Facility Major Risk Survey

An ioMosaic White Paper

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Abstract

This paper describes a method for identification of major acute risks in existing process facilities that have potential for serious impacts to on-site and off-site populations, and for prioritization of mitigating measures. The approach is based on a comprehensive assessment of the facility, which includes a review of process hazards, fire protection, emergency response, and management systems (administrative controls) using separate assessment protocols. The review involves interviews of key management and operating personnel, review of drawings, procedures and records, and inspection of plant facilities. Recommended risk mitigation measures are prioritized using a semi-quantitative risk ranking matrix. This paper presents the key elements of the methodology and provides examples of typical findings.

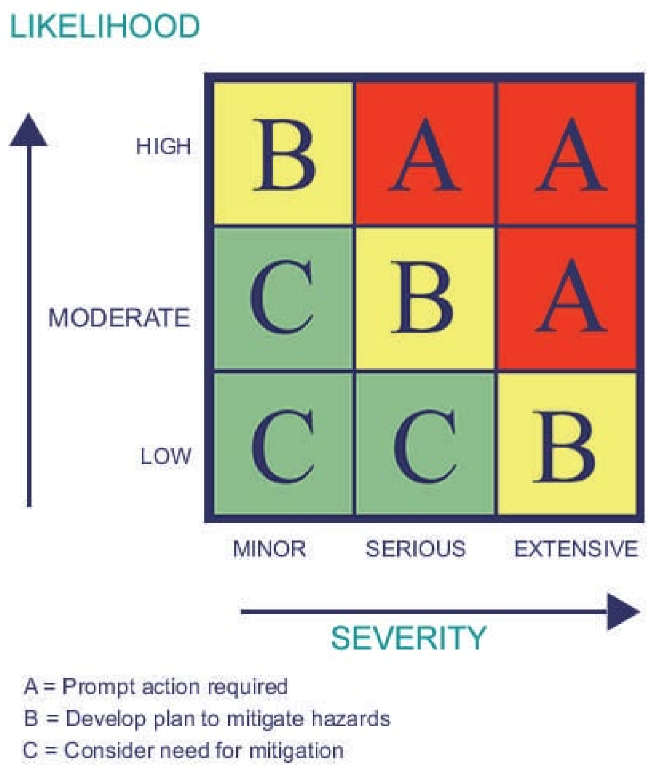
Introduction

In the aftermath of major industrial accidents, many managers ponder the question: "Could this happen to us?" Obtaining prompt and reasonable assurance that such accidents are relatively unlikely in existing facilities can require a major effort, particularly if there are many plant locations or manufacturing sites with multiple units such as in chemical complexes or petroleum refineries. Performing a full quantitative risk assessment (QRA) of each plant or process unit can involve a major allocation of company resources and can take considerable time to implement. Moreover, such a detailed study is not always necessary to identify the major areas for risk reduction at the plant level. Given an appropriate framework, experienced technical and safety personnel can locate major hazards and rank them in terms of relative risk.

Risk Assessment Tiers

Because quantitative risk assessment involves a significant commitment of a company's human resources, many companies have adopted a multi-tiered approach to risk assessment of existing facilities. The risk assessment levels presented in Figure 1, are generally consistent with practices we have encountered through various assignments for medium and large chemical and petroleum companies.

Figure 1: Risk Ranking Matrix



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Level 1 – Risk Screening

This is a top-down review of worst-case potential hazards/risks, aimed primarily at prioritizing plant sites or areas within a plant, which pose the highest risk.

Factors typically considered include:

- Inventory of hazardous materials
- Hazardous material properties (e.g., toxicity, flammability
- Storage conditions (e.g., temperature and pressure)
- Population distribution (density/distance)

The implementation relies mainly on data and information furnished by the site, with little or no site inspection. The results provide a relative indication of the extent of hazards and potential for risk exposure. More formalized programs use hazard ranking indexes (e.g., Dow Fire and Explosion or Chemical Exposure Index) to determine the need for further review or risk mitigation.

Computerized indices which incorporate simplified hazard models (e.g., ioFIRST) are also utilized for Level 1 screening.

Level 2 – Major Risk Survey (Semi-Quantitative)

This survey approach combines site inspection with established risk assessment techniques applied in a semi-quantitative fashion. The primary objective is to identify and rank major risks at a specific site and provide risk mitigation recommendations. Aspects covered in the risk survey usually include:

- Major process hazards
- Process Safety management systems
- Fire protection/emergency response equipment and programs
- Security Vulnerability
- Impact of hazard consequences (equipment damage, business interruption, injury, fatalities)
- Qualitative risk ranking of scenarios involving hazardous materials
- Risk reduction recommendations

The ranking of major risks provides a means of prioritizing mitigative actions, and allocating resources to those areas, which pose the highest risk.

Level 3 – Quantitative Risk Assessment (Deterministic)

This is a rigorous analysis of the risks associated with all credible hazards that have the potential to cause an undesirable outcome such as human injury, fatality, or destruction of property. It is usually a more narrowly focused assessment of a single process unit or portion thereof (e.g., a reactor system). The four basic elements include:

1. **Hazard Identification** utilizing a formal, systematic technique (e.g., line-by-line hazard and operability study [HAZOP]) applied to piping and instrument drawings (P&IDs).
2. **Frequency Analysis** Based on logic diagramming for depicting failure pathways and quantifying likelihood of toxic and flammable materials releases. (e.g., Fault /Event Tree Analysis).
3. **Hazard Analysis (HAZAN)** to quantify the consequences of the various hazards (fire, explosion, BLEVE, toxic vapor, etc.). Establishment of minimum values for damage criteria (e.g., IDLH, over pressure, radiation flux) to assess impacts is required.

4. Risk Quantification. Applying quantitative techniques which couple impact areas for each specific hazard with weather data, population data, frequency of occurrence, likelihood of ignition, etc., in order to depict the risk. For example, risk profiles can be developed which display the frequency with which consequences exceed a given magnitude for a full range of magnitudes. They are used to show the risk of injuries, fatalities, or property damage. The quantitative analysis indirectly incorporates process safety management and loss prevention through adjustment of failure rates and hazard duration. For example, instrumentation failure rates are modified depending on the frequency of testing and calibration.

QRA provides a means to determine the relative significance of each of a number of undesired events, allowing analysts and engineers to focus their risk reduction efforts where they will be most beneficial. The full quantitative risk analysis can generate information to be used in: deciding between risk mitigation alternatives; determining the tolerability of risk levels posed to workers and/or the public; deciding whether or not to issue permits for a project and what conditions to impose on that project; evaluating the adequacy of insurance, or assuring compliance to corporate standards for acceptable risk. Elements of QRA (e.g., HAZOP) are also mandatory under state laws in California and New Jersey.

Survey Risk Evaluation Approach

After Bhopal, chemical companies were looking for a simple, effective, yet streamlined approach to assess major risks at their existing facilities without the need for extensive skills or experience in risk analysis. Utilizing QRA for this purpose would be quite time consuming and costly, particularly if applied to large, multi-plant complexes. Moreover, such a detailed study is not always necessary to identify the major areas of risk reduction at the plant level. In the process of evaluating several plants for major risks, a survey approach to risk assessment was evolved. The survey risk evaluation approach is a Level 2 risk assessment methodology.

The survey risk evaluation is undertaken to identify and rank episodic events that have the potential for severe consequences in terms of property damage, business interruption, human injury and/or fatalities. It is particularly useful for operating companies with a substantial number of diverse process facilities. The approach involves the same steps used in deterministic risk assessment, but applied in a less rigorous manner. It combines our experience in quantitative risk assessment and hazard identification to qualitatively assess the likelihood and consequences of each identified hazard. The main elements include HAZAN Screening, Site Survey (hazard identification), Risk Ranking and Risk Reduction.

Hazard Analysis Screening

A hazard analysis (HAZAN) screening is performed sometime prior to beginning the site survey phase. This helps orient the team to the possible type of process/loss-of-containment hazards at the facilities, and directs the site survey to those areas with the greatest potential consequences. The HAZAN screening incorporates elements of risk screening such as identification of chemical hazards through review of material safety data sheets (MSDSs), material inventories, incident reports, etc. However, the screening also includes some consequence analysis based on worst-case incident scenarios for the more hazardous materials. This is done with the application of comprehensive hazard model packages such as SuperChems™ and PHAST®. The results, in the form of hazard zones, provide a benchmark for estimating the severity of impacts during the risk-ranking step. The HAZAN step may be omitted or done in a more quantitative manner. Conversely, additional consequence analyses may be performed after the site survey, to verify the extent of hazard impacts.

Site Survey

The onsite survey is the essential step of the survey risk evaluation approach. It is during this activity that potential hazards associated with the storage and handling of hazardous materials are identified. Hazards that do not get uncovered at this stage will be excluded from the remainder of the assessment. Factors that can contribute to increased risks are also considered, such as deficiencies in maintenance activities, fire protection, process safety management, security, and emergency response.

The survey is performed at the plant by a team of experienced process safety engineers and safety professionals, who review documents, conduct personnel interviews and inspect the facilities. As implied above, these reviews have an expanded focus beyond strict process hazards and include simultaneous review of fire protection, emergency response, and management programs. Established assessment protocols for each area of focus are used as a guide during the survey.

The onsite survey is performed by a team comprised of between 2 to 4 people, depending on the complexity of the facility. For a fairly simple, one process facility, the team would consist of a process safety engineer and a fire protection engineer/safety professional. The time required for this team to survey such a plant is 3-4 days including a closeout session, during which the major findings are presented. For a major facility such as a petrochemical complex or refinery, a four-person team is preferred, consisting of two process safety engineers, a fire protection engineer/safety professional, and a plant operations management specialist. In this case, it generally takes two weeks to complete the process hazards assessment, however, the safety management and fire protection/emergency response assessments are usually completed in one week.

The make-up of the team is vital to the quality and usefulness of the findings. The team members we employ have many years of hands-on experience in:

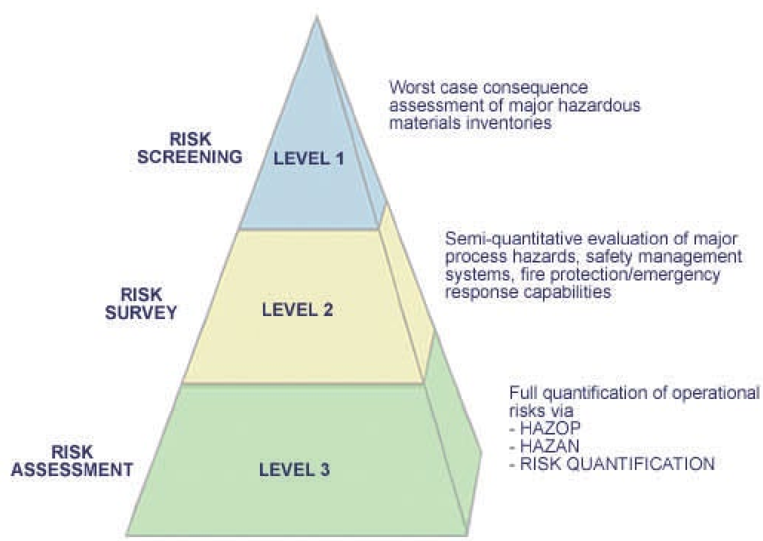
- Process engineering design/production,
- Operations management of chemical plants,
- Loss prevention/emergency response,

coupled with knowledge of hazard identification and practical, cost effective mitigation techniques; a capability that is not readily duplicated.

Risk Ranking

While onsite, the survey team broadly classifies the hazards according to relative risk utilizing a risk-ranking matrix as a guide. An example of a 3X3 matrix, which we have employed, is shown in Figure 2. We have sometimes used a 4X4 matrix for clients who wish to record very low risk hazards (i.e., low priority mitigation) that were identified during the survey. As can be seen, the risk-ranking matrix encompasses both dimensions of risk, namely, probability (likelihood) and consequence (severity).

Figure 2: Risk Management Tiers



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To apply the risk matrix, each identified process hazard meeting a set of minimum criteria is rated based on potential impact relative to other hazards. At the same time, the likelihood of having an incident with the potential for a defined severity is also estimated. Guidelines for assigning severity and likelihood are presented in Table 1. The anchor point for severity criteria is the "serious" category, which can be varied within reason (i.e., low values become meaningless) to suit client's tolerance to risk. The frequency categories shown are used to indicate the likelihood of occurrence of an incident with the potential for causing the specified consequence. It is not the frequency that the human or equipment damage actually occurs, since the conditional probability that someone or something was impacted is not included, as would be the case in a Level 3 QRA.

Table1: General Guidelines for Likelihood and Consequence Severity Categories

Likelihood	
High (>10^{-2} /yr)	A failure which could reasonably be expected to occur within the expected lifetime of the plant. Examples of a high failure likelihood are process leaks or single instrument or valve failures or a human error which could result in releases of hazardous materials.
Moderate (10^{-2}-10^{-4} /yr)	A failure or sequence of failures which has a low probability of occurrence within the expected lifetime of the plant. Examples of moderate likelihood are dual instrument or valve failures, combinations of instrument failures and human errors, or single failures of small process lines or fittings.
Low (<10-4 /yr)	A failure or series of failures which have a very low probability of occurrence within the expected lifetime of the plant. Examples of low likelihood are multiple instrument or valve failures or multiple human errors, or single spontaneous failures of tanks or process vessels.
Severity	
Minor Incident	Impact limited to the local area of the event with a potential for "knock-on-events".
Serious Incident	One that could cause: ▪ Any serious injury or fatality on/offsite ▪ Property damage of $1 million offsite or $5 million onsite
Extensive Incident	One that is five or more times worse than a serious incident.

Based on the criteria in Table 1, each process hazard is rated according to potential consequences and frequency of occurrence. Subsequently, each incident is classified according to relative risk level using the risk-ranking matrix. Definitions for the risk classifications are provided in Table 2. Assigning a relative risk to each scenario provides a means of prioritizing associated risk mitigation recommendations, and planned actions.

Table 2: Qualitative Ranking of Risks

Class	
A	Process risks or deficiencies in risk management systems that are judged to require prompt action to mitigate potential hazards.
B	Process risks or deficiencies in risk management systems of a less serious nature than those in Class A, and that have less urgency than those in Class A.
C	Other areas of possible risk reduction or improvement in risk management systems (advisory in nature)

Risk Reduction

Probably the most important result of the survey risk evaluation is the risk reduction recommendations provided by the review team. Risk reduction measures can take on many forms, including procedural changes, the addition/deletion/substitution of instruments, other design modifications, training, operating restrictions, facility or equipment relocation, or more detailed risk assessment. Because each potential hazard has been classified according to risk level, the appropriate priority for implementation of risk reduction measures is provided to plant personnel.

Typical Results

In reporting the results, each significant finding is described, classified as to risk level, and possible risk mitigation recommendations made. Some examples of the kinds of findings that are produced by a survey risk evaluation are presented in summary form in Tables 3 through 5. These examples are typical, and have been distilled from a variety of surveys. Findings from each of the focus areas are provided. Note that under process hazards, some of the findings apply to many production units (plant wide).

Depending on the risk ranking, it may be appropriate to organize a task force to address these items. The responsibility for mitigation of the specific process hazards can be assigned to that unit's operating staff.

Table 3: Risk Survey Findings Process Hazards

Risk Ranking	Plant Area	Potential Hazard	Cause	Possible Mitigation
A	Plant wide	Vessel rupture	Ineffective pressure relieving capability	Establish procedure for preventing pressure build-up between rupture disc and pressure relief valve
B	Plant wide	Uncontrolled release	Major release without adequate isolation capability	Establish policy for requiring a remotely operated block valves (RBV)
A	Unit X	Flammable/toxic feedlinebreak	Fed line to mixing tank unsupported	Repair broken piping supports
B	Unit Y	Reaction in storage Tank	Caustic and acid truck unloading couplings are the same	Use different hose couplings
A	Unit Z	Toxic release	Underground line corrodes and fails	Install cathodic protection and initiate inspection program

Table 4: Risk Survey Findings Management Systems

Risk Ranking	Potential Hazard	Cause	Possible Mitigation
A	Failure of critical instrument	No routine testing	Develop procedures and testing frequency
B	Design potential hazard into existing facility	Inadequate review of field changes	Combine existing/proposed programs
B	Same incident repeated	No follow-up or closeout on incident report	Initiate follow-up on incident mitigation
B	Control systems, piping,raw material, equipment,etc. changes introduce new hazards	Informal hazard/risk reviews conducted for existing facilities	Develop formal risk review program

Table 5: Risk Survey Findings Fire Protection/Emergency Response

Risk Ranking	Potential Hazard	Cause	Possible Mitigation
B	Inadequate water availability for effective response	Insufficient fire-water flow rate	Increase the maximum flow rate for fire water
B	Inadequate fire protection in plant locations which have been added or modified	Fire protection not always included as part of plant expansions/modifications	Institute a system of reviews by fire protection specialists on all projects over a certain budget
B	Limitations in water availability in an emergency	Fire pump flow tests not conducted	Conduct fire pump tests weekly and flow tests annually
B	Disorganized emergency response; response personnel unprepared	ER plan does not cover all possible emergencies (fires, explosions, toxic releases, external events)	Develop or improve comprehensive emergency response plan

In the course of conducting several survey risk evaluations, we have taken note of reoccurring findings. Some of the most common surveys findings are listed below:

- Lack of or incomplete preventative maintenance and testing programs (e.g., critical instruments, transfer hoses).
- Inadequate remote isolation of large inventories of hazardous materials
- Lack of or incomplete Management of Change procedures
- Outdated P&IDs and operating procedures
- Lack of formal training program and refresher training
- Informal hazard identification/design reviews
- Improper grounding/bonding
- Blocking valves under relief devices not locked or car sealed open
- Inadequate fire protection water supply, reliability, capacity, pressurization, distribution and/or application
- Lack of preventive maintenance for the loss prevention equipment in terms of implementation and/or frequency

- Lack of comprehensive emergency response planning, e.g., hazards identified, continuous coverage, training, personal protection equipment

Summary

This paper describes a survey approach to hazard identification and risk mitigation at existing facilities, which has proven to be effective in addressing major risk management concerns at the plant level. The methodology we have discussed represents the usual elements incorporated in the survey risk evaluation. It should be mentioned, that the methodology is not rigid, and can be modified to suit a company's particular needs. For example, the above discussion primarily addresses acute risk concerns. However, we have used this approach to identify chronic risks by incorporating an Industrial Health Assessment module into the site survey. In this case, the usual survey team is augmented by inclusion of an Industrial Hygienist. Likewise, security vulnerability concerns can also be covered, if needed.

A major feature of the survey risk evaluation approach is the prioritization of risk reduction recommendations, so that plant management can focus attention and finite resources on mitigating the major risk items. An additional benefit of conducting survey risk evaluations at several different locations is, that it allows an assessment of the consistency of the quality and effectiveness of safety and risk management across a company or division. Frequently we find many common areas of weakness at all or many sites within a company. These findings may require action at the Corporate or Divisional level to set appropriate policy. It is also useful in identifying process facilities or areas that need HAZOP review or a Level 3 QRA.

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Additional Resources

1. Henry Ozog, 2002