MARY KAY O'CONNOR PROCESS SAFETY CENTER
TEXAS A&M ENGINEERING EXPERIMENT STATION

20th Annual International Symposium
October 24-26, 2017 • College Station, Texas

Cost-Based Analysis for Risk Reduction

Donald DuPont
Jacobs Engineering
Houston, Texas 77052-3495 USA
donald.dupont@jacobs.com

Abstract

Owner/Operators are inundated with recommendations generated from various hazard identification and risk assessment studies. While there are a plethora of qualified engineering firms, consultants, and in-house specialists that produce lists of executable action items, there is very little guidance provided to owners to aid in the prioritization and allocation of scarce resources to meet the performance requirements of the company's process safety policy.
The Occupational Safety and Health Administration (OSHA), through its Process Safety Management (PSM) standard (29 CFR 1910.119), has requirements regarding the tracking, closure, and documentation of recommendations from PHAs, PSSRs, incident investigations, MOCs, and compliance audits. However, the PSM standard is a performance-based standard; therefore, there is no specific language regarding prioritization and implementation of resolutions. The Center for Chemical Process Safety (CCPS) has published literature such as "Tools for Making Acute Risk Decisions with Chemical Process Safety Applications." This document provides tools that aid in the application of a consistent and logically sound approach to ensure that appropriate resources are made available and effectively allocated to risk reduction activities. Yet this guidance falls short of providing a workable process to answer the question, "now that I have this long list of things that needs to be done, what do I do with it?"

This paper will present a practical approach for managing risks using a cost-based evaluation to allocate economic resources to a practical risk reduction program.

Keywords

Cost basis, process safety site assessment.

Introduction

Organizations are improving in their understanding and management of process related hazards and risks. They are training personnel internally or contracting with external entities to perform

studies that identify, evaluate and control hazards that affect personnel, the public, the environment, business assets and continuity, and their reputation. However, organizations continue to struggle with how to prioritize and allocate the appropriate time, money and other resources to invest towards reducing the impact and likelihood of those hazards propagating toward an undesired outcome.

Many organizations find success making decisions on risk reduction above and below two thresholds: one is the threshold above which risks are considered intolerable and therefore require immediate action, and the second is the threshold below which risks are considered tolerable and therefore the investment for further risk reduction is discretionary or not required. The difficulty arises between these two thresholds, where a multiplicity of other factors come into play which affects those risks which require further risk reduction.

The Center for Chemical Process Safety's (CCPS), *Tools for Making Acute Risk Decisions*, provides a cost-based, decision making approach, on the cost-benefit and cost-effectiveness of choosing alternative solutions to reduce risk. These approaches may be used by organizations where identified hazards extend beyond the property line and impact the public. The premise of these approaches are to estimate and evaluate the net benefits or impacts associated with risk reduction alternatives, incurring costs to the organization or the public, and creating a positive or negative effect from the project to the public; where those alternatives are measurably different in their implementation. The cost-benefit approach seeks to assign a dollar value to the available project implementation options.

Private organizations have found use in adopting these model for capital projects in densely populated areas where there may be mutual benefit to share costs with the public, promote the implementation of the project having sustainability outcomes, or make decisions that may delay or cancel the project based on reputational risks versus modest production gains. In either case, these models pose difficulty in its viability when considering the geographical location of many chemical facilities within industrial parks and isolated locations where some of these factors provide very little influence.

Companies need a repeatable process to prioritize capital and expense budgets to execute safety related projects that fall between the intolerable and tolerable thresholds in line with the expectations of the performance requirements of the process safety program. A practical approach to accomplish this goal is to:

- Implement tools and processes to manage all safety related activities from a single location
- Know your process safety performance target
- Identify systematic and management issues
- Have clear criteria for intolerable versus tolerable risks
- Categorize activities to achieve the greatest risk reduction with the smallest investment
- Provide a program level cost for the implementation of safety related activities
- Execute projects by prioritization

Hazard Register

A hazard register is an overview document that is useful for the compilation, categorization, assessment, and sorting of hazard scenarios. It plays an important role in knowing where risk reduction investment is required, by presenting management and those responsible for managing risks with a centralized location from which to make investment decisions.

It is important for this register to be actively updated and managed to include all hazard scenarios from all hazard and risk assessment studies performed in the facility. Table 1 is a fictional example of a hazard register for Company X that compiles multiple hazard and risk scenarios from various safety studies.

Table 1. Example Hazard Register

Id	Source Type	Document Reference	Hazard	Initiating Event	
				Cause	Type
HAZ-0001	HAZOP	20170001	Increased pressure in V101 (rated for 150 psig) up to the shut-in pressure of P101 (~170 psig) resulting in over-pressuring V101 with a LOPC of 150º hydrocarbon mixture to grade. Potential for personnel injury due to thermal burns. Or, health effect due to vaporization of a corrosive material. Or, environmental impact that can be remediated onsite.	Inadvertently leave the manual block valve in the closed position	Human error
LOP-0002	LOPA	201710005	Loss of inventory from V102 resulting in 400 psig gas blow-by into the downstream equipment/piping system (rated for 150 psig), leading to LOPC of hydrocarbon gas to atmosphere. Potential for ignition of flammable gas leading to personnel injury due to combustion products such as a fire event or blast wave. Or, health effect due to combustion products such as smoke, or toxic vapor generation. Or, environmental impact that may exceed the reportable quantity.	Malfunction causes LT101 to fully open	BPCS
BSS-0003	Building Siting Study	201710011	1.1 psig side-on pressure reached on the west and south of Building 100. Potential for personnel injury on the west of the building due to shattered glass, or flying objects on the south of the building due to unsecured objects on the walls and ceiling.	2” liquid release from flange/gasket at the top of R100 Note: site records show a history of leaks-*	Leak
SAF-0004	Safety Review	201710026	Inability to gauge high level in the tank resulting in hydrocarbon spillage via the overflow vent to grade. Potential for an environmental impact due to hydrocarbons entering the storm sewer transferring to the first flush system that can be remediated onsite.	Malfunction causes LT102 to read a false low	BPCS
AUD-0005	Compliance Audit	20170042	Pursuant to 1910.119(l)(2)(i), the MOC procedure was not followed which required a safety review prior to changing the specification for the gasket used on V100.	1910.119(l)(2)(i): The procedures shall assure that the following considerations are addressed prior to any change: The technical basis for the proposed change	MOC

Table 2. Example Risk Classification

Safety Consequence	Risk Classification	Operational Response
One or more fatalities (on or off-site)	Urgent	Requires plant manager's approval to continue operation; decision to remain in operation requires a solution within 6 months
Severe injury	High	Must be resolved within 12 months
Lost time from work	Medium	Must be resolved within 24 months
First aid	Low	Discretionary

Table 2 is a fictional example of the risk classification For Company X that provides guidance for prioritizing the completion of safety related recommendations. For the purposes of this paper, consequence severity is the sole criteria shown for simplicity. An action items report can be produced from the hazard register indicating the recommendation and the risk classification; see Table 3. The compilation of all hazard and risk scenarios in one location always for sorting and grouping recommendations that may have similar preventive or mitigative solutions.

Table 3. Example Action Tracking Log

Id	Recommendation	Risk	Assigned To	Due By	Resolution	Acceptance	Reference	Status
HAZ-0001	Add a new PT101 to annunciate in the DCS at a calculated set point on V101.	High	-	12 mon	-	-	-	-
LOP-0002	Close the RRF of #. One option for a non-instrumented means for risk reduction is to re-size the SV on the downstream piping system with a design case for gas blow-by.	Urgent	-	6 mon	-	-	-	-
BSS-0003	Remove loose pictures from the conference room on the south side of the building and replace the ceiling fixtures with appropriate supports to withstand the expected overpressure.	Low	-	-	-	-	-	-
SAF-0004	Add a new LT100 and modify the control logic to implement a deviation alarm with LT102 in the DCS.	Low	-	-	-	-	-	-
AUD-0005	Perform a safety review of the gasket specified for V100, and confirm the currently specified material or change the gasket as required.	Med	-	18 mon	-	-	-	-

Benchmarking

OSHA's Process Safety Management (PSM) Standard is intended to help prevent accidental releases of highly hazardous chemicals, thus protecting onsite personnel as well as neighboring plant personnel and the public. The PSM Standard is performance-based. Meaning, the implementation of the owner/operator's criteria for evaluating risk tolerance is used to judge the

program's effectiveness. The exact specifications are not spelled out, thereby giving a facility flexibility to design its own program to match its needs, if it meets the desired outcome of preventing or minimizing catastrophic releases of flammable, reactive, and toxic substances.

The flexibility granted to the owner/operator comes with great responsibility. Unlike specification-based OSHA standards that prescribe precise rules, such as Section 1910.23(e)(1) (Subpart D - Walking-Working Surfaces), which prescribes the height of guardrails, the PSM Standard expects owner/operators in the process industry to maintain safety programs in-line with current industry technology and practices applicable to their operating plants. Therefore, it behooves plant managers to continuously update their process safety targets in consideration of their peers and guidance issued by recognized regulatory agencies and national trade associations.

Periodically conducting a process safety site assessment is an excellent means to calibrate a site's process safety targets and meet the ongoing commitment to continuous process safety improvements. Process safety site assessments are not compliance audits. They do not focus on the evaluation of compliance with the elements of 29 CFR 1910.119. Rather, they focus on some of the tenants of CCPS' Risk Based Process Safety (RBPS) Management approach, described in the CCPS book *Guidelines for Risk Based Process Safety, 2007*. In particular, emphasis is placed on:

- Process Safety Culture and Leadership
- Process Safety Competence
- Hazard Identification and Risk Analysis
- Operating Procedures
- Safe Work Practices
- Asset Integrity and Reliability
- Management of Change (MOC)
- Measurement and Metrics
- Management Review and Continuous Improvement

A major outcome of the process safety site assessment is the identification of performance gaps in meeting the organization's risk tolerance criteria and systematic issues. Therefore, it is imperative the third-party vendor has accessors that are highly-qualified process safety professionals with access to a database of information of a cross-section of facilities in various segments of the process industry.

Performance Gaps

According to CCPS' *Guidelines for Implementing Process Safety Management*, a performance gap is normally an indication of a management system weakness. This means, the improvement of the process safety performance in those identified areas are within management's control. Table 6.2 list examples of an example PSM Assessment Protocol. An example assessment task under Operating Procedures are:

- Are employees satisfied with the completeness of process operating procedures?
- Are operating procedures clear and easy to understand?

- Do employees have an opportunity to make recommendations to update operating procedures when more efficient ways to operate are discovered?
- Are operating procedures laid out in checklist format?
- What systems are used for employees to access operating procedures?

A possible outcome of the assessment may result in a gap between the perception of the thoroughness and accuracy of operating procedures from management's point of view, and the actual applicability and effectiveness from the operator's point of view. This may be due a site implementing a corporate format that is too general for a specific site; an operating procedure written in narrative form for operators to complete multiple or complex procedural steps instead of in checklist format; perceived inability for operator's input; or a myriad of other root causes that should be compiled to identify systematic issues that can be better controlled by management.

Strategy for Implementing Maximum Risk Reduction

Once a process safety site assessment has been performed, and performance gaps identified, management is now in position to evaluate how to produce a strategy for maximum risk reduction. A qualified auditor may consider the performance gaps identified for operating procedures, with HAZ-0001, SAF-0004, and AUD-0005 shown in Table 1.

Many facilities may or may not utilize a hazard register or like compile all safety related activities. Those that don't, may have adequate processes to manage the completion of those activities, but those activities may be completed in isolation without the visibility to categorize activities across safety studies. Those that do utilize a hazard register or similar, and do not include a process safety assessment, may not have the visibility to identify systematic issues where those gaps closure can realize large preventive or mitigative benefits.

Considering HAZ-0001, the PHA team identified a high-pressure hazard that was evaluated to produce a LOC resulting in a severe injury. The controls were deemed inadequate and an action item was proposed to add new instrumentation to alert operators of the change in process dynamics to take an action to keep the process back in a safe state. Considering SAF-0004, the PHA team identified a high-level hazard that was evaluated to produce a LOC resulting in a first aid injury. The controls were deemed inadequate and an action item was proposed to also add new instrumentation to alert operators of potentially faulty equipment to take an action to prevent spillage. Considering AUD-0005, an audit identified a failure to follow the current procedures to MOC all changes that affects the PSI. An action item was proposed to perform a safety review, as required by the MOC procedure, to ensure the installed gasket is a replacement-in-kind.

The example process safety site assessment produced a performance gap in the management of operating procedures. A more detailed analysis derived from interviews with management and operators may have produced further insight into the management practices such as:

1. Lack of leadership in emphasizing the use of procedures to include operating procedures, maintenance procedures, MOC procedures, etc.
2. Lack of initial and refresher training on the use of procedures.
3. Lack of access by employees and contractors to pertinent procedures.

4. Lack of employee participation in the writing of procedures.

Providing a resolution to the management deficiency may address the root causes of HAZ-0001, SAF-0004, and AUD-0005. In this example, having a checklist for the procedural steps may better equip the operator to properly align the valves. With this update in the procedure, the PHA team may deem this control along with other controls to be adequate, thusly, eliminating the need for a new pressure transmitter. Based on the residency time of the tank, updating the operator procedure to use a checklist during operator rounds, and having the operator visually inspect the gauge may eliminate the new level transmitter. The team may evaluate this as an effective control if there is more confidence in the use of the checklist and the training the operator receives in performing the inspection. Lastly, having continual communication from management with consequences for non-conformance, the findings for non-compliance may be eliminated because employees will be well versed on the requirements for evaluating RIK versus NRIK.

This may change to recommendations produced in Table 3 from:

1. Add a new PT101 to annunciate in the DCS at a calculated set point on V101 [new control loop added in the DCS].
2. Close the RRF of #. One option for a non-instrumented means for risk reduction is to re-size the SV on the downstream piping system with a design case for gas blow-by [new pressure safety valve(s)].
3. Remove loose pictures from the conference room on the south side of the building and replace the ceiling fixtures with appropriate supports to withstand the expected overpressure [miscellaneous items].
4. Add a new LT100 and modify the control logic to implement a deviation alarm with LT102 in the DCS [new control loop added in the DCS].
5. Perform a safety review of the gasket specified for V100, and confirm the currently specified material or change the gasket as required [administrative action].

To:

1. Produce plan to improve the process safety performance for the training, use, and management of plant procedures [administrative action].
2. Close the RRF of #. One option for a non-instrumented means for risk reduction is to re-size the SV on the downstream piping system with a design case for gas blow-by [new pressure safety valve(s)].
3. Remove loose pictures from the conference room on the south side of the building and replace the ceiling fixtures with appropriate supports to withstand the expected overpressure [miscellaneous items].

The cost reduction and planning of these activities can lead to a measurable difference in the allocation of resources to achieve the maximum risk reduction.

Implementation

Table 4 shows the updated action items after completion of the process safety site assessment (PSSA). Action Id PSS-0001 becomes a high risk because it replaces the previous HAZ-0001, SAF-0004, and AUD-0005 shown in Table 1. HAZ-0001 was a high risk.

Table 4. Example Action Tracking Log Update after PSSA

Id	Recommendation	Risk	Assigned To	Due By	Resolution	Acceptance	Reference	Status
PSS-0001	Produce plan to improve the process safety performance for the training, use, and management of plant procedures	High	-	12 mon	-	-	-	-
LOP-0002	Close the RRF of #. One option for a non-instrumented means for risk reduction is to re-size the SV on the downstream piping system with a design case for gas blow-by.	Urgent	-	6 mon	-	-	-	-
BSS-0003	Remove loose pictures from the conference room on the south side of the building and replace the ceiling fixtures with appropriate supports to withstand the expected overpressure.	Low	-	-	-	-	-	-

Table 2 identifies LOP-0002 as an urgent risk which is above the tolerable threshold for Company X and must be resolved in 6 months. Once the SIL Determination study is complete to determine if the option to upsize the PSV is viable, or a SIF with the appropriate SIL rating is required, this action can be prioritized for immediate completion. Companies typically allocate funding for safety related projects above the tolerable threshold which may severely impact personnel safety, the environment or business continuity. Table 2 identifies BSS-0003 as a low risk which is below the tolerable threshold for Company X and may be de-prioritized or resolved as not required for further risk reduction. Table 2 identifies PSS-0001 as a high risk which falls between the intolerable and tolerable thresholds. If there were multiple actions that were classified between intolerable and tolerable, it would be very important for the owner to have an active plan for executing these projects within the corporate timeline for completion, or to provide to regulatory agencies should the timeline of completion need to be extended.

A practical approach is to provide a cost basis with a plan of execution that considers all factors involved with the completion of each action. Table 5 shows an example of accepted resolutions for prioritization and implementation.

Table 5. Implementation Plan for Safety Related Action Items

Id	Recommendation	Risk	Resolution	Cost	Duration	Notes
PSS-0001	Produce plan to improve the process safety performance for the training, use, and management of plant procedures	High	Produce a plan to provide to provide: - leadership training for senior management - gap analysis report with recommendations	$$	XX	-
LOP-0002	Close the RRF of #. One option for a non-instrumented means for risk reduction is to re-size the SV on the downstream piping system with a design case for gas blow-by.	Urgent	Add a SIL 2 rated SIF in the SIS to isolate the bottoms transfer line on low level in the V102.	$$	XX	-
BSS-0003	Remove loose pictures from the conference room on the south side of the building and replace the ceiling fixtures with appropriate supports to withstand the expected overpressure.	Low	Relocate all pictures from the south side of the conference room to the north side of the conference and an administrative control to prohibit loose objects from hanging on the wall.	$$	XX	-
			Install ceiling supports for each of the ceiling fixtures in the conference room to withstand the predicted overpressure.	$$	XX	-

The development of an implementation plan with allocated costs, durations, and other specifics about the execution of work, allows the owner to evaluate how and when projects should be executed based on capital and expense budgets, timing with turn-around schedules, impact to regulatory expectations and commitments, and communication with stakeholders. This requires a third-party vendor with vast experience not only in performing process safety activities, but experience with procurement, commissioning and construction to provide this information expediently and accurately.

Conclusions

Many companies are faced with the daunting task of managing a large collection of process safety action items that are often recorded and maintained in different files that may or may not be compatible. Their existing staffs are stretched and may be ill-equipped to meet their intended process safety performance targets. They have ample access to third-party vendors that can effectively identify and evaluate hazards and assess the risks associated with those hazards, but they often lack the ability to help companies produce meaningful implementation plans that assist companies with the operating within capital and expense budgets and in accordance with the expectations of regulatory agencies and their stakeholders.

A practical process is:

1. Compile all safety related scenarios in one location for visibility for complete evaluation.
2. Perform a process safety site assessment to benchmark the company's process safety performance against industry peers to provide the company with the best data to establish their process safety performance targets.
3. Identify performance gaps in meeting the organization's risk tolerance criteria.
4. Categorize the actions listed in the hazard register to take advantage of improvements to the performance of management systems.

5. Update the action list to show the reduction of actions that addressed the “symptoms”, replaced with actions that address the root cause.
6. Segregate intolerable risks for immediate action and tolerable risk for de-prioritization.
7. Provide a cost basis with duration and specific requirements for all risks. Focus on the prioritization of risks that fall between intolerable and tolerable.
8. Work with the company to develop an implementation plan that can be presented to stakeholders and regulatory agencies, and provide a road map for the successful completion of safety activities.

References

[1] OSHA’s Process Safety Management (PSM) Regulation is focused on minimizing the risk posed to employees within the fence line from the presence of extremely hazardous substances. (29CFR1910.119).

[2] CCPS Concept Book, Guidelines for Risk Based Process Safety, 2007.

[3] CCPS Concept Book, Guidelines for Implementing Process Safety Management, 2016.

[4] CCPS Concept Book, Tools for Making Acute Risk Decisions (1995), 1995.