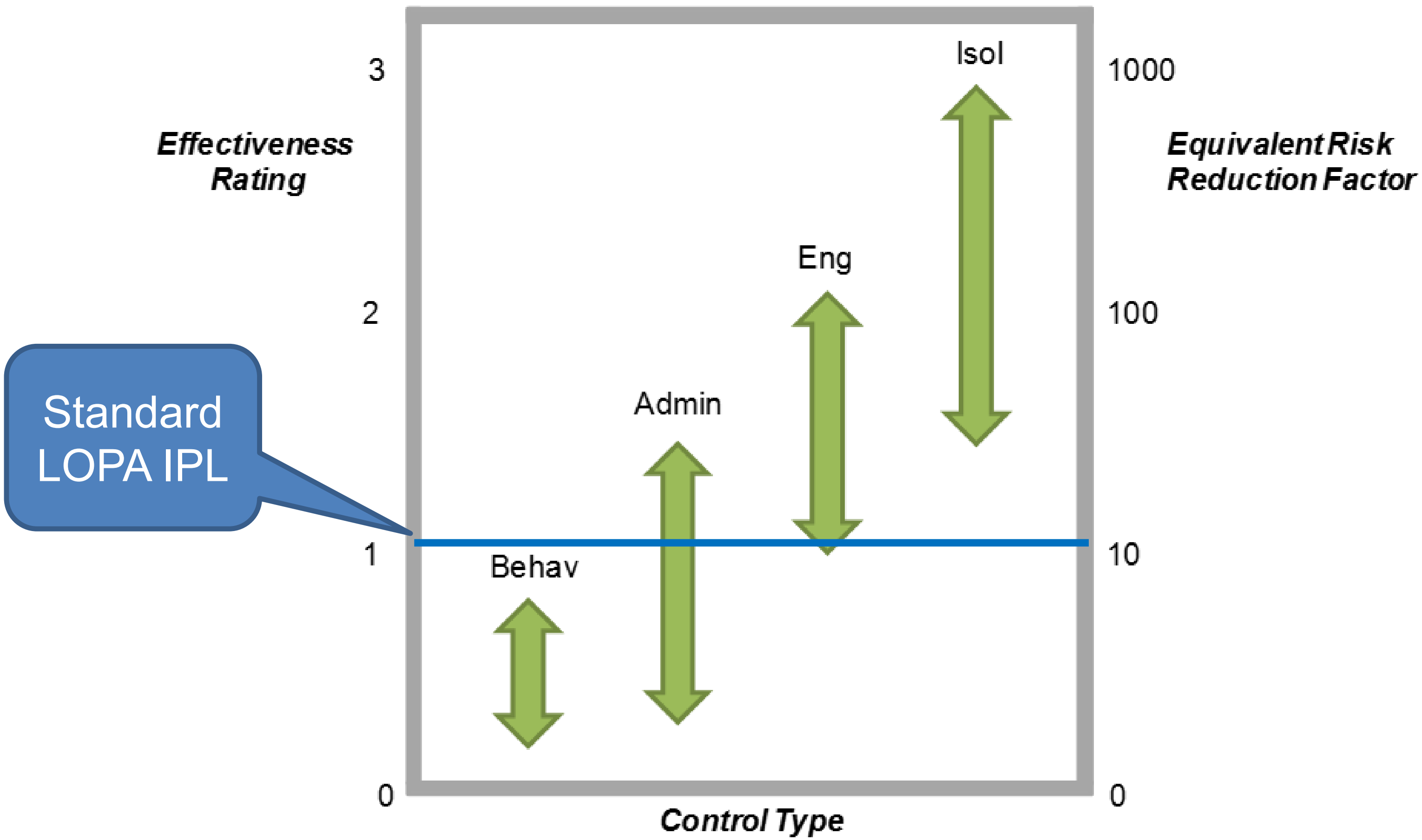


Control Type

Rating	Description	Score (R_{Typ})
Isol	Physical and permanent isolation system or barrier not dependent on procedural controls.	2.0
Eng	Engineering / automatic interlock system.	1.0
Admin	Administrative / procedural system.	0.8
Behav	Behavioural / training / competency based control	0.5

NOTE: Factor ratings shown are study-dependent and may not be appropriate for specific risk study context

Control Effectiveness Ratings



Implementation

Rating	Description	Score (R_{Imp})
Yes	Control measure is fully implemented.	1.0
Part	Control measure is partially implemented.	0.5
No	Control measure is not implemented.	0

NOTE: Factor ratings shown are study-dependent and may not be appropriate for specific risk study context

Reliability

Rating	Description	Score (R_{Rel})
HISS	High Integrity Safety System. Reserved for very high integrity safety systems (e.g. SIL3 SIF, high integrity LOTO system).	3.0
Excellent	Control will function on demand >99% of the time. e.g. SIL2 SIF, very high reliability procedural/administrative control.	2.0
V. Good	Control will function on demand 90 - 99% of the time. e.g. SIL1 SIF, high reliability procedural/administrative control.	1.5
Good	Control will function on demand 90% of the time. e.g. Basic process control, standard operating procedure supported with proper documentation and training	1.0
Fair	Control will function on demand 50-90% of the time. Control with known performance issues or where reliability/availability cannot be assured.	0.5
Poor	Control will fail to function more than half the time. Control with known serious performance issues.	0.1

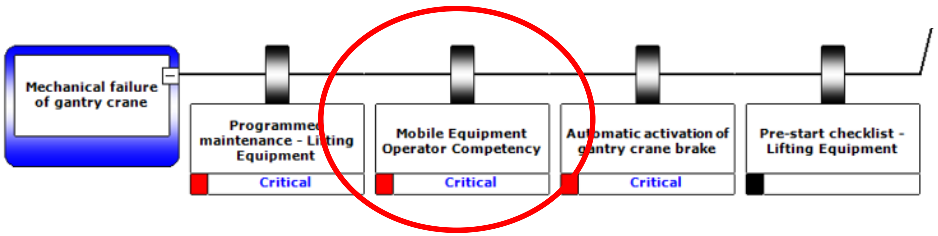
NOTE: Factor ratings shown are study-dependent and may not be appropriate for specific risk study context

Monitoring and Auditing

Rating	Description	Score (R_{Mon})
Monitored and Audited	Performance indicators and standards are set for the control with active monitoring. Management system underlying the control is subject to formal internal and/or external audits.	1.25
Performance monitoring	Performance indicators and standards are set for the control with active monitoring or control performance is constantly supervised. No formal auditing of the management system underlying the control.	1.0
Ad-hoc	Performance indicators and standards are not set for the control however the control is subject to ad-hoc management or supervision oversight.	0.5
None	No specific monitoring or auditing of the control is conducted.	0.1

NOTE: Factor ratings shown are study-dependent and may not be appropriate for specific risk study context

Control Inherent Effectiveness



Control Measure	Factor		Effectiveness Comment	Rating	Score
Mobile Equipment Operator Competency	Type	R_{Type}	Competency-based control	Behav	0.5
	Implementation	R_{Impl}	All operators must complete mandatory training / refresher training to remain competent.	Yes	1.0
	Reliability	R_{Rel}	Training includes all critical safety aspects. A fully competent operator will substantially reduce the likelihood of an accident.	V. Good	1.5
	Monitoring and Auditing	R_{Mon}	Systems are in place to confirm competency annually. The system is externally audited.	Monitored and Audited	1.25

$$Control\ Inherent\ Effectiveness\ Rating = R_{Type}.R_{Impl}.R_{Rel}.R_{Mon}$$

$$= 0.5 \text{ x } 1.0 \text{ x } 1.5 \text{ x } 1.25$$

$$= 0.94$$

Assess Inherent Effectiveness – All Controls

- Spreadsheets or specialised tools may be used to assist with the control adequacy assessment

Preventative Controls (Critical)

Preventative Control	Control Global Comment	Control Effectiveness Comments	Critical	Control Implemented	Control Type	Control Reliability	Control Auditability	Inherent Control Effectiveness
17. Mobile Equipment Operator Competency	CB Licence: "Gantry Crane" and LF Licence "Forklift" followed by site-specific off-job and on-job training & assessment. 2 yearly refresher training required.	Training considered to be well ahead of typical industry standards. Audited externally.	Yes	Yes	Behav	V.Good	Monitored and audited	0.94
18. Programmed maintenance - Lifting Equipment	Regular maintenance program for lifting equipment.		Yes	Yes				1.20
19. Automatic activation of the gantry crane brake	Centring or releasing the Dead Man button the control joystick de-energises the motors and automatically activates the Motor Brakes, which are capable of holding the cranes against wind gusts of up to 138 km/h. Four Storm Pin locations are also provided along the gantry line and are guaranteed to hold the cranes in winds gusts in excess of 150 km/h. Hoisting interlocks during top lift lock lift in position if container becomes unstable. Note: Emergency Brakes on the cranes will bring them to a stop more quickly but will not provide any additional holding power against winds.		Yes	Yes				1.25
20. Pre-start checklist - Lifting Equipment	Daily checklist conducted by operators.							0

Code	Description	Control Type
Isol	Physical and permanent isolation system or barrier not dependent on procedural controls	2
Eng	Engineering / automatic interlock system	1
Admin	Administrative / procedural system	0.8
Behav	Behavioural / training / competency based control	0.5

Scenario-based Factors

- The inherent effectiveness only needs to be assessed once for each control
- Depending on the scenario, the control may be:
  - less than fully effective at preventing the specific cause
  - may not be a fully independent control within the suite of controls for that cause.

Applicability

Rating	Description	Score (R_{App})
High	Control is highly applicable to the scenario. A high probability that the control functioning as designed would prevent the scenario in all circumstances. (e.g. purpose built safety system).	1.0
Mod-High	Control is applicable to the scenario. A high probability that the control functioning as designed would prevent the scenario in most circumstances.	0.8
Moderate	Control is somewhat applicable to the scenario. The control functioning as designed would the scenario in some circumstances.	0.5
Low	Control is only loosely applicable to the scenario. Control functioning as designed is unlikely to prevent the scenario.	0.1

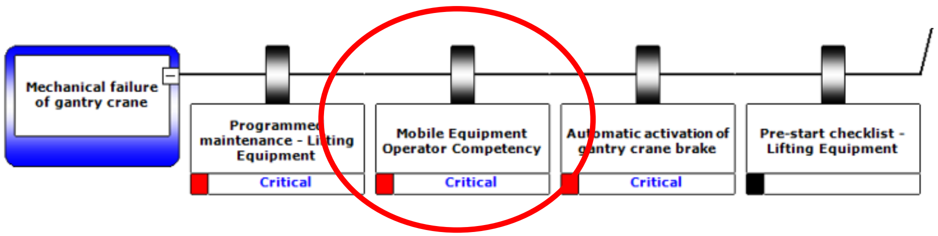
NOTE: Factor ratings shown are study-dependent and may not be appropriate for specific risk study context

Independence

Rating	Description	Score (R_{Ind})
High	Fully independent control within the scenario	1.0
Moderate	Generally independent control within the scenario with some minor sources of common mode failure (e.g. common BPCS system, several layers of operating procedures but performed by different people).	0.5
Low	Not an independent control within the scenario	0

NOTE: Factor ratings shown are study-dependent and may not be appropriate for specific risk study context

Scenario Effectiveness



Cause: Mechanical failure of gantry crane					
Control Measure	**Factor**		**Effectiveness Comment**	**Rating**	**Score**
Mobile Equipment Operator Competency	Applicability	R_{App}	There is little time for the operator to react and some catastrophic failures may not be recoverable by the operator.	Moderate	0.5
	Independence	R_{Ind}	The operator is independent from the cause and the other controls.	High	1.0

$$Control\ Effectiveness\ Rating = Control\ Inherent\ Effectiveness\ Rating . R_{Appl} . R_{Ind}$$

$$= 0.94 \text{ x } 0.5 \text{ x } 1.0$$
$$= 0.47$$

Overall Effectiveness Rating – All controls for a single cause

$$\mathit{Overall\ Control\ Effectiveness\ Rating} = \sum_{\substack{\mathit{All\ controls} \\ \mathit{in\ cause}}} \mathit{Control\ Effectiveness\ Rating}$$

- Apply the scenario factors for each control on the cause and then sum the control effectiveness ratings
- The "Overall Control Effectiveness Rating" provides a measure of the control effectiveness for the suite of controls on a single cause

The relationship between Control Effectiveness Rating and RRF indicated is an approximation

Scenario Factors Applied

LOC Event	Cause	Preventative Control	Critical	Inherent Control Effectiveness	Control Applicability	Control Independence	Control Specific Comments	Prev Control Effectiveness Rating	RRF
5. Containers dropped during lifting	12. Mechanical failure of Gantry Crane	17. Mobile Equipment Operator Competency	Yes	0.94	Moderate	High	There is little time to react and some catastrophic failures may not be recoverable by the operator.	2.17	147
		18. Programmed maintenance - Lifting Equipment	Yes	1.20	High	High	Contract maintenance programs		
		19. Automatic activation of the gantry crane brake	Yes	1.25	Moderate	Moderate	The gantry crane brake will activate automatically if the load control joystick is released.		
		20. Pre-start checklist - Lifting Equipment		0	Low	Low	Visual inspection only.		

- For this scenario (bowtie pathway), the overall control effectiveness rating is calculated to be 2.17 (i.e. slightly better than 2 x LOPA IPLs).
- The resulting risk reduction provided by this suite of controls (on this cause) is 147 times

Practical Applications

- As per LOPA, utilise the numerical estimate of control effectiveness to assess control adequacy – review scenario by scenario
- Assessing the effectiveness factors is a good way to methodically identify practical improvements in controls
- Identify causes in which the controls provide a low level of risk reduction and look for additional or improved controls
- All of the above are useful tools to assist with SFAIRP demonstration in qualitative risk studies.

Extension to Determine Scenario Frequency and Risk

- By assigning a numerical frequency for the cause, the scenario frequency can be determined and compared with tolerability criteria (i.e. as per LOPA approaches)
- The cause frequency can be estimated using qualitative likelihood estimates (e.g. from a risk matrix) or by using guidance from LOPA “rules”

Points to Remember…

- This method is still largely an “order of magnitude” level of risk assessment as per LOPA
- An experienced and knowledgeable team is central to any risk assessment and this is no different
- Good judgement is needed to apply the basic built-in rulesets consistently
- Care is needed in applying these approaches to actual risk studies
- LHS of bowtie (preventative controls) works best

In Summary…

- Diligently assessing the adequacy of controls measures is important in risk assessment.
- Draw on LOPA principles (IPLs) extended to qualitative analysis
- Use qualitative terms to rate the effectiveness of controls that are meaningful to a workshop group and avoid confusing small numbers (frequencies, PFDs etc)
- Derive estimates for the risk reduction that can be applied to the controls on a scenario that is broadly calibrated to the LOPA “IPL credit”.

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Thank you

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