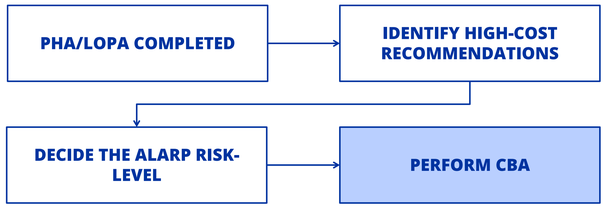
COST BENEFIT ANALYSIS TO WIELD OR TO YIELD THIS DOUBLE-EDGED SWORD

PRACTICAL APPROACH



GUIDELINES AND CONSIDERATIONS

CBA cannot be used to argue against implementing a relevant good practice: CBA cannot be used to argue against the implementation of relevant good practice, unless the alternative measures are demonstrated unequivocally to be at least as effective as statutory duties

CBA cannot be used to justify risks that are intolerable: CBA can help make an informed choice between risk reduction options and not replace or undermine safeguards. The depth of analysis should be fit for purpose, i.e., more rigour is required where the risk is higher or the consequences themselves are great (e.g., multiple fatalities).

CBA cannot be used to argue against statutory duties: CBA cannot substitute compliance requirements with safety regulations

CBA cannot be used to justify what is evidently poor engineering: CBA is not recommended when the engineering of a process or mechanical assembly is questionable wherein the combination of discrete hazards cannot be foreseen and the decision-making process on risk reduction action is less straightforward, mostly unreliable.

SENSITIVITY

Sensitivity Analysis for CBA Variable - Cost of Accident (C_{ACC})	D	C_{ACC}	F_{WOUT}	F_{WITH}	C_{AS}	T	B	CBA	CBA Calculation outcome
	5	550,000	0.001	0.0001	100,000	25	12,375	-38,125	Benefit is grossly disproportionate to the cost of consequence. No other alternative is identified.

A sensitivity analysis assesses the robustness of the outcomes of the CBA. The more robust are the results of a CBA, the more suitable it is as a tool for ALARP decisions.
Sensitivity Analysis utilizes multiple handles or variables, systematically changing one variable at a time (keeping the others constant) to see swings in outcome that are the most sensitive and critical to get right.

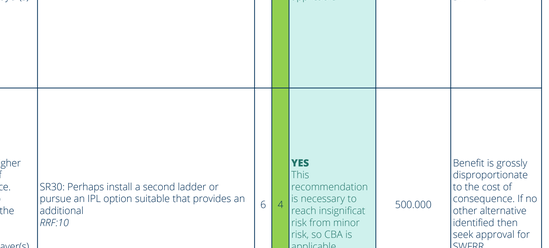
For this particular project below are the handles used and the basis of selecting the variables and constants:

Handle#	Description	Variable/Constant	Basis of selecting Variables and Constants
1	Initiating Event Frequency	Constant	They are consistent as they follow LOPA Standard
2	**Cost of Accident (C_{ACC})**	Variable	Critical variable - most sensitive and critical to get right.
3	Cost of implementing additional safeguards (C_{AS})	Constant	They are estimated at reasonable accuracy for this stage of the project.

C_{ACC} Var.Interval 10%

B	Variance C_{ACC} (%)	CBA Sens		C_{ACC}($)
11137.5	90%	-44313		495000
12375	100%	-38125	Baseline C_{ACC}	550000
13612.5	110%	-31938		605000
14850	120%	-25750		660000
16087.5	130%	-19563		715000
17325	140%	-13375		770000
18562.5	150%	-7187.5		825000
19800	160%	-1000		880000
21037.5	170%	5187.5		935000
22275	180%	11375		990000
23512.5	190%	17562.5		1045000
24750	200%	23750		1100000
25987.5	210%	29937.5		1155000
27225	220%	36125		1210000
28462.5	230%	42312.5		1265000
29700	240%	48500		1320000
30937.5	250%	54687.5		1375000
32175	260%	60875		1430000
33412.5	270%	67062.5		1485000
34650	280%	73250		1540000
20000	162%	-1E-10		888889

Crossover CC%



PRECURSORS TO CBA AND COMPONENTS

Data Collection	Scenario (Re)Evaluation	Validating ECs and CMs	Recs re-definition
Identification of key Recs Recognize ALARP risk level required Cost estimation data available	Throuroughly (re)evaluating hazard Validating IEs, Safeguards as IPLs and Risk Scoring	Validating accuracy of ECs/CMs Re-scoring mitigated frequencies	Re-defining Recs to match ALARP risk level De-scoping Recs where CBA is not applicable

C_{AAC}	Cost of accident	*Consequence level and its associated monetary equivalent value*
C_{AS}	Cost of Additional Safeguards	*Monetary value/cost of implementing additional Safeguards*
T	Life of Protection	*Estimated service life of proposted mitigations*
D	Disproportion Factor	*Factors for a given risk (Higher the risk, higher the degree of disproportion)*
F_{WOUT}/F_{WITH}	Frequency Comparison	*Frequency without Safeguards / Frequency with additional Safeguards*

PITFALLS

Valuing intangibles and the uncertainty in forecasting: Assigning monetary values to aspects such as health, safety, or environmental quality proves difficult and subjective. Additionally, forecasting future costs and benefits is prone to error due to unpredictable technological changes, market shifts, and inflation, often leading to incomplete or misleading analyses.

Bias and manipulation: Practitioners may unintentionally or deliberately understate costs and overstate benefits to favour a project. Short timeframes can obscure long-term impacts, and mistakes like double-counting benefits can distort results.

Overuse/Misuse of ECs/CMs: In organisations with very conservative risk criteria, analysts may excessively rely on CMs and ECs to artificially lower risk scores.

CASE STUDY

ID	Plant	Scenario	Consequences	M	S	UL	UR	Safeguards	ML	MR	Recommendation	PL	PR	Justification for CM Applicability	ML1	MR1	Recommendation (Level 1)	PL1	PR1	CBA Req. based on RR	Cost MMUSD (+/-40%)	CBA Outcome (Implement / Sign SWFRR)	Recommendation (Level 2)	PL2	PR2	CBA Req. based on RR	Cost MMUSD (+/-40%)	CBA Outcome (Implement / Sign SWFRR)
39	UTY	Failure of the BV in TK-3811 not breaking vacuum created in a tank during the pump out of the tank leading to low pressure in the tank and loss of containment	Collapse of the tank resulting in release of hydrochloric acid to the surrounding area causing personnel burn injury and possible lost workday	I	3		2	Note: BV is replaced within 8 hours when taken out for maintenance and spare is installed. *IPL Type: Non-IPL: Not tested/documented* Breather valve for TK-3811, (Note: BV-3811 is 4" in size and bigger than other hydrochloric acid tanks) *IPL Type: Non-IPL: Not capable/big enough* Typical safeguards for loss of containment (see Table C.2) PM of the breather valves BV-3811 every 3 years as per existing strategy *IPL Type: Non-IPL: Not tested/documented* The pressure of the tank (TK-3811) is not equalized with the pressure of the other hydrochloric acid tanks. No additional relief is available *IPL Type: Non-IPL: Not capable/big enough*	3	2	S 16. Require respirators as part of the PPE for hydrochloric acid unloading SOP and other SOPs and for maintenance activities (SMPs) in the area. Confirm with the industrial hygeine specialist for the exact cartridge type. *RRF: 10* S 17. Install a PV or a second BV to break the vacuum. PII recommends to accept the risk as per the industry practice instead of implementing this recommendation. *RRF: 10* S 22. The dikes, pits, trenches, and culverts that are in contact with hydrochloric acid or caustic are periodically inspected by the civil engineer but the actions are not being followed through. Develop a management system with enforcment to ensure follow through on any repairs and correction of any findings. *RRF: 10*	4	3	**Probability of Vessel Rupture (Pvr) = 1** (low pressure during pump out below the design presure on vacuuum) **Probability of ignition (Pi) = NA** (not fire scenario) **Probability of Personnel Fatality (Pf) = 1** (since it is part of the consequence severity selection) **Probability of a Hazardous Atmosphere (Pha) = NA** (since it is part of the consequence severity selection) **Probability of Personnel Presence (Pp) = 1** (Many alarms will draw workers into area; but the event happens so quickly, the operators will not have time to enter the hazardous area.) **Time at Risk (Ptr) = NA** (not applicable since nothing is unique to a mode of operation) **Campaign Enabling (Pc) = NA** (same as Ptr. Since no change in raw materials (chemicals, concentrations, rates, quantities), catalysts, final products, operating conditions and/or process configuration (e.g., recycle vs. non-recycle mode of operation), and these differences do not result in non-uniform risk	3	2	S 17. Install a PV or a second BV to break the vacuum. *RRF: 10*	4	3	**NO** This recommendation is necessary to reach minor risk, so CBA is not applicable	1.500.000	Benefit is grossly disproportionate to the cost of consequence. If no other alternative identified then seek approval for SWFRR	S 16. Require respirators as part of the PPE for hydrochloric acid unloading SOP and other SOPs and for maintenance activities (SMPs) in the area. Confirm with the industrial hygeine specialist for the exact cartridge type. *RRF: 10* OR S 22. The dikes, pits, trenches, and culverts that are in contact with hydrochloric acid or caustic are periodically inspected by the civil engineer but the actions are not being followed through. Develop a management system with enforcment to ensure follow through on any repairs and correction of any findings. *RRF: 10*	5	4	**YES** This recommendation is necessary to reach insignificat risk from minor risk, so CBA is applicable	100.000	Benefit is grossly disproportionate to the cost of consequence. If no other alternative identified then seek approval for SWFRR.
41C 42C	UTY	High pressure and Temperature due to Wrong chemical tanker (such as HCl) connected and unloaded in NaOH tank leading to loss of containment	Rupture of the tank and the vent tank due to chemical reaction and high pressure resulting in exposure of personnel to caustic with potential for mulitple injuries or fatality	I	2	2	1	Goose neck vent to atmosphere *IPL Type: Non-IPL: Not capable/big enough* Typical safeguards for loss of containment (see Table C.2) Sampling of the material (in a glass bottle that can visually confirm the material) in the truck and verify COA and awaitng the result (as sometimes the quality of the material is not on-spec) before connecting the tanker and unloading *IPL Type: Human response* *PFOD: 1E-1* Caustic truck comes with its own hose, while hydrochloric acid hoses are supplied by the plant *IPL Type: Non-IPL: Not independent*	3	2	S 19. Install a bigger relief system such as a Relief hatch on all the hydrochloric acid Tanks (TK-811/1811/3811) and for the caustic tanks (TK-810/3810) manways or any alternate design to relieve the sudden surge of pressure. *RRF: 100* S 20. Add a procedure step where operator vents the pump suction before pumping is started that would help him notice is any caustic is reacting with the acid between the pump suction valve and the pump, to warn that caustic is being pumped into the acid tank. *RRF: 10* S 21. Provide an alternate confirmation for the chemical to be unloaded that utilizes the QR code of the SDS on the truck and checks it against the QR code on the flange before hooking up the truck to the flange/hose. *RRF: 10* S 22. The dikes, pits, trenches, and culverts that are in contact with hydrochloric acid or caustic are periodically inspected by the civil engineer but the actions are not being followed through. Develop a management system with enforcment to ensure follow through on any repairs and correction of any findings. *RRF: 10*	6	4	**Probability of Vessel Rupture (Pvr) = 1** (pressure can exceed 2x DP in case of wrong chemical unloaded) **Probability of ignition (Pi) = NA** (not fire scenario) **Probability of Personnel Fatality (Pf) = 1** (since it is part of the consequence severity selection) **Probability of a Hazardous Atmosphere (Pha) = NA** (since it is part of the consequence severity selection) **Probability of Personnel Presence (Pp) = 1** (Many alarms will draw workers into area; but the event happens so quickly, the operators will not have time to enter the hazardous area.) **Time at Risk (Ptr) = NA** (not applicable since nothing is unique to a mode of operation) **Campaign Enabling (Pc) = NA** (same as Ptr. Since no change in raw materials (chemicals, concentrations, rates, quantities), catalysts, final products, operating conditions and/or process configuration (e.g., recycle vs. non-recycle mode of operation), and these differences do not result in non-uniform risk	3	2	SR 29. Add a procedure step where operator vents the pump suction before pumping is started that would help him notice if any acid is reacting with the caustic between the pump suction valve and the pump, to warn that acid is being pumped into the acid tank. *RRF: 10* S 21. Provide an alternate confirmation for the chemical to be unloaded that utilizes the QR code of the SDS on the truck and checks it against the QR code on the flange before hooking up the truck to the flange/hose. *RRF: 10*	5	3	**NO** This recommendation is necessary to reach minor risk, so CBA is not applicable	10.000	Benefit is higher than cost of consequence. Consider to implement the proposed additional protection layer(s)	S 19. Install a bigger relief system such as a Relief hatch on all the hydrochloric acid Tanks (TK-811/1811/3811) and for the caustic tanks (TK-810/3810) manways or any alternate design to relieve the sudden surge of pressure. *RRF: 100*	7	4	**YES** This recommendation is necessary to reach insignificat risk from minor risk, so CBA is applicable	1.500.000	Benefit is grossly disproportionate to the cost of consequence. If no other alternative identified then seek approval for SWFRR.
44A	UTY	Person falls in the SW inlet pit chamber or discharge pit due to Fatigue or tripping on rough surface leading to possible drowning	Possible drowning	I	2	3	2	Guard rail with toe boards IPL Type: Movement-limiting device, adjustable PFOD: 1E-1	4	2	S 28. Install a ladder in the SW pit chamber after the screen and in SW return pit, as an emergency escape feature (similar to the ladders available in the intake pit). *RRF: 10*	5	3	**Probability of Vessel Rupture (Pvr) = NA** (not a high pressure/loss of containment scenario) **Probability of ignition (Pi) = NA** (not fire scenario) **Probability of Personnel Fatality (Pf) = 1** (since it is part of the consequence severity selection) **Probability of a Hazardous Atmosphere (Pha) = NA** (since it is part of the consequence severity selection) **Probability of Personnel Presence (Pp) = 1** (Many alarms will draw workers into area; but the event happens so quickly, the operators will not have time to enter the hazardous area.) **Time at Risk (Ptr) = NA** (not applicable since nothing is unique to a mode of operation) **Campaign Enabling (Pc) = NA** (same as Ptr. Since no change in raw materials (chemicals, concentrations, rates, quantities), catalysts, final products, operating conditions and/or process configuration (e.g., recycle vs. non-recycle mode of operation), and these differences do not result in non-uniform risk	4	2	S 28. Install a ladder in the SW pit chamber after the screen and in SW return pit, as an emergency escape feature (similar to the ladders available in the intake pit). *RRF: 10*	5	3	**NO** This recommendation is necessary to reach minor risk, so CBA is not applicable	500.000	Benefit is higher than cost of consequence. Consider to implement the proposed additional protection layer(s)	SR30: Perhaps install a second ladder or pursue an IPL option suitable that provides an additional *RRF:10*	6	4	**YES** This recommendation is necessary to reach insignificat risk from minor risk, so CBA is applicable	500.000	Benefit is grossly disproportionate to the cost of consequence. If no other alternative identified then seek approval for SWFRR.

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