

# **Risk Guidelines as a Risk Management Tool**

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“Wise men foresee calamity in order the better to bear it.”

- Attributed to King Arthur at his coronation by Geoffrey of Monmouth (c. 1136) in *Histoiria regum Britanniae* (Goodrich, 1986)

## ABSTRACT

Quantitative risk analysis (QRA) is a valuable tool for understanding and managing risk in the chemical process industry. QRA is most useful when used to evaluate the impact of design alternatives on facility risk (comparing the risk of one design option to one or more alternatives). QRA is also valuable in determining what are the major contributors to facility risk, so that efforts to manage and reduce that risk can be directed to those areas where they will have the largest impact and be the most cost effective. However, it is inevitable that the use of a tool which generates a numerical estimate of risk will raise questions as to the tolerability of that estimated risk. The use of quantitative risk guidelines as one tool in the risk management and decision making process will be discussed.

## INTRODUCTION

Risk has been defined as a measure of human injury, environmental damage or economic loss expressed in terms both of the incident likelihood and the magnitude of the injury, damage or loss (CCPS, 1989, 1995b). Risk can therefore be considered to be a function of the existence of a hazard, the frequency of occurrence of an incident associated with the hazard and the consequence or impact of the incident should it occur:

$$\text{Risk} = f(\text{incident, frequency, consequence})$$

The risk function can be quite complex, and many numerically different measures of risk can be calculated from the same set of incident, frequency and consequence data (CCPS, 1989). These measures view different aspects of risk, and might consider, for example:

- individual risk
- societal risk
- risk of different kinds of injury or damage
- different populations which are potentially exposed

Chemical Process Quantitative Risk Analysis (CPQRA) is the numerical estimation of the frequency and consequences of potential incidents, and the development of quantitative risk estimates as applied to the chemical process industry (CCPS, 1989). CPQRA is generally limited to consideration of the immediate impacts of episodic chemical process incidents - fires, explosions, and the immediate effects of exposure to toxic chemicals. The remainder of this discussion will relate to management of this episodic, acute risk.

## **USE OF CPQRA**

The primary purpose of any CPQRA study should be to identify cost effective ways to improve the safety of a chemical plant. This implies that there will be potential risk reduction options either already available or to be identified. Elliott (1988) states that “the use of QRA has little intrinsic value outside the context of decision making.” When CPQRA is used in this way, the absolute value of the numerical risk results is less important than the relative risk values of various design alternatives. A quantitative analysis provides the engineer with valuable information in the following areas:

- It identifies the major contributors to risk for a facility (Van Sciver, 1990). This knowledge is essential to understanding where scarce engineering, technical and financial resources should be directed to cost effectively reduce and manage that risk. Even the complete elimination of risk sources which contribute only a few percent to total risk has little impact on total facility risk. Resources must be directed to the parts of a facility which make the largest contribution to total risk, and CPQRA is a valuable tool in identifying those major risk contributors. Ness and Chavarria (1995) provide an excellent example of the use of CPQRA as a tool for understanding the sources of risk in an ammonia refrigeration system.
- CPQRA allows design alternatives to be compared. These alternatives may arise from alternate designs or technology options for manufacturing a product, or they may be developed as modifications to the same basic process as risk mitigation options. Understanding the risk associated with technology or risk reduction

options is an important benefit of CPQRA. A number of case studies illustrating the use of CPQRA for evaluating design alternatives have been published (for example, Frank, 1995; Hendershot, 1991; Purdy and Wasilewski, 1995).

- The understanding of the major contributors to residual risk derived from a CPQRA is very useful in the ongoing management of that risk. For example:
  - ◆ Actual plant operation and component performance can be monitored and compared with the assumptions of CPQRA. Any significant difference between actual performance and CPQRA assumptions should be evaluated and its impact on risk determined.
  - ◆ The CPQRA can be used to establish interim operational strategies in the event of failure or temporary outage of equipment. The impact of the temporary equipment outage on risk can be estimated and interim operating strategies for implementation during the outage can be evaluated.
  - ◆ CPQRA can be used as a management of change tool. Any future plant modifications associated with major contributors to the residual risk should receive particular attention.
- The results of a CPQRA can also be compared to established risk guidelines. Although the most important benefits of CPQRA are derived from the understanding of risk sources and design and operational strategies, a CPQRA study does generate a numerical estimate of risk. It is therefore almost inevitable that questions about whether or not that numerically estimated risk is unacceptable will arise. Pikaar (1995) refers to this type of use as “Judgmental QRA”, distinguishing it from “Comparative QRA” as discussed above. He likens this use to a mountain climber who reaches a point from which he cannot identify a feasible route upward, and then attempting to determine if he is high enough. For this reason, many organizations have developed formal or informal guidelines for “tolerable” risk. The remainder of this paper will describe a strategy for developing such guidelines.

## **DEVELOPMENT OF RISK GUIDELINES**

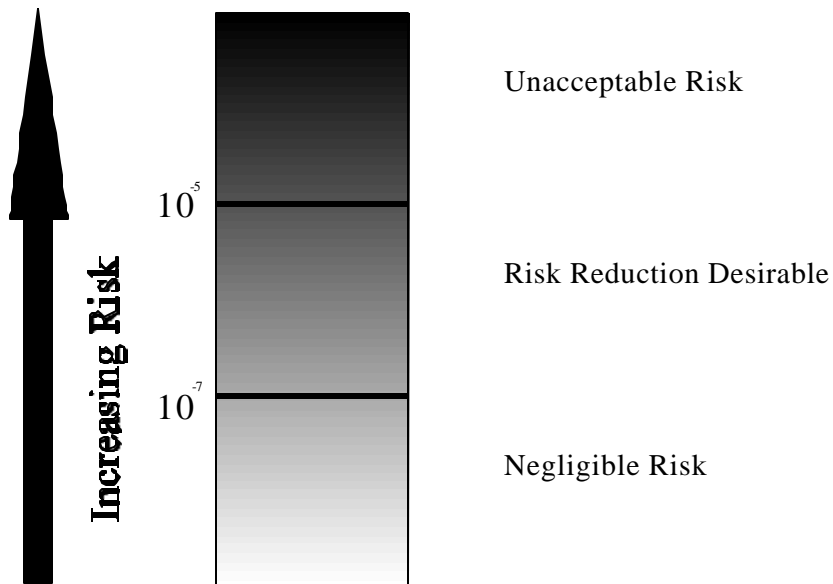
Rohm and Haas risk guidelines are a part of the company’s Major Accident Prevention Program (MAPP). The overall MAP Program is described by Renshaw (1990) and Chiang and Lantzy (1993). The program emphasizes inherent safety and incident consequence reduction. However, the MAP Program recognizes that it is not always possible to eliminate the potential for incidents which could impact the public, and provides guidelines for the application of CPQRA when this happens. The primary purpose of the CPQRA is, as described above,

to identify cost effective ways to reduce facility risk. However, guidelines for assessing the numerical CPQRA results are also provided. The risk guidelines are summarized in Table 1 and Figure 1 (Renshaw, 1990).

**Table 1: Risk Guidelines  
(Renshaw, 1990)**

Risk Measure	Units	Unacceptable Risk	Negligible Risk
Individual Risk at the location of a potential resident	Probability of fatality, per year	$> 1 \times 10^{-5}$	$< 1 \times 10^{-7}$
Societal risk of 10 or more fatalities	Probability of an incident causing 10 or more potential fatalities, per year	$> 1 \times 10^{-5}$	$< 1 \times 10^{-7}$

**Figure 1: Risk Reduction Guidelines  
(Renshaw, 1990)**



## **THE ROLE OF RISK GUIDELINES**

Risk guidelines should be regarded as a first step in the risk management and decision making process. Their primary purpose is to identify and draw attention to processes or design alternatives which do not meet the guidelines. Hamm and Schwartz (1993) identify several drawbacks of risk guidelines:

- Guidelines can be inflexible. Once the guidelines are met, further risk reduction options may be ignored even if they are inexpensive or cost effective.
- Conversely, projects with high social value which marginally violate the risk guidelines may be rejected.
- If the scope of operations intended to be covered by the guidelines is not clearly defined, the guidelines may encourage dividing projects or operations into more, smaller pieces which individually meet the guidelines, while the total risk may be much higher.
- The guidelines do not help in comparing a number of options, all of which meet the guidelines.

In response to the first issue, many regulations and company policies implementing risk guidelines specify both a maximum tolerable risk and a “de minimis” risk, below which a risk is considered low enough that further action is not required. Between these two risk values there is a range where risk reduction must be considered and implemented to the extent that it is “practical”. Because the guidelines themselves do not provide any guidance on what is “practical”, other decision tools may be needed to evaluate options in this region. Hamm and Schwartz (1993) and CCPS (1995a) describe a number of decision tools which can be used to evaluate options, and discuss how these tools can be implemented in an organization.

## **HOW TO ESTABLISH RISK GUIDELINES**

A risk guideline is analogous to a specification and, like any specification, a test method to generate the numbers which will be compared to the guideline is required. Risk guidelines should be established in the context of the risk analysis methodology to be used to calculate the risk estimates. Quantitative risk analysis involves many judgments and assumptions which will impact the resulting risk estimates. Consider two organizations with the risk analyses cultures described in Table 2:

**Table 2: Examples of Risk Analysis Cultures**

	Organization A	Organization B
Description	“Conservative”	“Realistic”
Equipment Failure Rate Data	Use worst (highest) reported.	Use typical or average data
Consequence Models	Use “worst case” (longest distance) models	Use “realistic” consequence models
Toxicity	Use worst reported toxicology data	Use best estimate toxicity models based on evaluation of all available data
Other Factors	Use “Worst Case”	Use “Best Estimate”

In general, if Organization A and Organization B do a CPQRA on the same facility, Organization A will develop a numerically higher estimate of risk. This is because Organization A uses more “conservative” assumptions. In fact, the “real” risk of the facility (if it could be known) is the same - it is the same facility. However, Organization A and Organization B can each establish its own set of risk guidelines based on its own risk analysis culture. The guidelines are unlikely to be the same; Organization A will almost certainly have numerically higher guidelines, consistent with its more conservative risk analysis assumptions. Each organization can effectively use CPQRA and its own risk guidelines for risk management and decision making. However, it is not appropriate to compare a risk analysis done by Organization B to the Organization A risk guidelines.

**WHAT MUST THE GUIDELINE ACCOMPLISH?**

A useful guideline must be credible. By this, I mean that the guideline must be a useful screening tool. A guideline which passes every facility, even those which the organization’s management and engineers believe require improvement, is not credible. Similarly, a guideline which fails all or nearly all facilities, even those with a state-of-the-art design which meets or exceeds all requirements of industry standards and regulations should be considered suspect.

A risk guideline must also drive continuing improvement. Our objective is to improve safety and reduce facility risk in a cost effective manner. It should not be “good enough” simply to meet a set guideline without an additional requirement for a search for cost effective risk reduction

options. The use of a risk range in which risk reduction alternatives must be evaluated for cost effectiveness is a strategy to address the desire for continuing improvement.

Finally, a risk guideline must be consistent with society's expectations. A lot of information on risk guidelines established by governments and companies is becoming available. CPQRA methodologies and risk guidelines established to evaluate those results should be reasonably consistent with these guidelines established by others.

### **WHO SHOULD BE INVOLVED IN ESTABLISHING RISK GUIDELINES?**

Because the use of risk guidelines have a broad impact on a company's operations, it is essential that all potentially affected parts of the organization be involved in the development of the guidelines. This is important in ensuring that the entire company understands and supports the use of the guidelines. The team should include:

- Safety, health and environmental
- Research, development and engineering
- Operations
- Business and upper management

Finally, the team must include risk analysis professionals. Among their major functions are:

- ensuring that all members of the team clearly understand the risk measures to be used
- explaining the uncertainties in the risk estimates
- confirming that the same methodologies and judgements are used for CPQRA across the enterprise

### **RESOURCES FOR ESTABLISHING RISK GUIDELINES**

In order to establish risk guidelines satisfying the requirements described, an organization has a number of resources available. Some particularly valuable sources of information include:

- Previous CPQRA results. It is best to have some experience in doing CPQRA studies before considering the establishment of quantitative risk guidelines. This is important in defining the organization's quantitative risk analysis "culture." A database of CPQRA results can be created, and the proposed guidelines compared to the studies already completed. The application of the proposed guidelines should, in general, make sense. Because decisions based on prior studies will have been made in the absence of quantitative guidelines, a few exceptions to decisions

which would have been made based on the guidelines can be expected. However, a large number of decisions which are inconsistent with the guidelines may suggest a problem and should be investigated.

- Many organizations and governments have published risk guidelines. While these guidelines have been developed in the context of a specific risk analysis methodology and culture, they do provide general guidance. Some examples of published risk guidelines are found in Ale (1991, 1992), Goyal (1993), HSE (1989), Helmers and Schaller (1982), Pasma (1995), Renshaw (1990) and Whittle (1993). Pikaar and Seaman (1995) have provided an excellent summary of the use of risk guidelines by both governments and companies in Europe and the United States.
- Safety records for both the organization considering the establishment of guidelines, and the chemical industry in general should be considered (Gibson, 1988 and Kletz, 1982). A proposed risk guideline should ensure that facilities tested against the guideline and passing will be at least as safe as the organization's past safety record. Furthermore, the risk guideline should provide a driving force for continuing improvement of that safety record.
- Government and regulatory decisions when establishing regulations, and safety and health standards should be considered. Sometimes these decisions are based on some type of quantitative risk analysis, and they provide some guidance on society's expectations with regard to risk management. In some cases these decisions will also include some kind of cost-benefit analysis. The current political climate in the United States may encourage more extensive use of risk analysis in the establishment of future regulations.
- General societal risk data can be considered in establishing risk guidelines. It is important to consider the context of that societal risk data. Some particularly important factors include whether or not the risk is voluntary, and whether persons exposed to the risk derive any benefit from the activity which generates the risk. Covello, Sandman and Slovic (1988), Slovic (1987) and Wilson and Crouch (1987) provide examples of general societal risk data and discuss risk comparison and perception.

## **BEYOND RISK GUIDELINES**

Risk guidelines represent only the first step in risk decision making. Their primary function is to screen out design options which do not meet the guidelines. In practice, many, if not most,

installations analyzed will fall into the “risk reduction desirable” category. The guidelines themselves do not provide guidance on how to prioritize the costs and benefits of various options in this region, or on the cost effectiveness on any of the options. Other decision making methodologies are required. Hamm and Schwartz (1993) summarize some strategies for consideration. CCPS (1995a) provides an introduction to a number of decision analysis tools which can be used, including:

- Voting methods
- Weighted scoring methods
- Cost-benefit analysis
- Mathematical programming
- Payoff matrix
- Decision analysis
- Multi attribute utility analysis

At Rohm and Haas, we have begun to use a technique called the Safety, Health and Environmental issue Resolution Process (SHERP). This is a weighted scoring method similar to Kepner-Tregoe Decision Analysis (Kepner and Tregoe, 1981; CCPS, 1995a). A decision matrix is constructed listing design options on one axis, and decision parameters on the other. The decision parameters are assigned a weight based on their relative importance, and the process options are assigned a performance factor based on how well each satisfies that decision parameter. These weights and performance factors can then be used to identify the most desirable process option. Table 3 is an example of a SHERP decision matrix.

## **SUMMARY**

Chemical process quantitative risk analysis is a valuable tool in understanding and managing risk in the chemical process industry. The most important benefit of CPQRA is in recognizing the sources of process risk and directing resources for risk reduction into those areas where they will have the greatest impact. Risk guidelines can be a useful aid in the interpretation and use of CPQRA results. The guidelines must be carefully established with proper consideration for the CPQRA methodology used to generate the numbers to be compared to the guidelines. The use of guidelines must be carefully managed so that the objective of CPQRA does not become an exercise in generating numbers, losing the benefits of understanding and managing risk and identifying risk reduction opportunities. Risk guidelines also represent only a first step in the risk decision making process, and other techniques will be required in many cases, particularly to select among a number of alternatives, all of which meet the guidelines.

**Table 3: An Example SHERP Decision Matrix**

<i>Parameters</i>	<i>Weighting Factors</i>	<i>Options</i>			
		<b>#1</b>	<b>#2</b>	<b>#3</b>	<b>#4</b>
<b>COST</b>	<i>Performance Factors &gt;</i>	x 2 =	x 9 =	x 10 =	x 1 =
	9	18	81	90	9
<b>SAFETY</b>	<i>Performance Factors &gt;</i>	x 10 =	x 5 =	x 3 =	x 1 =
	10	100	50	30	10
<b>ENVIRONMENT</b>	<i>Performance Factors &gt;</i>	x 3 =	x 5 =	x 1 =	x 10 =
	7	21	35	7	70
<b>OPERABILITY</b>	<i>Performance Factors &gt;</i>	x 3 =	x 10 =	x 2 =	x 1 =
	5	15	50	10	5
<b>DESIGN</b>	<i>Performance Factors &gt;</i>	x 1 =	x 9 =	x 10 =	x 3 =
	3	3	27	30	9
<b>OTHER</b>	<i>Performance Factors &gt;</i>	x 7 =	x 5 =	x 10 =	x 1 =
	3	21	15	30	3
	<b>SUM</b>	<b>178</b>	<b>258</b>	<b>197</b>	<b>106</b>

PROCEDURE: Assign a weighting factor (1 to 10) to the various parameters based on your judgment of the relative importance of each with respect to this SHE issue. Then, with each option, assign a performance factor from 1 to 10 based on the relative performance of that option with respect to the particular parameter. Multiply the weighting factor by each performance factor and sum the products for each option. The highest total is most desirable.

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