

# A Risk-Based Approach to Addressing Recommendations From Process Hazard Analysis Studies

By

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## Abstract

The OSHA regulation, "Process Safety Management (PSM) of Highly Hazardous Chemicals" (29 CFR §1910.119) and EPA's rule, "Risk Management Programs (RMP) for Chemical Accidental Release Prevention," (40 CFR Part 68) require qualitative Process Hazards Analysis studies to be conducted. Neither regulation defines a model for making risk management decisions. And yet, management is held to an implied standard of care in making acceptable risk decisions. Taking a risk-based approach is sensible, but most PHA studies were not conducted with this type of decision process clearly in mind. Most studies were focused on the identification of hazards and did not benefit from using a formal risk management framework, or used only simple approaches.

As these studies are revalidated, or when new studies are conducted, companies would benefit from improved planning and a formal system for making these decisions. Three areas of improvement are recommended: better guidelines for conducting the studies that including rules for hazard analysis, a risk ranking system for ranking the hazard scenarios, and a decision process for addressing recommendations.

This paper discusses an approach aimed at streamlining the decision-making process and minimizing ambiguity in decisions. The characteristics and benefits of improved prioritization processes will be reviewed. Possible barriers to the implementation of improved processes, and the future of risk-based prioritization of risk reduction actions will be discussed.

## I. Introduction

Process Hazards Analysis (PHA) studies (PHA's) can be thorough, formalized, well documented studies. But often the good efforts of the PHA team are not focused and the discussions are not well captured. This, combined with a lack of a rigorous system for evaluating the PHA results and making decisions on PHAs, limits the effectiveness of PHA programs. The most critical process, that of managing the risks and/or responses to risks identified by PHA's, is too often done quickly and using overly simplistic tools. In this paper, we review the characteristics and benefits of improved risk management processes are reviewed. (We define a risk management process is defined as the method used to decide what portfolio of responses to risks will be budgeted and conducted.) We also discuss barriers to the implementation of improved processes, and the future of risk-based management of responses are also discussed.

What are some of the problems we see with current processes for deciding on responses to PHA's? The problems divide into two classes: organizational and technical problems. The most severe organizational problem is the lack of no management involvement. It is critical that management sets clear objectives and measures by which risks will be evaluated. This is a management task, not a technical task. It is critical that management sets objectives clearly so that the PHA team members know what they are trying to achieve and the relative worth of those competing objectives to the organization. Another organizational problem is that decisions on which responses will be undertaken are often made using ad hoc procedures, and are not well aligned with corporate goals.

Technical problems with poor risk management decision processes include:

- Risks are improperly evaluated, which potentially leads to unnecessary risks being accepted or expenditures being made unnecessarily
- Informal or poorly designed processes are inefficient. Whatever the corporate objectives, the projects undertaken do not maximize the value per dollar spent.
- Another problem, linked to the first, is inconsistency. Poor processes lead the organization to spend inconsistently. For example, the organization may spend \$100,000 in one case to prevent an injury, but not to spend \$70,000 in another case to prevent a similar injury with a similar likelihood of occurrence. (Theoretically an organization could be perfectly consistent in making bad choices, but this is rare.)
- Poor processes often work well fine for a period, but then are subject to unexpected breakdowns when the procedure produces an obviously bad recommendation or when someone uses a lack of logic or formality as an excuse to attack specific decisions.
- Poor processes can waste time directly, or can waste time as the process breaks down and decisions must be revisited numerous times.
- Finally, and very important in an era when decisions are open to wide scrutiny, poor processes are neither auditable, nor defensible. When stakeholders cannot

audit a decision, they will conclude that it is neither rational, nor in the public interest.

In the next section of the paper, we will discuss characteristics of good risk management decision processes. This discussion will cover characteristics of the general process, PHA's, risk evaluation, and decision making. The following section will outline the benefits from a good process, and the final section will talk about future directions for risk management decision processes.

## **II. Characteristics of Good Risk Management Decision Processes**

### **II.A Process Characteristics**

The process must have management involvement and support to work. Management must "buy-in" and accept their role in setting objectives which will guide decisions.

The process must balance the effort expended on the system to the value achieved. We don't want to spend \$100 making a \$10 decision. To balance effort and value, we need a multi-level approach that makes the easy decisions quickly, but devotes greater resources to more complex and larger decisions. Many people fear that formal decision making processes are too costly to implement. Actually, these processes often have payoffs over 10 to 1.

Another important characteristic of a good process is a focus on evaluating and prioritizing hazard reductions or responses to risks. How much risk reduction or benefit can be achieved for what cost? This is the key question,; and this is not the same question as, "Where are my highest risks?"

Other good process characteristics are:

- Processes should have enough formalism and structure that evaluations are similar across risks. The process must be general enough that it is transportable from risk to risk, and we must provide people must be provided with tools and training such that they can apply the process similarly to a wide scope of risks.
- In large organizations with broad implementations, data and evaluations will be developed by many people. Processes must be capable of producing consistent evaluations despite involvement from a large number of individuals from these many people.
- The process should be auditable. There is a great deal of scrutiny placed on organizations, and the best processes leave a paper trail that illustrates the firm has made a sincere attempt at spending money efficiently to reduce risks to workers and the public.
- Lastly, one of the general characteristics of a good process is that it provides feedback. Built into the process, are regular reviews are built into

the process to determine if actions produced the anticipated results and to otherwise learn from the process.

## II.B PHA Characteristics

The primary purpose of the PHA is to both identify and analyze the hazards of the process. The PHA team normally focuses on these objectives, and makes recommendations when the team collectively judges where the collective opinion of the team is that the risks are unacceptable. A key decision is how much authority to give the team. Some companies authorize the team to make final decisions on the hazards of the process and to make definitive recommendations for change. Other companies have the team identify the hazards of the process, leaving exact solutions and oversight of the recommendations to other groups or individuals. Experience shows that those companies that have a rigorous decision-making process, and that give their teams more authority, can save considerable time in the overall effort of hazard identification and resolution.

Usually the group is trusted with this evaluation without the benefit of rules on how the PHA should be conducted or how risks should be evaluated. Even in companies using explicit risk ranking systems, the underlying rules of how to identify and evaluate the risks are not normally well defined. Without rigor to the methodology, the possibility for inconsistent and inefficient risk decisions is troubling.

What are the attributes of a good PHA study? The PHA should be:

- **Complete.** (It should identify all significant risks.),
- **Well defined.** (It should identify all risks of similar severity across the plant or organization under study. It should be consistent in following rules or guidelines on the level of risks of concern.),
- **Fully informative.** (It should cover all risks of concern and collect all the appropriate information to support the evaluation step of the process. It is undesirable making We do not want to make one review of the facility to identify risks to workers, another to identify risks to the public, another to identify actions that can reduce risks, another to estimate the costs of actions to reduce risks, and so on.),
- **Documented.** (It should be fully documented, yet clear and brief.), and
- **Risk-based.** (To support clear communication, it should be based on well-defined scales for measuring likelihood and severity of each type of cost or benefit.).

To assure a good PHA study, rules and guidelines must be established for the PHAs. The purpose of these rules is to more concretely define each risk scenario so that improved decisions can be made. Without clear rules and guidelines, typical failures are:

- Completeness failure, where the study addresses only first order failures (simple failure of equipment and corresponding consequence with all safeguards functioning) versus second, third or ultimate level of failures (one or more safeguards fail to control the hazard). If this occurs, the conclusion of the team could range from "a trivial operational problem may occur" to "a catastrophic event could occur". The rules of cascading failures needs to be established or teams will make one of two mistakes - overstating or understating the risk.
- Completeness failure, where the study focuses on smaller hazards versus larger ones, or on operability versus safety concerns.
- Definition failure, where the study may judge the need for a recommendation inconsistently. Unless rules are established for ranking hazards and making recommendations where risks are determined to be above a certain level, the teams may not make recommendations. It is important to set rules where, for risks that fall within a certain range, a recommendation is required or is not required.
- Information failure, where the study could document insufficient information for the analysis. The team should be trained to document specific information, such as causes, consequences, and safeguards. Unless this is done, ambiguous information may be produced and the results could be unclear, or, worse, misleading. Rules about how complete the PHA is expected to be are recommended. For example, if a risk is high, for example, the details necessary to evaluate the recommendation and the underlying assumptions in determining the risk are needed.
- Information failure, where the study may not present a full range of responses. The teams should be encouraged to present alternative responses, especially when responses are high cost. This provides management with the most flexibility in creating a high value portfolio of responses. It is usually not difficult for a team to provide alternative risk reduction approaches. The team should consider responses that vary in cost, reliability, and impact on the organization (training and other costs, for example)

To simplify the analysis, the defined responses (recommendations) should be independent and similar in size (same magnitude).

- Independence means that neither the worth nor cost of one response depends on another. For example, two responses to a fire risk might be: install a new monitoring system and train employees to use the monitoring system. These responses will be much more valuable if done together. Their merits re worths are dependent. Responses also need to be cost independent. For example, projects to redesign the interior of a building and to install new wiring in the building might be less expensive if done jointly. These project are not independent. The most frequent technique for dealing with dependence is to combine dependent projects.

- It is very difficult to evaluate projects that vary very widely in size. To overcome this problem, we usually create groups of smaller projects with common goals. For example, we may create groups of all fire prevention projects or training projects.

## II.C Risk Evaluation Process Characteristics

Most of the PHA processes now used recognize the severity of the risk and the likelihood of the risk. This information is critical; they are two critical pieces of information for proper evaluation. For some companies, this is a formal system; for others, it is simply the thought process that the teams employ.

If no action is taken with respect to a risk, certain outcomes are anticipated. If a response is taken, a different set of outcomes is anticipated. The evaluation process should rank the proposed responses to the risk, not only the risks themselves. To rank the responses, the process evaluates the change in the outcomes or the risk reduction. In most cases, attacking the biggest risks first will not have the greatest payoff in public, worker or environmental protection. We need to find the set of responses that offer the greatest improvement in outcomes per dollar spent must be found.

For most firms, the responses to risks identified by PHA's will affect several corporate objectives. Thus, decisions about responses are multi-attribute. A good process will clearly identify individual objectives, and measure the worth of outcomes with respect to each objective. The process will include an explicit weighting of the relative worth to the organization of changes in these objectives. A mathematical function (often a simple linear combination) will be used to combine the different measures and weights into a single value measure of the total worth (or cost) of outcomes.

Key components of a risk evaluation process are: a list of organizational objectives, scales for describing performance on each objective, a determination of the worth within each objective, and a determination of relative worth across objectives. Characteristics of each of these components are:

- **List of organizational objectives.** Organizational objectives that are almost always of concern in risk decision making are cost, worker safety, public safety, and environmental protection. Regulatory compliance is often a separate corporate objective. It is not unheard of that an action that is less protective of workers, the public, and environment may be seen as more compliant. Corporate reputation is often an important objective that we may take actions to protect. Worker, community, and customer relations, because they depend on perceptions and factors separate from health and safety, constitute separate objectives. Responses that improve these relations may appropriately be judged to have greater worth. Identifying organizational objectives is properly a management task.

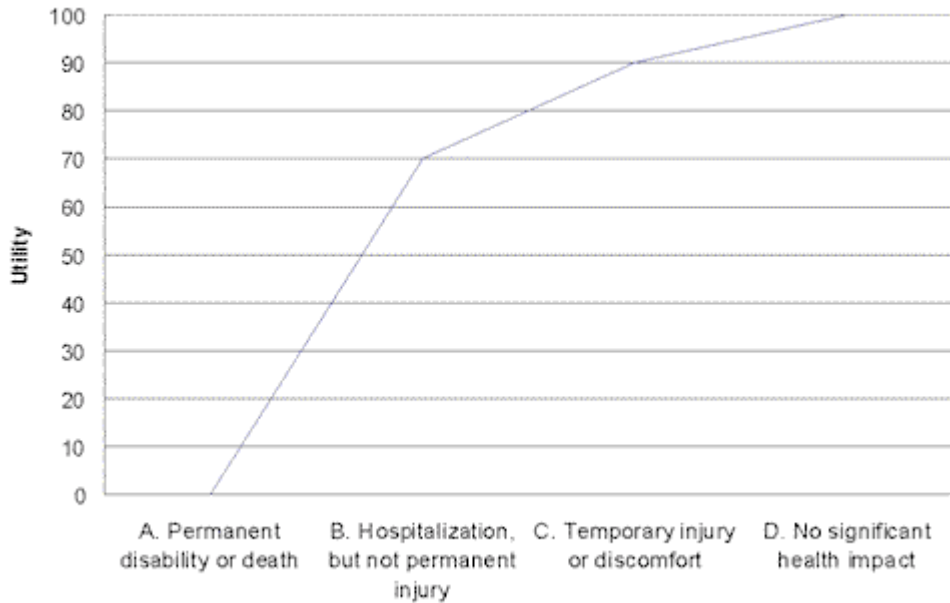
- Scales for describing performance.** After we have determined the core objectives of the organization are determined, we then need a method of measurement is needed. Measurement requires clear descriptions of different outcomes and the relative worth of those different outcomes. Outcomes can sometimes be described very briefly with numbers, 10 injuries or \$10 MM. In other cases, longer, more detailed descriptions are needed to assure that the outcome can be clearly communicated. Defining scales that accurately describe potential outcomes is a technical task. Table 1 provides an example of a scale for measuring the severity of injury. In many cases, more detailed descriptions will be needed to assure that the scale will be absolutely clear.

**Table1: Example of Defined Scale for Injuries**

Level	Level Description
A	Permanent disability or death
B	Hospitalization, but not permanent injury
C	Temporary injury or discomfort
D	No significant health impact

- Worth within each objective.** After we have a well understood method of measuring individual objectives, we need to determine the worth of different levels of each objective and weights must be determined that describe the relative worth of different objectives. These questions of worth are issues of core organizational values, and thus should be determined by management, not technical teams. The simplest, though sometimes controversial, way to measure worth is in dollars. For comparing different outcomes, we set an appropriate dollar value for a specified state of public safety or corporate reputation. These dollar values are tools to aid the efficient allocation of funds, not measures of the intrinsic worth of these outcomes. If measuring value in dollars is unacceptable to the organization, the relative worth of different objectives can be measured in abstract units. Economists and decision scientists call these abstract units utilities (utils.) Figure 1 shows a graph of a utility function for the severity of injuries.

**Figure 1: Example of a Utility Function**



- **Relative worth across objectives.** After a well understood method of measuring individual objectives is established, we need weights that describe the relative worth of different objectives to the organization are needed. Weights answer questions such as how important is an improvement in worker versus public safety. Weights allow us to make tradeoffs when actions improve one value but reduce another. For example, assume we are dealing with a hazardous process. One response places workers close to the process so they can act quickly to protect the public. Another response places workers further from the process to increase worker safety. Table 2 illustrates weights for different objectives and how weights and scores are combined to evaluate a response, Action A. Identification of objectives and placing relative worth on outcomes are management, not technical, functions.

**Table 2: Example of a Benefit Cost Calculation**

<b>Objective</b>	<b>Weight</b>
Public Health and Safety	100
Worker Health and Safety	100
Environment	80
Regulatory Compliance	50
Corporate Reputation	50
Community Relations	10

One additional issue that must be dealt with in the evaluation step is timing. The importance of timing is most clear when a problem is rapidly getting worse. For example, a corrosion problem may currently create a minor risk. However, the corrosion problem can now be treated with a coat of paint, but in one-year equipment replacement will be needed. Urgency needs to be identified during information gathering and urgent problems need to be given a higher priority rank during decision making.

#### **II.D Decision Making Characteristics**

Decision making needs to be multi-level. That is, there needs to be simple screening criteria and more complex decision criteria for actions remaining after screening. The screening criteria should identify risks that are really not of concern and risks that are so severe and immediate that they must be dealt with right away. Based on our experience organizations should be cautious about what is identified as an urgent, must-resolve risk. It is common for very large numbers of risks to be placed in this category. Usually the claim will not be that a response is essential due to health and safety, but that it is essential from a regulatory standpoint.

We will pick responses to risks not screened into the not-of-concern and act-now categories. We then need decision rules to choose which responses will be taken. The two rules that seem to make the most sense are the net benefit rule and the benefit-to-cost ratio rule. The net benefit is the dollar value of all the benefits from a response minus the cost of the response. The highest positive net benefit response is taken. The benefit-to-cost ratio rule recognizes that budgets are often limited and seeks to determine the set of responses that provides the greatest total

benefit for a fixed budget. An advantage of the benefit-to-cost ratio rule is that benefits do not need to be placed on a dollar basis.

After the basic rule for decision making is determined, there are lots of details that need to be considered. One of these details is the approach to discounting. The issue is how benefits, such as prevention of injuries that occur in different time periods, should be compared. For example, what is it worth to prevent an injury ten years from now versus preventing an injury today? This is a value judgment that should be made by management.

Time horizon is another issue in decision making. How far into the future should costs and benefits be estimated? This issue has both technical and value components. The appropriate time horizon will usually depend on the useful life of technical solutions, understanding of future conditions, and the rate of change in the organization.

We try to define responses that can be evaluated independently; however, there is almost always some remaining dependence. The decision making process can ignore this or can explicitly deal with it. Sophisticated mathematical techniques are available to identify optimal portfolios of responses when dependence is considered. For high cost portfolios, use of these techniques will usually have very high payoffs.

Treatment of uncertainty is another issue in decision making. Most risk evaluation processes deal with the uncertainty of a problem occurring, but many processes do not deal with uncertainty in the effects of the event, the effectiveness of the solution, or the cost of the solution. For complex problems and expensive solutions, it will usually be worthwhile to deal explicitly with these uncertainties.

Finally, a good evaluation process with appropriate information on risks and responses can have the capability of indicating when more information should be gathered prior to action. Such a capability requires statistical data or expert judgment about the ability of additional data to resolve uncertainty. With this information, relatively simple decision science tools, value-of-information calculations, can provide guidance on collecting additional information.

### **III. Outline of a Process**

We have discussed the characteristics of a good process, but what is the series of steps that we go through to uncover risks, evaluate responses, and decide on a set of responses to undertake?

First, a certain amount of investment in building the system is required. Building the system includes:

- Establishing buy-in and support by management. Management should understand that they will need to set the objectives and be clear about the organizational

values. Management should be committed to investing to developing a good process and believe in the pay-back that the process can provide.

- Defining the objectives, risks and benefits, to be considered; the relative worth of different objectives, and how outcomes will be measured. Again, the first two of these will need management involvement.
- Putting the tools in place that assure consistency, accuracy, and completeness. This will be a set of forms, checklists, ranking protocols, procedures, and often computer programs.
- Establishing PHA teams and a system of assumption of responsibility and follow-up for the action items. The PHA teams are not expected to solve all of the problems, but it may be advisable to use the PHA team as a jury on the subsequent actions taken to address the findings they felt needed attention.
- Training the people to carry out the process.

Next, we move onto the steps that are part of the actual implementation. These would include:

- Identify and evaluate the risks via HAZOP's, siting studies, and risk assessments, and gather information needed in the evaluation process. (PHA team)
- Define possible responses (recommendations) to address risks. (PHA team)
- Screen on level of risk. Identify non-problems and must-act-now situations. (Evaluation team with oversight by PHA team)
- Evaluate responses to determine benefits and costs. For large sets of responses, multiple teams of experts will perform the evaluations. In this situation, we recommend the use of a review panel to assure consistency of evaluations. For high expense responses, it is likely that a probabilistic evaluation will be also be worthwhile. The probabilistic evaluation can provide a more accurate estimate of costs and benefits and a better picture of risks. (Evaluation team)
- Do the calculations. Simple benefit-to-cost ratio calculations or net benefit calculations are needed at a minimum. Sensitivity analyses covering key assumptions and weights on objectives build insights and confidence in the process. The process works much more smoothly if people have tools that allow them to manipulate and test the results quickly and easily. For example, users may want to include or exclude particular projects from the portfolio, try certain fairness rules, etc. The simplest technique for analyzing portfolios of responses is to list the responses in order of benefit-to-cost ratio and implement the highest ratio projects that fall within the budget. However, for large, expensive portfolios of responses, more complex algorithms for constructing the portfolio will have high returns. This is particularly true if the projects stretch over several years, some projects are very large, and/or if its success of projects depends on common factors. (Evaluation team)

- Review the results and learn. The last step in the process is to review the results at regular intervals, and, as far as possible, test the performance of the process. Issues such as the accuracy of cost estimates, the effectiveness of responses, and the history of problems not addressed should all be reviewed. (Audit team)

#### **IV. Benefits of a Good Risk Management Decision Process**

The chief benefits of a good risk management decision process are better alignment of decisions with corporate objectives and much higher benefits for the same or reduced levels of expenditure. Closely related benefits are: greater control over the decision making process, less politicization of decision making, greater consistency in decision making, and the ability to learn and improve. After the process is set up, most organizations will find that it is not more expensive than prior approaches, and is less apt to fail and require revisions of priorities.

A good risk management process also provides a good framework within which to interact with stakeholders. A good process, by providing a clear statement of objectives and of beliefs about the efficacy of responses, is a great aid to communication. Often, Many times consensus or negotiation can be blocked by value or information disagreements that in fact do not affect the decision. Sensitivity analyses can identify the relevant unimportant and the important areas of conflict and focus discussions on the most critical elements.

Finally in an era of much considerable outside scrutiny, a good process is extremely auditable, highly logical, and, therefore we think, more defensible.

#### **V. Future**

In our practice and in the literature, we see more companies are adopting a benefit-to-cost framework to address risk management decisions. Also, we see more companies that use formal multi-attribute decision criteria—realizing that benefits and costs come in many forms, and more companies that understanding the need to formally deal with uncertainty in costs and impacts.

Every organization that we have worked with to develop formal prioritization processes believes that the formal identification of criteria, the careful weighting of criteria, the careful ranking of activities versus criteria, and calculation of net benefit or benefit/cost ratios is extremely worthwhile, and has provided the organization with a combination of increased value and decreased costs.

However, we have also seen that logical systems are difficult to maintain in spite of the accolades they get when first implemented. The temptation to declare pet projects indispensable, and therefore outside the process, is enormous, and the temptation to fall

back on horse trading among decision makers to determine priorities is also very strong. The fact that these processes are oriented toward organizational goals, and are not constructed to bend to the politics of the organization, often causes their downfall.

A second problem is that, while we have described auditability and explicit decision rules as strengths of a good process, these are sometimes viewed as problems with these processes. They leave behind a clear track record of why some actions were taken and others were not. Some organizations are afraid that this leads to greater not lesser liability.

Finally, though it is very slow and enormously hampered by the distrust among the public, regulators, and industry, certainly there is a great deal of interest among regulators about benefit-to-cost approaches as a way of achieving for society a higher level of protection of human health and the environment at a lower cost.