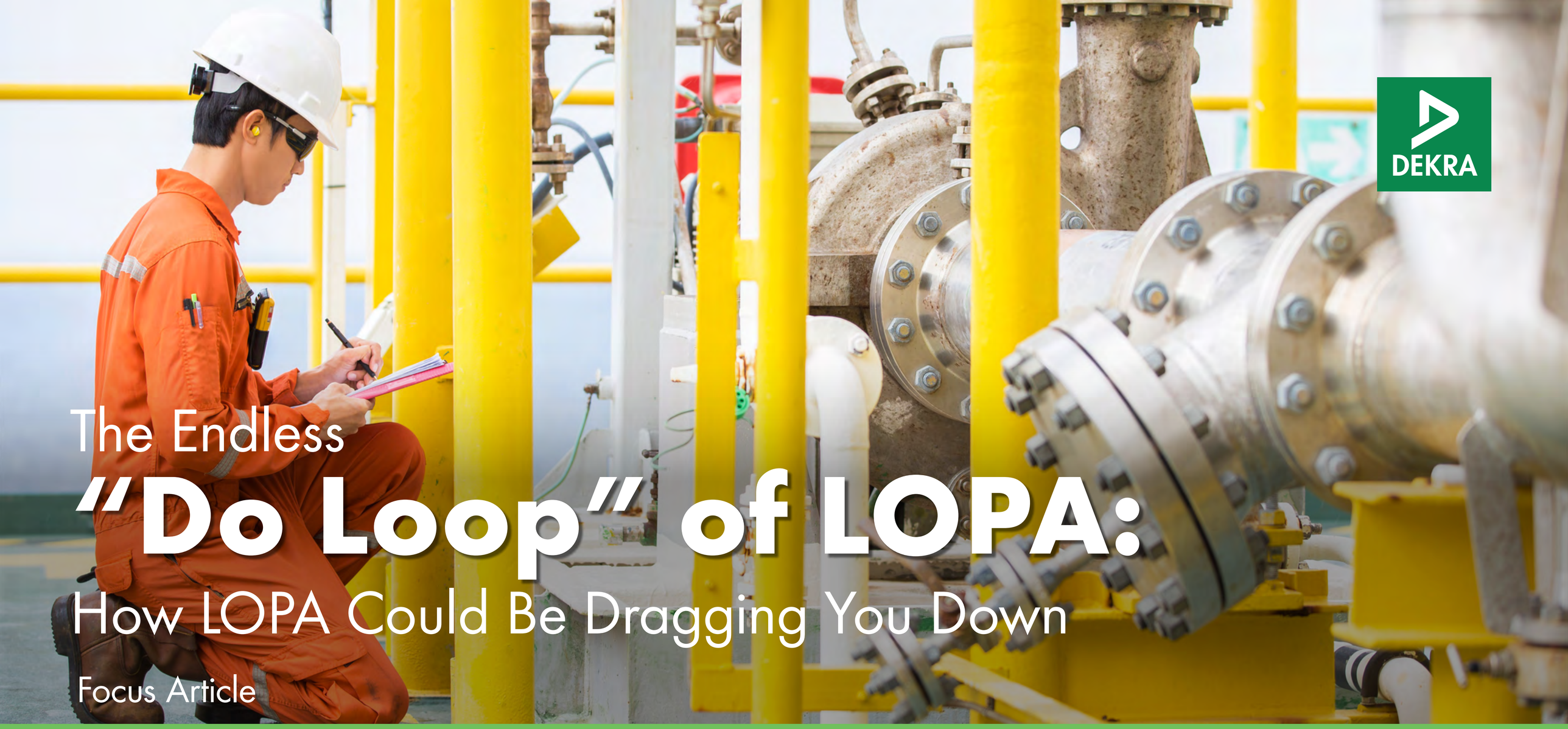

The Endless

"Do Loop" of LOPA:

How LOPA Could Be Dragging You Down

Focus Article

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Layer of Protection Analysis (LOPA) provides a method for conservatively estimating the frequency at which an Initiating Event (cause) will occur and the probability that one or more Independent Protection Layers (safeguards) will fail to prevent the consequence. By mathematically combining this information, we can determine a calculated estimate of the frequency at which the consequence might occur.

Precursors to LOPA filled several needs. They provided an objective alternative to qualitative assessments, where consensus could not always be reached among Hazard Study team members. In many cases, they could simplify a complex scenario, revealing a linear path from the initiating event to the consequence, with the safeguards aligned between the two. Other uses included a method of classifying Safety Instrumented Functions to determine the required Safety Integrity Level and assisting with the identification of safety-critical equipment.

LOPA Origin

The concept of a LOPA-type assessment originated in the late 1980s through the early 1990s. The Responsible Care® Process Safety Code of Management Practices required that a sufficient number of layers of protection be provided to prevent catastrophic incidents. CCPS Guidelines for Safe Automation of Chemical Processes suggested a risk-based method for determining Safety Integrity Levels. Throughout the 1990s, individual companies developed their own interpretations of and methods for performing LOPA-style assessments. By the end of the decade, the need for unified guidance for conducting these types of assessments was apparent.

CCPS' Layer of Protection Analysis

In 2001, the Center for Chemical Process Safety (CCPS) published Layer of Protection Analysis. This book describes the consensus of several companies using similar internal methods to perform LOPA. The LOPA method was designed to provide conservative estimates of consequence frequency. Used correctly, LOPA provides estimates that are less conservative than a qualitative assessment but more conservative than a Quantitative Risk Assessment (QRA). To this end, the book contains strict rules for developing a scenario, ensuring the independence of protection layers (hence the name "Independent Protection Layers") and properly determining the Probability of Failure on Demand (PFD) of the protection layers.

Overview of LOPA

To provide a somewhat conservative result, LOPA uses order-of-magnitude estimates of the frequency of initiating events and the PFD of Independent Protection Layers. Frequencies and probabilities that would be used in a QRA are effectively rounded up to the next order of magnitude. Initiating event frequencies and IPL PFDs are, typically, standardized across a company.

Scenarios for LOPA are, typically, taken from a process-hazard analysis. The causes identified in these studies are used as the basis for initiating events, while identified safeguards are used as candidates for independent protection layers. The causes may need to be refined to form appropriate initiating events. Typically, only a subset of safeguards qualifies as IPLs. To qualify as an IPL, a safeguard must be (1) effective in preventing the consequence, when it alone functions as designed, (2) independent of both the initiating event and the components of any other IPL already claimed for the same scenario, and (3) auditable, in that the assumed effectiveness in terms of consequence prevention and PFD must be capable of validation in some manner (e.g., documentation, review, testing).

In 2015, CCPS published Guidelines for Initiating Events and Independent Protection Layers in Layer of Protection Analysis. This book provides, for 23 different types of initiating events, the generic initiating event frequency (IEF), the required conditions for using it, special considerations, and methods for validating the IEF. For IPLs, the book provides guidance on the use of 49 different IPLs. Similarly, for each IPL, the book provides the suggested generic PFD, special considerations, and assumptions for each. Additionally, activities such as inspections, tests, and preventive maintenance, which should be performed to avoid degradation of the PFD, are listed.

The probability of other events and conditions can be included in the LOPA calculation, such as:

- Enabling Conditions
  - Time at risk, where a process is not continuously operating
  - Campaign-Enabling Conditions – Similar to time at risk, the portion of time during a process that the initiating event would result in the stated consequence.
- Conditional Modifiers
  - Probability that a person is exposed to a hazard
  - Probability that an event results in a hazardous atmosphere (e.g., whether a spill will produce hazardous airborne concentrations of the material)
  - Probability of ignition
  - Probability that the consequence results in an injury or fatality

To ensure that these are used properly, CCPS published Guidelines for Enabling Conditions and Conditional Modifiers in Layer of Protection Analysis. This book provides guidance on determining the probability of occurrence for the enabling conditions and conditional modifiers, when they should (and should not) be used, and how to document and validate them.

Limitations of LOPA

Like any other tool, there are limitations to when LOPA can be relied upon to provide the desired results. These include:

- LOPA is limited to evaluating only one cause-consequence pair at a time. For every cause-consequence pair subjected to LOPA, a separate LOPA must be conducted.
- The result of a LOPA is not a precise measurement of risk or frequency. It is an approximation of the risk. This is also true in a QRA, where more precise frequencies and probabilities are used.
- LOPA should not be used for all scenarios. For some, a qualitative assessment of risk is sufficient, given the complexity and severity. For others, it may be overly simplistic.
- LOPA requires more time and effort (expense) than a qualitative risk assessment. It is worth the extra investment only if it provides a significant improvement in decision-making related to risk. For simple decisions, the value of LOPA is minimal.
- LOPA is not intended to identify hazards. The events subjected to a LOPA must be identified by some other method.
- Comparison of Risk Between Scenarios – This can be done only if the same LOPA method is used. Assumptions, frequencies, and probabilities must be consistent between the analyses.

Conducting LOPA

Layer of Protection Analysis suggests that LOPA can be conducted by a team or a single analyst, with periodic input from others. An operations representative and controls engineer frequently have information that is critical to LOPA. It also states that the LOPAs can be performed during or after a PHA. When performed during a PHA, a LOPA analyst must participate in the PHA and be adept at documenting the analysis to not excessively slow down or distract the team from the PHA process.

Where We May Have Gone Astray

A variety of LOPA practices can be found in industry today. Many companies are applying these tools correctly in their risk assessments and using the results to make better risk-based decisions; however, some poor habits have formed over the years when utilizing LOPA. These practices include policies that do not capitalize on the standard tools and tables of LOPA literature, programs that depend too heavily on LOPA as a tool and the results it provides, and practices that result in misapplying LOPA altogether.

Because of this, many companies have reached the point of diminishing returns when using LOPA, which has resulted in overly complicated, inefficient, and less-valuable risk assessments.

Stop Being so Hard on Yourself

LOPA base-ten methodology was deliberately designed for simplicity and ease of use; however, when company-specific policies differ from CCPS standard resources, LOPA may become needlessly complicated. This is especially true for companies that lack a LOPA guidance document altogether or when the guidance lacks consistency and standardization of Initiating Event Frequencies (IEF), Probabilities of Failure on Demand, Conditional Modifiers, and Enabling Conditions.

LOPA is dependent on standardized inputs. Without well-developed reference tables documenting assumptions, frequencies, and probabilities, the accuracy and consistency of the analysis will be questionable.

Some companies have developed overly complex macro-enabled spreadsheets to aid in their analysis when simple tools would easily suffice. These complex spreadsheets may also hurt the transparency of the process.

Apply the Resources Elsewhere

Conducting any risk assessment requires a serious time commitment from all contributing team members. Adding LOPA requirements to a PHA can add days to the duration of the PHA, degrading the team's ability to focus and perform. It is important that it adds value.

Like any risk assessment, inefficiencies can be caused by insufficient pre-work. More specifically, if cause-consequence pairs are not fully developed, safeguard independence is unknown or undocumented (e.g., interlock lists), or reference tables are not readily available for the team's use, the team will face significant delays.

Unlike some forms of risk assessment, specifically HAZOP and What If, LOPA does not require the diverse team necessary for brainstorming cause-consequence pairs,

consequences, etc. Where the LOPA team consists of the full PHA team, plus a LOPA analyst, the team may either get bogged down or some members will have little information to provide.

Another reason a team may be held back is that they default to using LOPA when a more appropriate tool is available. For example, if the residual risk is particularly sensitive to human actions, a human reliability analysis may be a better approach. If the risk is more dependent on the spread of a vapor cloud than on a conditional modifier or initiating event, tools such as DOW's Chemical Exposure Index or dispersion modeling may be a better choice.

For All the Wrong Reasons

Most companies tend to go through phases of using LOPA. Companies new to LOPA start slow, using it for only a few scenarios. Once comfortable with its use, they apply it to an increasing number of scenarios ("if a little is good, more is better" principle). Some companies eventually realize that many of the LOPAs they conduct do not provide additional value.

LOPA is often misapplied to scenarios in which a reasonable qualitative assessment can be made for non-complex scenarios or when the consequences are not significant enough to warrant it. When a company's threshold for conducting LOPA is too low, a team may find itself applying LOPA to a very large portion of the cause-consequence pairs in its assessment. This may result in spending too much time on LOPA, when their time would have been better spent in a qualitative assessment, brainstorming new causes, or focusing on other plant risks.

Another trap companies can find themselves in is selecting scenarios for LOPA based on overall risk ranking instead of on the scenario severity. This can misguide efforts to focus on high-frequency low severity scenarios, for which LOPA will add very little value. Layer of Protection Analysis offers the following suggestions on when to use LOPA:

- When the PHA team believes that:
  - A scenario is too complex for the team to make a reasonable risk judgment using purely qualitative judgment
  - The consequences are too severe to rely solely on qualitative risk judgment

Scenarios that are too complex for a qualitative analysis might include those in which the PHA team believes that they:

- Do not understand the initiating event well enough
- Do not understand the sequence of events well enough
- Do not understand whether safeguards are truly IPLs

> LOPA has provided industry with a robust tool to use when a qualitative assessment of risk is not good enough.

Another stumbling block comes in the form of blanket LOPA criterion (e.g., LOPA requirements for the top-10 most severe scenarios of the study; the single most severe scenario in each node; or requiring LOPA, regardless of severity). These blanket policies can fail to evaluate the costs and benefits of using LOPA. Hence, they never determine the sweet spot, or the best use of time and resources, to review key scenarios in which the most value can be gained.

Since LOPA is more objective than its qualitative counterparts, some organizations have used LOPA with the intent to justify not completing a recommendation. LOPA sometimes shows that the risk of a scenario is sufficiently low without implementing a recommendation. However, if the goal is to eliminate the need for implementing a recommendation, motivated reasoning and confirmation bias can prevent proper assessment. LOPA can be used to better understand the risk and determine if further risk reduction is necessary, but if a team finds itself trying to justify a predetermined conclusion, it is likely not using the tool appropriately.

Not Always a Trusted Friend

LOPA is attractive because it provides clear, concise, and mathematically unambiguous answers to its users; however, many misinterpret this unambiguity as certainty. Placing too much faith in LOPA results has been observed in several cases, and too many decisions are made using LOPA as the sole arbiter. It is important to note that all probability inputs are industry averages, rounded to the nearest order of magnitude. This results in only an approximation of the risk. QRAs use more precise frequencies and probabilities but still present only an estimate of risk (perhaps with less uncertainty). Like any other risk assessment tool, LOPA has limitations that do not allow it to deliver high-precision answers. It is important to understand how the built-in assumptions and limitations of LOPA will affect an organization's risk assessments and overall risk profile.

Alternatives to LOPA

While LOPA provides significant benefits, it is not the only "game in town." In fact, some of the concepts from LOPA are being used to improve qualitative decision-making.

Alternative Tools

One offshoot of LOPA uses the concept of independent protection layers within a PHA. After safeguards have been listed for a specific cause-consequence pair, the needed expertise to establish independence is likely on the PHA team. If the safeguards that would qualify as IPLs are identified, it gives the team a clearer picture of which and how many safeguards can be relied upon. Neither numbers nor math is required.

Some companies are using Bowtie Analysis where they once used LOPA to help understand complex scenarios. Where the relationship between the cause, consequence, safeguards, etc., is difficult to envision, a bowtie diagram for that single scenario can be quickly constructed to clarify the sequence of events. Even if just drawn on a white board, it can improve clarity and result in better qualitative assessment.

When You Choose to Use LOPA

Do your homework. If necessary information is nonexistent or unavailable during the LOPA, several people may end up sitting around the table while one or two people dig up the answer. You must be able to quickly validate the initiating event and unmitigated consequences. Sufficient information must be available to determine probabilities for conditional modifiers and enabling events. And finally, you must be able to determine the independence and auditability of IPL candidates.

When LOPA is to be conducted, be sure you know how or if it will help you make better risk-based decisions. If the PHA team is confident in its qualitative assessment of risk and simply doing LOPA to document that the team is correct, LOPA may not provide any additional benefit. Consider the scenario in which LOPA is being used. Are you trying to determine if a specific recommendation should be implemented, or are you questioning if the risk is tolerable when no feasible risk reduction can be taken? LOPA may not be a benefit in the latter case.

If conducting LOPAs separately from the PHA, consider using a smaller team with a larger on-call resource group than the PHA. LOPA can very often be competently done by as few as three people, with others participating only as needed.

If LOPA is integrated with your PHA, consider segregating the two activities from one another. The danger here is that the team loses focus on brainstorming to identify hazards, the primary purpose of PHA, when switching to LOPA and back. Part of the PHA Team's job is to brainstorm as many causes of process deviations as possible, while LOPA is focused on a single cause-consequence pair. Perhaps the LOPAs required could be conducted following each guideword or node instead of conducting them as they arise. This allows the team to focus on one thing at a time, minimizing how many times it must change mindsets.

Many companies require that any scenario with a risk ranking of X be subjected to LOPA. This can result in using LOPA to evaluate scenarios with less-severe consequences than necessary, simply because the frequency is relatively high. While these scenarios can be very important to employee safety and health, there may be better tools to evaluate them. Some companies have had better success using consequence severity instead of risk ranking. For example, one may limit the use of LOPA to scenarios that could produce fatal injuries, where we sometimes want more than a qualitative assessment of risk. Less-severe scenarios (e.g., a small release from a damaged pump seal) can be subjected to LOPA on an ad hoc basis.

Conclusion

LOPA has provided industry with a robust tool to use when a qualitative assessment of risk is not good enough. The continued evolution of the tool, combined with better guidance, has led to its widespread adoption in industry. But as the adage goes, “Always Use the Right Tool for the Job.” It is easy to become overly reliant on LOPA to the exclusion of other considerations relevant to good risk-based decision-making. While we have identified some pitfalls and traps, there are ways to avoid them. Doing so will help you allocate your resources in a risk-based manner, reducing risk where it is most needed.

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