CHALLENGES IN USING LOPA TO DETERMINE SAFETY INTEGRITY LEVELS (SILS)

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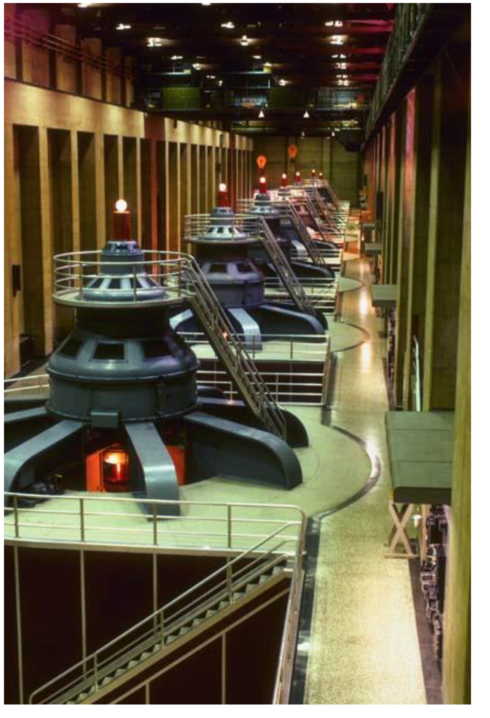

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OVERVIEW

- SIL determination
- LOPA and SIL determination
- Issues in using LOPA for SIL determination
- Procedure for SIL determination using LOPA
- Example

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SIL DETERMINATION

- IEC 61511 / ISA 84 requires the determination of SILs for SIFs in SISs
  - Increasingly accomplished using LOPA
- Estimates of risk levels for a process are compared with risk tolerance criteria
  - SIL required to close a gap is specified
- SIFs protect against specific hazardous events
  - Standard calls for risk tolerance criteria to be established for them

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LOPA AND SIL DETERMINATION

- LOPA calculates the risk of individual hazard scenarios
- Only overall facility risk is meaningful
  - Allocated to individual hazard scenarios
  - Scenario risk estimates are compared with allocated criteria
- Sometimes hazardous events are used
  - Risks of scenarios that produce the same hazardous event are aggregated

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ISSUES IN USING LOPA FOR SIL DETERMINATION

- Hazardous events and hazard scenarios cannot be defined invariantly
- Allocation of facility risk tolerance criteria to scenarios or events is problematic
- LOPA is susceptible to errors in using risk tolerance criteria

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BENCHMARKING LOPA

- UK HSL / HSE analyzed seven representative LOPA studies
  - Submitted by operators of Buncefield-type sites that store flammable liquids
- Multiple inconsistencies and problems found
  - Including confusion over risk tolerance criteria
- Majority of studies were carried out by consultants

Ref. A review of Layers of Protection Analysis (LOPA) analyses of overfill of fuel storage tanks, HSE Books, 2009.

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PROCEDURE FOR SIL DETERMINATION USING LOPA

- Use a risk model that employs facility risk tolerance criteria
- Aggregate the risks of individual scenarios
  - For comparison with facility risk tolerance criteria
- Check that risk to receptors has been allocated equitably within and across facilities
  - Ensure no processes, areas, units, process modes, etc. contribute disproportionately to risk

STEPS IN THE PROCEDURE

Step 1. Define receptors at risk

- Usually people onsite and offsite, and the environment

Step 2. Determine type of risk to use

- Both individual risk and societal (group) risk

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STEPS IN THE PROCEDURE (CONTD.)

Step 3. Determine form of risk to use

- Geographical
- Actual

Step 4. Specify consequence severity levels

- For people, impacts ranging from fatalities to first-aid cases may be possible

STEPS IN THE PROCEDURE (CONTD.)

Step 5. Specify risk tolerance criteria for each type of receptor

- Specify correct type of criteria
  - Comparison of group risk estimates with criteria for individuals is incorrect
- Group risk can be calculated for the public and facility personnel separately, or in combination
  - Pair with the correct risk tolerance criterion

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STEPS IN THE PROCEDURE (CONTD.)

Step 6. Determine offsets to risk tolerance criteria

- Facility risk tolerance criteria address all hazards
  - PHA addresses only major hazards
- Criteria should be offset to account for casualties from excluded sources
  - Offsets can be significant
- PHA studies are incomplete
  - Conservative offset should be applied

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STEPS IN THE PROCEDURE (CONTD.)

Step 7. Specify risk tolerance criteria for consequence severities

- Available reference criteria are for fatalities
- Criteria for injuries to people can be developed using the equivalence concept
  - Equivalences are debatable
- Accidents that produce fatalities can produce accompanying and more numerous injuries
  - Significant component of the harm

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STEPS IN THE PROCEDURE (CONTD.)

Step 8. Decide on risk allocations and scaling

- Both individual and group risk tolerance criteria can be allocated to receptors within a facility
- Some companies allocate group risk across all their facilities
- Can scale the allocation of risk to a facility
  - According to a measure of the number of operations and size

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STEPS IN THE PROCEDURE (CONTD.)

Step 9. Identify hazard scenarios

- Typically obtained from PHA studies for a process
- Include risk to receptors from other contributing processes

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STEPS IN THE PROCEDURE (CONTD.)

Step 10. Calculate scenario risks

- All scenarios protected by a SIF must be evaluated
- Scenarios not protected by a SIF may be protected by other means
  - Still make a contribution to the risks of a process
  - Must be included in the risk model

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STEPS IN THE PROCEDURE (CONTD.)

Step 11. Calculate individual and group risks

- Combine scenario risk estimates
- Risks of all scenarios that could impact an individual contribute to individual risk
  - Regardless of the number of people impacted by the scenario
- Calculation of group risk begins with groups of one

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STEPS IN THE PROCEDURE (CONTD.)

Step 12. Make risk comparisons

- Estimates and criteria for the overall facility
- Allocations to receptors from applicable sources

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STEPS IN THE PROCEDURE (CONTD.)

Step 13. Formulate risk reduction measures

- Any one safety function may impact the risk of multiple hazard scenarios
  - And across its operating modes
- Risk model that incorporates linking of safety functions is needed

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STEPS IN THE PROCEDURE (CONTD.)

Step 14. Update PHA and LOPA Studies

- Reflect any changes made to the process
- Use risk model that incorporates all hazard scenarios for the process

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EXAMPLE OF USING LOPA TO DETERMINE SIL'S

- Toluene storage and charging process
  - High level shutdown system separate from the BPCS
- Various other safeguards are present
  - Some of which are credited as independent protection layers (IPLs)
- Two modes of operation
  - Tank filling and transfer
- Hazard scenarios may result in fires and explosions
- Scenario and facility risks were calculated using LOPAWorks®

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EXAMPLE OF LOPA WORKSHEET FOR A HAZARD SCENARIO

Number	1		
Description	Tank level transmitter fails and overfill tank, TK-104, with fire and employee impacts.		
Process	Toluene Storage and Charging		
Process Mode	Tank filling		
Consequence	**Description**	**Type**	**Level**
	Overfill tank, TK-104	EMP	2
Hazard Type	Fire		
Events	**Item**	**Type**	**Value**
	Initiating Event		**Frequency**
	Level transmitter, LT TK-104, fails to detect high level	EQP	1×10^{-1}
	Enablers (regular, at-risk factors, and conditional modifiers)		**Value**
	Time in tank filling mode	ARF	1×10^{-1}
	Lack of PM on level transmitter LT TK-104	REG	5
	Probability of ignition	CM	5×10^{-1}
	Probability of personnel in affected area	CM	5×10^{-1}
	Probability of harm from exposure	CM	1
	Independent Protection Layers		**PFD**
	High level shutoff for TK-104	SIF	1×10^{-1}
	Operator action to stop pump, P-100	HUM	1×10^{-1}
	Safeguards (non-IPL)		
	Plant fire brigade	HUM	
Summary	**Item**		**Value**
	Frequency of Mitigated Consequence		1.3×10^{-4}
LOPA Recommendations	**Recommendation**	**By**	**Due Date**
	<no recommendations for the scenario>		
Notes	<no Notes for the Scenario>		

TOTAL RISK FOR THE PROCESS

Main | Options | Project | Sessions | LOPA | LOPA Form | LOPA Sheet | Lists | **Summation** | Reports

Risk Summation Types

Type: Consequence types

Show: ☑ All

Risk Summations

Consequence Type	Consequence Level	Scenario Count	Frequency	Risk Tolerance	Risk Reduction Required	Risk Reduction Factor
EMP	1	6	1.7×10^{-4}	1×10^{-3}	None	None
	2	9	3.5×10^{-4}	1×10^{-2}	None	None
PUB	1	4	7.2×10^{-5}	1×10^{-5}	1.4×10^{-1}	7.2
	2	3	1.9×10^{-4}	1×10^{-4}	5.3×10^{-1}	1.9

Scenarios for Selected Summation

#	Description	IPLs			%
		Description	Type	PFD	
3	Tank level transmitter fails and overfill tank, TK-104, with explosion and public impacts.	High level shutoff for tank, TK-104	SIF	1×10^{-1}	69.4
		Operator action to stop pump, P-100	HUM	1×10^{-1}	
6	Tank level indicating controller fails and overfill tank, TK-104, with explosion and public impacts.	High level shutoff for tank, TK-104	SIF	1×10^{-1}	1.4
		Operator action to stop pump, P-100	HUM	1×10^{-1}	
9	Pump P-100	High level	SIF	1×10^{-1}	27.8

Process Mode: Tank filling

Consequence

Description	Type	Level
Overfill tank, TK-104	PUB	1

Hazard Type: Explosion

Events

Item	Type	Value
Initiating Event		**Frequency**
Level transmitter, LT TK-104, fails to detect high level	EQP	1×10^{-1}
Enablers (regular, at-risk factors, and conditional modifiers)		**Value**
Time in tank filling mode	ARF	1×10^{-1}
Lack of PM on level transmitter LT TK-104	REG	5
Probability of ignition	CM	1×10^{-1}
Probability of personnel in affected area		1
Probability of harm from exposure		1
Independent Protection Layers		**PFD**
High level shutoff for tank, TK-104	SIF	1×10^{-1}
Operator action to stop pump, P-100	HUM	1×10^{-1}
Safeguards (non-IPL)		
Public evacuation	HUM	

ADJUSTED TOTAL RISK FOR PROCESS

Main | Options | Project | Sessions | LOPA | LOPA Form | LOPA Sheet | Lists | **Summation** | Reports

Risk Summation Types

Type: Consequence types

Show: ☑ All

Risk Summations

Consequence Type	Consequence Level	Scenario Count	Frequency	Risk Tolerance	Risk Reduction Required	Risk Reduction Factor
EMP	1	6	1.1×10^{-4}	1×10^{-3}	None	None
	2	9	3.3×10^{-4}	1×10^{-2}	None	None
PUB	1	4	8.1×10^{-6}	1×10^{-5}	None	None
	2	3	1.9×10^{-4}	1×10^{-4}	5.3×10^{-1}	1.9

Scenarios for Selected Summation

#	Description	IPLs Description	IPLs Type	IPLs PFD	%
3	Tank level transmitter fails and overfill tank, TK-104, with explosion and public impacts.	High level shutoff for tank, TK-104	SIF	1×10^{-2}	61.7
		Operator action to stop pump, P-100	HUM	1×10^{-1}	
6	Tank level indicating controller fails and overfill tank, TK-104, with explosion and public impacts.	High level shutoff for tank, TK-104	SIF	1×10^{-2}	1.2
		Operator action to stop pump, P-100	HUM	1×10^{-1}	
9	Pump P-100	High level	SIF	1×10^{-2}	24.7

Process Mode: Tank filling

Consequence

Description	Type	Level
Overfill tank, TK-104	PUB	1

Hazard Type: Explosion

Events

Item	Type	Value
Initiating Event		**Frequency**
Level transmitter, LT TK-104, fails to detect high level	EQP	1×10^{-1}
Enablers (regular, at-risk factors, and conditional modifiers)		**Value**
Time in tank filling mode	ARF	1×10^{-1}
Lack of PM on level transmitter LT TK-104	REG	5
Probability of ignition	CM	1×10^{-1}
Probability of personnel in affected area		1
Probability of harm from exposure		1
Independent Protection Layers		**PFD**
High level shutoff for tank, TK-104	SIF	1×10^{-2}
Operator action to stop pump, P-100	HUM	1×10^{-1}
Safeguards (non-IPL)		
Public evacuation	HUM	

RISK BREAKDOWN FOR PROCESS

Risk Summations

Process M...	Consequence Type	Consequence Level	Scenario Count	Frequency	Risk Tolerance	Risk Reduction Required	Risk Reduction Factor
Tank filling	EMP	1	4	7.2×10^{-5}	□ 1×10^{-3}	None	None
		2	4	1.8×10^{-5}	□ 1×10^{-2}	None	None
	PUB	1	4	7.2×10^{-5}	□ 1×10^{-5}	1.4×10^{-1}	7.2
Transfer	EMP	1	2	9.9×10^{-5}	□ 1×10^{-3}	None	None
		2	5	3.3×10^{-4}	□ 1×10^{-2}	None	None
	PUB	2	3	1.9×10^{-4}	□ 1×10^{-4}	5.3×10^{-1}	1.9

Risk Summations

Hazard T...	Consequence Type	Consequence Level	Scenario Count	Frequency	Risk Tolerance	Risk Reduction Required	Risk Reduction Factor
Fire	EMP	2	8	2.6×10^{-4}	□ 1×10^{-2}	None	None
Explosion	EMP	1	6	1.7×10^{-4}	□ 1×10^{-3}	None	None
		2	1	9×10^{-5}	□ 1×10^{-2}	None	None
	PUB	1	4	7.2×10^{-5}	□ 1×10^{-5}	1.4×10^{-1}	7.2
		2	3	1.9×10^{-4}	□ 1×10^{-4}	5.3×10^{-1}	1.9

Risk Summations

Process...	Hazard...	Consequence Type	Consequence Level	Scenario Co...	Frequency	Risk Tolerance	Risk Reduction Required	Risk Reduction Factor
Tank filling	Fire	EMP	2	4	1.8×10^{-5}	□ 1×10^{-2}	None	None
	Explosion	EMP	1	4	7.2×10^{-5}	□ 1×10^{-3}	None	None
		PUB	1	4	7.2×10^{-5}	□ 1×10^{-5}	1.4×10^{-1}	7.2
Transfer	Fire	EMP	2	4	2.4×10^{-4}	□ 1×10^{-2}	None	None
	Explosion	EMP	1	2	9.9×10^{-5}	□ 1×10^{-3}	None	None
			2	1	9×10^{-5}	□ 1×10^{-2}	None	None
		PUB	2	3	1.9×10^{-4}	□ 1×10^{-4}	5.3×10^{-1}	1.9

CONCLUSIONS

- Various issues affect the use of LOPA for SIL determination
- A procedure was described that addresses the issues
  - Uses a risk model that allows the estimation of the risks posed to receptors by:
    - Overall facility
    - Contributions from processes, units and operating modes

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